TABLE OF CONTENTS

Page

List of Tables

List of Figures

List of Maps

7.7 GEOMORPHOLOGY RESOURCES AFFECTED ENVIRONMENT

This section describes the channel geomorphology of bypass and peaking reaches associated with the Middle Fork American River Project (MFP or Project). This section also describes reservoir processes associated with geomorphology, including sediment capture and management, shoreline erosion, and large woody debris capture and management.

The information presented in this section focuses on describing the existing geomorphic environment in the vicinity of the MFP, including channel geomorphic conditions, sediment storage in the reservoirs, existing erosion, mass soil movement, slumping, and other forms of instability in the Middle Fork American River Watershed (Watershed) that may affect stream or reservoir conditions. Hydrology and geology information pertinent to the discussion of geomorphic resources in the vicinity of the MFP are summarized in this section. Other geologic and soils information, such as the geologic setting and history, seismic hazards, mineral resources, and soils are described in Section 7.2 – Geology and Soils Affected Environment. Hydrologic conditions associated with the MFP are summarized in Section 7.3 – Water Use Affected Environment.

7.7.1 Information Sources

Existing information regarding the geomorphic environment in the vicinity of the MFP was collected, reviewed, and evaluated. Relevant information used to prepare this section included the following reports:

- Final 2005 Physical Habitat Characterization Study Report (PCWA 2006). This report provides a characterization of the geomorphology of the river channels upstream and downstream of the MFP dams and diversions.

- Final 2006 Physical Habitat Characterization Study Report (PCWA 2007a). This report provides a quantified assessment of channel classifications and conditions upstream and downstream of the MFP dams and diversions.

- Pre-Application Document (PAD) for the Middle Fork American River Project (PCWA 2007b). The PAD includes a general description of the existing geomorphic conditions within the MFP.

- AQ 9 – Geomorphology Technical Study Report (TSR) (2008) (AQ 9 – TSR [2008]) (PCWA 2011a; Supporting Document [SD] B). This report provides information on sediment conditions in the bypass and peaking reaches; and sediment and large woody debris (LWD) captured in MFP reservoirs and diversion pools.

- AQ 1 – Instream Flow TSR (AQ 1 – TSR) (PCWA 2011b; SD B). This report includes analyses of the sediment transport conditions (initiation of motion) of gravel-sized particles in the river and stream reaches associated with the MFP.

7.7.2 Stream Channel Characterization

7.7.2.1 Bypass Reaches

The majority of the bypass reaches associated with the MFP are confined within narrow, fluvially dissected V-shaped valleys. Only the upper half of Long Canyon Creek (River Mile [RM] 7.0–11.3), the entire lengths of the North Fork and South Fork Long Canyon creeks, and the upper Rubicon River (from Hell Hole Dam downstream approximately 5 miles) are located within wider, glacier formed U-shaped valleys. Stream channel gradients are mostly steep (>2%), which is typical of mountain systems. Longitudinal profiles of the bypass reaches are shown in Figure 7.7-1 and stream gradients within each reach are listed in Table 7.7-1.

The majority of the lengths of the bypass reaches are characterized as mixed bedrock-alluvial channels. These types of channels have frequent bedrock and boulder exposures, usually with coarse steps and riffles (boulders) that are interspersed with channel sections where alluvial materials of smaller size (cobble and gravel) collect. Throughout most of the streams, the dominant channel bed particle sizes observed were boulders, cobble, and gravel in roughly equal proportions. Sand rarely was observed as a dominant particle size in any of the streams.

Valley walls typically are comprised of exposed bedrock near the toe of the hillslope/bankfull channel interface. The narrow steep canyons present throughout the Watershed substantially limit the development of a floodplain. Where floodplains are present, they are limited to a very narrow width (less than the width of the bankfull channel).

Stream reaches associated with the MFP were classified based on morphological characteristics following the Rosgen stream channel classification system (Rosgen 1996), including Rosgen Level I, II, and III (PCWA 2006 and 2007a). The majority of the bypass reaches were classified as B and/or F Rosgen stream channel types (Map 7.7-1). B channels are described as moderately entrenched or confined with moderately steep to extremely steep side slopes. They are relatively narrow and deep, resulting in a moderate width to depth ratio. B channels are typically vertically and laterally stable, and have low bank erosion and sediment supply rates, especially when dominated by coarse materials (bedrock and boulders). F channels are also confined within steep narrow bedrock canyons; but the channel slope is flatter, and the shape of the channel is broader and shallower than B channel types resulting in a higher width to depth ratio. F channels can be laterally unstable and develop high bank erosion rates (especially when dominated by finer particles), which leads to bar formations (sediment storage) and/or high rates of sediment transport.

A notable exception is the 5.6-mile-long reach of the Rubicon River immediately downstream from Hell Hole Dam, which was classified as a C channel type. This section is an alluviated valley flat (gradient 1 to 2%) that demarcates the most downstream limit of glaciation. In addition, this reach aggraded by approximately 7 feet with material derived from the 1964 failure of Hell Hole Dam. C stream channel types are located in a wider valley compared to B and F channel types. The valleys are constructed by alluvial deposition and can develop floodplains or terraces because the stream is not confined by valley walls. Channel stability and potential for lateral adjustments can vary within this channel type depending upon the cohesiveness of the bank material and the presence of riparian vegetation.

7.7.2.2 Peaking Reach

The Middle Fork American River downstream of Ralston Afterbay is highly entrenched within a wide canyon with a high width to depth ratio. Stream gradient is more moderate (0.5 to approximately 2%) compared to the bypass reaches. High amplitude meanders around large point bars are common, and side bars are also frequent within the peaking reach. The longitudinal profile is shown in Figure 7.7-1 and gradients are summarized in Table 7.7-1.

The peaking reach downstream to the high-water mark of Folsom Reservoir (which includes the North Fork American River) is predominantly alluvial. The pool-riffle bedform and large sediment storage features (bars) are characteristic of the alluvial channel type. Alluvial channels adjust over long periods of time so that the sediment supplied to them is transported under the prevailing flow regime. Unlike the channel reaches upstream of Ralston Afterbay, no bedrock exposures were visible during surveys along the channel bottom. Most of the first 18 miles below Ralston Afterbay were dominated by boulder to cobble sized material. The next downstream 7 miles of this reach were dominated by smaller materials, typically cobble and gravel. Previous studies performed by Ayres and Associates (1997) found a similar trend in particle size fining in the downstream direction from Ralston Afterbay. Based on pebble count surveys performed at the head of selected bars, coarse cobble material was more prevalent in the uppermost 12 miles of the river below Ralston Afterbay, with smaller gravel material dominating in the lower 12 miles, including below the confluence with the North Fork American River.

The majority of the peaking reach was classified as an F channel type, except for the 1.2-mile Ruck-a-Chucky Rapids section, which was characterized as a B type channel. As described above for the bypass reaches, F stream channels are located within steep bedrock canyon, with broad and shallow channel shapes. These types of channel can be laterally unstable, with lateral instability, bar deposition (sediment storage), and/or high rates of sediment deposition.

A small 1.2-mile-long section within the peaking reach known as Ruck-a-Chucky Rapids is a B type channel. This reach is characterized by a narrow valley with no bars. The valley narrowing is due to differences in lithology (rock type). The majority of the Middle Fork American River downstream of Ralston Afterbay is comprised of weaker metasedimentary rocks, while the Ruck-a-Chucky Rapids reach is comprised of ultramafic, serpentinite bedrock, which is more resistant to erosion (Ayers Associates 1997). Large boulders within the reach were delivered to the channel by rockfalls. Sand was the dominant particle size for a short, 1-mile-long reach immediately upstream of Ruck-A-Chucky Rapids. This accumulation of sand is due to the local constriction formed at the rapids, which controls the channel hydraulics at higher flows, causing backwater conditions and the deposition of fine sediment.

7.7.3 Sediment Supply and Sediment Transport Characteristics in Bypass and Peaking Reaches

The general sediment supply and sediment transport characteristics for the bypass and peaking reaches were determined through ground and aerial surveys. Pertinent information was also derived from previously published reports, including the Scour Evaluation at Middle Fork American River below Ralston Afterbay (Watermark Engineering, Inc. 1999 and 2004), Sediment Study of Ralston Afterbay Reservoir (Bechtel 1997), and suspended sediment data from United States Geological Survey (USGS) stream gages. The 2005 and 2006 study information (PCWA 2006 and 2007a), combined with information available from previously published reports, was used to describe the extent and location of sediment contributions to stream channels from hillslope mass wasting and bank erosion and the relative capacity of study streams to transport and store these sediments.

7.7.3.1 Bypass Reaches

The majority of the bypass reaches are characterized as mixed bedrock-alluvial channels. The gradient and morphology of these steeper gradient mountain channels are highly variable and are often controlled by bedrock exposures, faulting, or large bed particle sizes recruited to the channel from mass-wasting along steep canyon walls (Montgomery and Buffington 1997). In addition, these high gradient mountain streams are considered to be supply limited. Supply limited channels are able to transport considerably more material than is delivered to them resulting in either bedrock, or mixed bedrock-alluvial channels.

Most of the bypass reaches have limited amounts of alluvium stored in the river channel (e.g., bars) or on the valley bottom (e.g., terraces). The main sediment sources along the bypass streams are shallow slope failures (rock falls and debris slides) and erosion of stored alluvium (e.g., banks and terraces) (Table 7.7-2). Hillslope processes are a primary source of sediment to the bypass reaches. Although bank erosion occurs, it is not as significant a sediment delivery process as mass wasting in the bypass streams. Other sediment sources are likely associated with debris flows from steep tributary channels. Boulders are also present throughout the study streams, which were likely derived in part from mass-wasting processes, such as rockfalls, along the inner gorge sections. Areas of glacial deposits, which are poorly consolidated to unconsolidated sediments, (primarily till) are also recognized as a source of sediments. Exposed sediment deposits were observed on side slopes and banks along the North Fork Long Canyon Creek, South Fork Long Canyon Creek, and upstream portions of the Rubicon River (downstream of Hell Hole Dam).

7.7.3.2 Peaking Reach

The peaking reach is considered to be transitional between supply limited and transport limited. The channel is neither aggrading nor degrading and the dimensions of the channel are stable (PCWA 2006 and 2007a).

Throughout the peaking reach, large channel bar deposits were observed. Sediment sources were from a combination of hillslope mass wasting and bank erosion processes. Sixty percent of the sediment contribution sources mapped in 2006 were identified as debris slides (Table 7.7-2). Approximately 25% of the mapped sediment sources were locations with bank erosion on the outside of meander bends. Additional sediment sources observed included debris torrents and rockfalls (PCWA 2006).

7.7.4 Channel Stability

Stream channels in the bypass and peaking reaches were assessed for their potential to respond to changes to the flow or sediment regime. The type and magnitude of channel response to alterations of the flow or sediment regime were described based on two channel classification systems; one developed by Montgomery-Buffington (1997) (Table 7.7-3 and Map 7.7-2), and the other was based on channel characteristics related to the Rosgen Level II and Level III (Rosgen 1996) assessments. The Montgomery-Buffington channel classification is based on the channel bed morphology (e.g., pool-riffle, step-pool, cascade, bedrock, etc.). A detailed explanation of the Montgomery-Buffington classification is included in the 2005 Physical Habitat Characterization Study Report (PCWA 2006). The Rosgen Level III methodology is a different approach that uses inventory rating forms to evaluate the stability of the stream bed, bank and valley walls. A description of the Rosgen Level III evaluation is presented in the 2006 Physical Habitat Characterization Study Report (PCWA 2007a).

Stream channel sensitivity, or the responsiveness of the stream channel to change, is based on several factors that depend upon the channel type, as well as the nature, magnitude, and persistence of the disturbance. The physical setting of the channel including confinement, bank materials, vegetation, fires, or other historical disturbances is also important in predicting channel response. Some channel types are more responsive to alterations of the flow and sediment regime than other channel types. In general, bedrock or mixed bedrock-alluvial channel types (prevalent in the bypass reaches) are less responsive to alterations than entirely alluvial channels (i.e., the peaking reach).

7.7.4.1 Bypass Reaches

Most of the lengths of the bypass stream channels (65–70%), including the larger Middle Fork American and Rubicon rivers, are relatively stable and have a relatively low channel responsiveness potential (Table 7.7-4 and Map 7.7-3). This is due in part to the periodic exposures of bedrock and boulders in the channel and valley walls throughout most of the bypass streams and to the highly to moderately entrenched channel morphology. The exceptions are the South Fork Long Canyon Creek, with a moderate response potential rating along most of the reach (61%) and the North Fork Long Canyon Creek, with a high response potential along approximately 84% of the reach. On the North Fork Long Canyon Creek, the channel is primarily composed of coarse substrates that are not very responsive; however, some banks are composed of gravel and sands and undercut banks were observed in some locations (resulting in a high responsiveness rating). For all of the bypass reaches, the most likely channel response to changes in flow and sediment regimes, even in the steeper gradient, entrenched channels, is a coarsening of the bed particle size if there are high-flows that are adequate to transport bed sediments because the transport capacity is much greater than the sediment supply (PCWA 2006).

7.7.4.2 Peaking Reach

The peaking reach is predominately alluvial and exhibits relatively greater potential for adjustment than the bypass reaches. Most of the reach (95%) was rated as highly responsive. This lower gradient stream reach is dominated by alluvial (erodible) material and has bedforms, which are indicative of more responsive channel types. However, bars include large coarse materials and lateral shifts in channel planform appear to occur infrequently, as few were observed in a comparison of historic and recent aerial photography (PCWA 2006). Based on the channel types present, other types of adjustments that could occur include changes in sediment storage (channel bars), depth, width, and slope. Stream responsiveness (based on Montgomery-Buffington Classification [1997]) is summarized in Table 7.7-4 and Map 7.7-3).

7.7.5 Channel Maintenance Flows in Bypass and Peaking Reaches

7.7.5.1 Spawning Gravel Transport Conditions

The flow required to mobilize spawning gravels (e.g., 0.3–2.5 inches [8–64 mm]) (Kondolf and Wolman 1993; Reiser and Bjornn 1979; Grost et al. 1991) (remove fines from gravel interstices and loosen gravel structure) without excessive downstream displacement/loss of gravel was determined by calculating the discharge required to initiate gravel transport at instream flow study sites (Table 7.7-5). Bulk sediment samples were collected in the field on transects where the dominant particle size fraction was gravel and suitable for use as spawning gravel (Table 7.7-5). The median (D_{50}) particle size was calculated for these surface bulk samples. The critical shear stress (τ^*_{ci}) needed to initiate motion of the D_{50} particle was calculated using the Wilcock and Crowe (2003). Additional details describing the methods are available in the AQ 1 – TSR (PCWA 2011b; SD B).

The goal of the analysis was to determine the discharge at which initiation of motion occurred for 25% of the gravel within the portion of the channel wetted at the high-flow calibration discharge. This discharge was used as the spawning gravel initiation of motion threshold.

A summary of the flow required to initiate motion of gravel sized particles (8-64 mm) in each stream reach is provided in Table 7.7-5. The calculated threshold discharge calculated at each individual study site was regressed against the 2.0 year impaired recurrence flow data to create an estimator of initiation of gravel motion (91% of the 2.0 year impaired recurrence flow) (Regression column in Table 7.7-5). For two study sites, MF44.7 and R25.7, that didn't correlate well with the 2.0 year recurrence flows, the actual modeled 25% gravel initiation flow appears to be the best estimate (Table 7.7-5).

The frequency that the gravel "initiation of motion" threshold occurred during the period of record (1975–2007) by water year type in each study reach is summarized in Table 7.7-6. In general, the "initiation of motion" thresholds were exceeded for at least 11 days per wet water year in the bypass and peaking reaches (and up to almost 50 days per year in a couple of locations [South Fork Long Canyon Creek and Middle Fork American River downstream of Middle Fork Interbay]). Initiation of motion occurred for a few days on average (1-4 days) in above normal water years in all the reaches and infrequently (zero or 1 day on average) during dry and below normal water years.

7.7.6 Sediment Conditions in Bypass and Peaking Reaches

7.7.6.1 Residual Fine Sediment in Pools

As part of the 2006 Physical Habitat Characterization Study (PCWA 2007b) and the AQ 9 – TSR (2008) (PCWA 2011a; SD B), the amount of residual fine sediment in pools in the bypass and peaking reaches was characterized using the V* index developed by the United States Department of Agriculture-Forest Service (USDA-FS) (Lisle and Hilton 1991, 1992 and Hilton and Lisle 1993). Details of sampling methods are provided in AQ 9 – TSR (2008) (PCWA 2011a; SD B). Two different V* studies were performed: a quantitative V* assessment in 2006 and a visual V* estimation assessment in 2007. The quantitative V* analysis of fine sediment was conducted in 12 pools along the Middle Fork American and Rubicon rivers above Ralston Afterbay in the fall of 2006. In 2007, visual V* estimates were conducted at a total of 108 pools within the bypass and peaking reaches and also at one comparison stream reach on the North Fork American River.

The V* value calculated for each pool is an index that quantifies the proportion of the residual pool volume that is filled with fine sediment. Excess collection of fine sediment in pools is a possible indication of insufficient magnitude or frequency of sediment transporting flows that are needed to maintain channel morphology and aquatic habitat.

The V* values at all sampling sites in the bypass and peaking reaches were less than 0.10, indicating very little fine sediment storage (Table 7.7-7). V* values less than 0.10 are considered to be indicative of a relatively low proportion of fine sediment storage in pools, and indicates that there is adequate flow to maintain pool volume and transport fine sediments on a regular basis. Pools with V* values ≤0.10 can be characteristically described as having fine bed material confined to small and discontinuous deposits in eddies or in slack water areas (Lisle and Hilton 1999).

7.7.6.2 Particle Size Composition and Fine Sediment Content in Spawning Gravels

As part of the AQ 9 – TSR (2010) (PCWA 2011c; SD B), bulk sediment samples were collected from sites in the bypass and peaking reaches to determine the particle size distribution (composition) and fine sediment content in potential spawning gravels. The bulk sediment samples provide a quantitative measure of spawning gravel particle size composition, including that portion of spawning substrates, which are comprised of fine sediments. Fifty-eight bulk samples were collected in typical trout spawning habitat (i.e., pool tail out, pocket gravel, or riffles). Details of sampling methods are provided in AQ 9 – TSR (2008) (PCWA 2011a; SD B).

Particle size statistics are more often used to determine the suitability of river sediments to successfully support spawning fish. Particle size is a direct indicator of: (a) the ability of the fish to move the framework gravels and construct a redd; and (b) the extent to which fine sediments may affect reproductive success. Although there is no definitive particle size statistic universally considered optimum for trout spawning, the fisheries literature indicates that most rainbow and brown trout spawning occurs in the medium to coarse gravel size range (based on the Udden-Wentworth scale) of 8–64 mm (Kondolf and Wolman 1993; Reiser and Bjornn 1979; Grost et al. 1991).

To determine if the gravel deposits would successfully support egg incubation and fry emergence, the fine sediment content of the deposit was also measured. A review of laboratory and field studies suggests that sediment finer than 1 mm can reduce gravel permeability, affecting dissolved oxygen content and removal of metabolic wastes from the redd. Sediments in the 1 to 10 mm size range are generally considered to inhibit fry emergence through interstitial gravel spaces (Kondolf 2000).

Gravel within the constructed redd typically has less fine sediment than prior to redd construction (Kondolf 2000). The process of redd construction winnows fine sediments from the "potential" unspawned gravel deposit. To account for this cleaning effect, the amount of fine sediment content in the bulk samples collected from potential spawning gravels (i.e., unspawned) were adjusted using relationships between the gravel content in the redds and initial unspawned gravels developed by Kondolf (2000). The following relationships were used to determine the percent of fine sediment remaining in gravels following winnowing:

- Percent of fine sediment <1 mm in winnowed gravels =

  0.67 x Initial gravel percent <1 mm particle size

- Percent of fine sediment <6.4 mm in winnowed gravels =

  0.58 x Initial gravel percent <6.4 mm particle size

Additional details describing this approach are available in the AQ 9 – TSR (2008) (PCWA 2011a; SD B).

The following criteria for spawning gravels (i.e., final sediment content of constructed redds) and high incubation success, based on Kondolf (1988, 2000) were used:

- Percentage finer than 1 mm should be less than 14%; and
- Percentage finer than 6.4 mm should be less than 30%.

Based on the aforementioned criteria, all of the study sites contained suitably-sized spawning material for trout (8–64 mm) (Table 7.7-8). The statistical results from the analyses of bulk sediment samples are presented in Table 7.7-9. Additional statistical information on the particle size distribution is available in the AQ 9 – TSR (2008) (PCWA 2011a; SD B).

The fine sediment levels associated with 18 of the total 58 bulk samples on study streams were greater than 30% fines at the 6.4 mm size threshold prior to accounting for winnowing of fine sediments during spawning. However, after accounting for winnowing, the fine sediment content in the bulk samples at all of the study sites was within the established criteria to support high trout reproductive success (Table 7.7-9).

7.7.6.3 Scouring Flows

High magnitude, infrequent flow events maintain the channel by scouring banks and the channel bed, including emerging vegetation and some established riparian vegetation. These flows are important for maintaining channel complexity and redistributing sediments. In the absence of these flows (either by flow regulation or a sequence of drier water years), vegetation encroachment can result in "berm" development that causes channel narrowing and downcutting.

The results of the geomorphology and riparian studies (e.g., high quality pool and spawning gravel habitats, lack of berm development) indicate that sediment/channel conditions in the Project streams are being maintained by the current high-flow regime. An index flow, impaired 5-year recurrence interval[1], representative of the current high-flow regime was used to develop a scouring analysis.

The total number of days that scouring flows occurred during the period of record (1975–2007) by water year type was calculated and is summarized in Table 7.7-10. In general, scouring flows occurred during the wetter water years in the bypass and peaking reaches for a total of 14 to 22 days total (depending on reach) during the period of record.

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[1] The 5-year recurrence interval flow (Q5) was selected to represent a flow that would scour the channel. Based on the results of the relicensing studies (AQ 1 – TSR [PCWA 2010b; SD B]; AQ 9 – TSR (2010) [PCWA 2010c; SD B]; and AQ 10 – Riparian Resources TSR [PCWA 2010d; SD B], the Q5 flow for each reach is estimated to be able to mobilize the channel bed (McBain and Trush 1997; Schmidt and Potyondy 2004) and exceed bankfull elevations. The Q5 flow is also within the range of high-flows that are typically associated with large-scale cottonwood and willow regeneration in the literature (i.e., Mahoney and Rood 1998).

7.7.7 Sediment Capture and Management in Project Reservoirs and Diversion Pools

Sediment capture and management in the MFP reservoirs and diversion pools were characterized based on a review of existing sediment management information (e.g., volume and frequency of sediment removal) and data collected in the field to estimate the total amount of sediment captured and to describe the distribution of particle sizes captured. A focus of the particle size analysis was to estimate the approximate amount of medium and coarse gravels (8–64 mm) captured within the reservoirs and diversion pools, which are the typical sizes used for trout spawning. Analytical and field methods for estimating sediment accrual rates and particle size distributions are described in detail in AQ 9 – TSR (2008) (PCWA 2011a; SD B) and the AQ 9 –TSR (2010) (PCWA 2011c; SD B).

7.7.7.1 Large Reservoirs

The MFP large reservoirs (Hell Hole and French Meadows) have captured sediments since the Project began operations in 1967. Sediment management activities are not necessary at these reservoirs because the captured material does not effect Project operations or reservoir storage capacity (it is estimated that less than 0.09% of total reservoir capacity at the two reservoirs has been lost since Project operations began).

The underlying granitic headwaters of the Rubicon River generally produce low sediment yields. Approximately 443,500 cubic yards of sediment has accumulated in Hell Hole Reservoir (1966–2007). This sediment accumulation rate is consistent with California watersheds that yield low sediment loads (Leopold 1994). Sand-sized particles comprised the majority of the total sediment accumulation (72%). Gravels of medium and coarse size ranges together comprised approximately 12% of the total volume of sediment accumulation (52,000 cubic yards). Average annual gravel load captured in Hell Hole Reservoir is approximately 1,250 cubic yards/year.

At French Meadows Reservoir, approximately 29,523 cubic yards of sediment has accumulated in the reservoir since Project operations began. Sand and medium gravel-sized particles comprised the majority of the total sediment accumulation (32 and 27%, respectively). Approximately 37% of the deposited sediments were medium or coarse gravels (10,800 cubic yards total). Average annual gravel load captured in French Meadows Reservoir is approximately 251 cubic yards/year. Upstream of French Meadows Reservoir, the river flows through a relatively wide, low gradient (approximately 1%) valley, where sediments are likely accumulating.

7.7.7.2 Medium Reservoirs

Sediment has been routinely excavated from MFP medium reservoirs (Middle Fork Interbay and Ralston Afterbay) on an as-needed basis (generally after episodic high-flow events) (Table 7.7-11). In the past, a single high-flow event (e.g., winters of 1986 and 1997) was sufficient to almost completely fill Middle Fork Interbay with sediment. Sediments are removed as soon as possible, if necessary, for continued operations of the MFP. If removal can be delayed, then sediment is removed during the summer and fall low-flow period. Accumulated sediments in Middle Fork Interbay and Ralston Afterbay that are not immediately impacting operations are typically removed during scheduled maintenance outages, generally from mid-September through October. Once excavated, the sediment is hauled to an approved sediment disposal area on USDA-FS property (Table 7.7-12).

At Middle Fork Interbay, sediment removal occurred on average once every six years, typically after episodic high-flow events. Typically, all of the accumulated sediment was removed and hauled to an approved sediment disposal area. The average volume of sediment removed per maintenance activity was approximately 36,000 cubic yards (ranging from 16,000–68,000 cubic yards). The grain size distribution of the removed material was approximately 56% sand, 16% fine gravel, 21% medium to coarse gravel, and 8% cobble and greater AQ 9 – TSR (2010) (PCWA 2011c; SD B). The total amount of sediment removed during all the removal activities and the particle size distribution was used to estimate an annual volume of sediment and medium and coarse gravels captured[2]. At Middle Fork Interbay, an average of approximately 6,207 cubic yards was removed per year. Twenty-one percent of the removed sediments were medium and coarse gravels (approximately 1,303 cubic yards/year) (AQ 9 – TSR [2010] [PCWA 2011c; SD B]).

At Ralston Afterbay, sediment removal occurred on average once every 4.5 years and sediments only can be removed from approximately the upper half (longitudinally) of the reservoir due to access limitations. The average volume of sediment removed per maintenance activity was approximately 48,700 cubic yards (ranging from 10,000–80,000 cubic yards). The grain size distribution of the removed material was approximately 32% sand, 8% fine gravel, 25% medium to coarse gravel, and 35% cobble and greater (AQ 9 – TSR [2008] [PCWA 2011a; SD B]). Sediment removed from Ralston Afterbay historically has been hauled to an approved disposal site.

In 2002, Placer County Water Agency (PCWA) initiated a sediment management pilot project associated with sediment removal at Ralston Afterbay (Jones & Stokes 2002). In that year, PCWA placed approximately 45,000 cubic yards of coarse sediment from Ralston Afterbay on Indian Bar as part of the pilot project. Indian Bar is located within the floodplain of the Middle Fork American River near Oxbow Powerhouse. The sediment was placed at Indian Bar in a configuration that allowed the sediment to be naturally mobilized into the Middle Fork American River and transported/deposited downstream during high-flows. Over the past seven years, approximately 15,000 cubic yards has been mobilized and transported downstream.

[2] The average volume of sediment and medium and coarse gravels captured is an estimate based on the long-term average volume of sediment removed. Sediment transport is episodic and historic sediment removal activities occurred after high-flow events, not on an annual basis. Therefore, these annual estimates of sediment and gravel capture are not expected to occur every year.

At Ralston Afterbay, PCWA removes on average approximately 48,700 cubic yards of material during each maintenance activity (approximately 10,580 cubic yards/year[3]). Approximately 25% of the removed sediment from Ralston Afterbay are medium or coarse size gravels (approximately 2,645 cubic yards/year) (AQ 9 – TSR [2008] [PCWA 2011a; SD B]).

7.7.7.3 Diversion Pools

The small diversions (Duncan, South Fork Long Canyon, and North Fork Long Canyon) have low trap efficiencies, so that most of the suspended sediment load (predominantly sand) is transported over the dams during high-flow events. Bedload sediments (coarse sand, gravel, and cobble) also pass over the diversion dams whenever the diversion pools become nearly filled with sediment or during very large storm events that can entrain material from the diversion pool. Historically, PCWA routinely excavated sediment from the three small diversion pools on as as-needed basis (generally after episodic high-flow events—every three to seven years on average) during the summer and fall low-flow period (Table 7.7-11). During these sediment management activities, typically all of the accumulated sediments are removed and hauled to approved-sediment disposal areas.

The average amount of sediment removed during each maintenance activity varied at the three diversion pools (Table 7.7-11). The following is the average amount of sediment removed from each small diversion pool per maintenance activity: Duncan, 3,000 cubic yards; South Fork Long Canyon, 2,700 cubic yards; and North Fork Long Canyon, 1,100 cubic yards. An average of approximately 416 cubic yards per year, 622 cubic yards per year, and 374 cubic yards per year were removed from the Duncan Creek, South Fork Long Canyon Creek, and North Fork Long Canyon Creek diversion pools, respectively[3]. The particle size distributions of sediments removed from each small diversion pool are summarized in Table 7.7-13. In Duncan Creek Diversion Pool, approximately 36% of the total volume removed was medium and coarse gravels (148 cubic yards/year). In South Fork Long Canyon Diversion Pool, approximately 62% of the total volume removed was medium and coarse gravels (386 cubic yards/year). The proportion of gravels removed from North Fork Long Canyon Diversion Pool was approximately 20% (75 cubic yards/year).

7.7.8 Shoreline Erosion in Project Reservoirs

The MFP reservoirs generally are surrounded by rock outcrops with steep slopes. The banks of French Meadows and Hell Hole reservoirs consist primarily of granitic and volcanic rock, and the soils derived from the weathering of these rocks. Hell Hole Reservoir is located almost entirely within the Sierra Nevada batholith, which is

[3] The average volume of sediment and medium and coarse gravels captured is an estimate based on the long-term average volume of sediment removed. Sediment transport is episodic and historic sediment removal activities occurred after high flow events, not on an annual basis. Therefore, these annual estimates of sediment and gravel capture are not expected to occur every year.

dominated by massive and fractured bedrock, with very little soil development on steep slopes that border the reservoir shoreline. Based on a review of aerial photography and video of the shoreline, at least 8.5 miles of the 11-mile-long shoreline is bedrock or boulder-sized material that is highly resistant to any erosion (PCWA 2007b). Most of the material that would be subject to erosion along the remaining 2.5 miles of shoreline is decomposed granitic material that is comprised of coarse sands found in small, interspersed pockets along bedrock joints and fractures or coarse sands intermixed with glacial (in moraines) gravel and cobble deposits on steep slopes. Estimated sediment loading from the erodible shoreline areas is 2,600 cubic yards. This is an extremely small percentage (0.0009%) of the 335,000,000 cubic yard volume (207,590 acre-feet) of the existing reservoir capacity at full pool. Similarly, the shorelines around French Meadows Reservoir are also primarily comprised of large substrates that are highly resistant to any erosion.

Ralston Afterbay and Middle Fork Interbay are also surrounded by rock outcrops with steep side slopes. The banks of Ralston Afterbay and Middle Fork Interbay consist of vertically tilted schists and slates, and soils derived from these rocks. The shorelines are comprised of large substrates that are highly resistant to erosion (PCWA 2007b).

7.7.9 Large Woody Debris Capture and Management in Project Reservoirs and Diversion Pools

The amount of LWD captured in Project reservoirs and diversion pools, and the relative extent to which LWD capture may effect the recruitment of LWD in downstream reaches, were characterized during the 2006 and 2007 field seasons. While various sizes of woody debris may have been present in the reservoirs and diversions, LWD was visually recognized as: (1) any piece with a diameter greater than approximately 1 foot; and (2) greater in length than half the bankfull width of the downstream channel (PCWA 2007b). The specific survey methods and length criteria for LWD used for the surveys are available in the AQ 9 – TSR (2008) (PCWA 2011a; SD B).

Wood large enough to be classified as LWD was observed in Hell Hole and French Meadows reservoirs, Duncan Creek Diversion Pool, North Fork Long Canyon Diversion Pool, and Middle Fork Interbay (Table 7.7-14). In Duncan Creek and North Fork Long Canyon diversion pools, and Middle Fork Interbay small amounts (one to six pieces) of LWD were observed; in Hell Hole and French Meadows reservoirs 40–50 and 100-150 pieces of LWD were observed, respectively. No LWD was observed in the South Fork Long Canyon Diversion Pool or Ralston Afterbay.

Recruitment of LWD into Project reservoirs and diversion pools comes from either upstream sources transported downstream in the channel or from steep vegetated hillslopes surrounding the reservoir or diversion pool. LWD observed in Hell Hole and French Meadows reservoirs was stored along the high water mark and along the back of the dam. Any LWD transported into Duncan Creek, North Fork Long Canyon, and South Fork Long Canyon diversion pools likely was transported downstream past the diversion dams during high-flows. Any LWD transported into the medium reservoirs (Middle Fork Interbay and Ralston Afterbay) likely was transported downstream past the dam due to maintenance practices that flush LWD caught along the log booms or intake structures.

PCWA conducted LWD management on an as-needed basis at all the reservoirs and diversion pools, approximately once every five years, except French Meadows Reservoir. The maintenance practices used at each reservoir and diversion pool are described in Table 7.7-14. When LWD maintenance was necessary, maintenance activities focused on removal of debris surrounding intake structures or along log booms to ensure proper functioning of the spillway and diversion inlets. The LWD removed was typically burned on site.

The density of LWD per mile upstream and downstream of the diversions and reservoirs was similar, as described in the 2006 Physical Habitat Characterization Study (PCWA 2007b). The findings of that study noted that LWD was most prevalent in the upper river reaches below the diversions and dams (particularly Middle Fork American and Rubicon rivers) and decreased further downstream in the watershed. A similar trend was also observed in other Sierra Nevada streams where the amount of large wood decreased with higher order streams located more downstream in the watershed (Reudiger and Ward 1996). Typically, transport of LWD during high-flow events, particularly on channels of smaller width (relative to the length of LWD pieces), does not occur very frequently or over long distances. This is because the LWD remains very stable during high flows and is not subject to downstream transport. To be stable, LWD requires a large portion of the wood mass to be anchored on the hillslope or streambank or caught between other standing trees and boulders so that it is not easily washed downstream. This occurs most often when the length of wood can easily span the bankfull width of a relatively smaller channel.

The overall relative effect of wood trapping and removal on Sierra Nevada channels is generally small. This is because once LWD is subject to transport it rarely becomes well-anchored in a manner where it can provide habitat benefits. Therefore, while LWD may provide habitat and geomorphic benefits, interruption of LWD transport does not have a substantial influence on habitat conditions. In fact, LWD has much less of an influence on channel morphology compared to prevailing geologic factors such as the type and size of bed materials (bedrock outcrops and boulder dominated lower bank areas), which has been confirmed by other researchers (Berg et al. 1998).

LITERATURE CITED

Ayres Associates. 1997. American and Sacramento River California Project, Geomorphic, Sediment Engineering, and Channel Stability Analyses, final report. Prepared for U.S. Army Corps of Engineers, Sacramento District, DACW05-93-C-0045. Sacramento, CA.

Bechtel Corporation. 1997. Geotechnical and Hydraulic Engineering Services, Sediment Study of Ralston Afterbay Reservoir Final Report. May.

Berg, N, A., A. Carlson, and D. Azuma. 1998. Function and dynamics of woody debris in stream reaches in the central Sierra Nevada, California. USDA Forest Service, Pacific Southwest Research Station, Berkeley, CA.

Grost, R. T., W. A. Hubert, and T.A. Weshe. 1991. Description of brown trout redds in a mountain stream. Transactions of the American Fisheries Society Vol. 120:582-588. September.

Hilton, S., and T. E. Lisle. 1993. Measuring the fraction of pool volume filled with fine sediment. Res. Note PSW-RN-414. Albany, CA: Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture.

Jones & Stokes. 2002. Ralston Afterbay Sediment Management Project Indian Bar Pilot Project. Placer County Water Agency. Auburn, CA.

Kondolf, G.M., M.J. Sale, and M.G. Wolman. 1993. Modification of gravel size by spawning salmonids. Water Resources Research 29:2265-2274.

Kondolf, G.M., and M.G. Wolman. 1993. The Sizes of Salmonid Spawning Gravels. Water Resources Research, Vol. 29, No.7, pg 2275-2285.

Kondolf, G.M. 1988. Salmonid spawning gravels: A geomorphic perspective on their size distribution, modification by spawning fish, and criteria for gravel quality. PhD thesis. Johns Hopkins University, Baltimore.

____. 2000. Assessing salmonid spawning gravel quality. Transactions American Fisheries Society, 129: 262-281.

Leopold, L. B. 1994. A view of the river. Harvard University Press, Cambridge, Massachusetts.

Lisle, T. and S. Hilton. 1991. Fine sediment in pools: an index of how sediment is affecting a stream channel. FHR Currents. R-5 Fish Habitat Relationship Technical Bulletin. No. 6. USDA Forest Service, Pacific Southwest Region.

____. 1992. Volume of fine sediment in pools: an index of sediment supply in gravel-bed streams. Water Resources Bulletin 28(2):371-383.

____. 1999. Fine bed material in pools of natural gravel bed channels. Water Resources Research, Vol. 35, No.4 pgs 1291-1304.

Mahoney, J.M. and S.B. Rood. 1998. Streamflow requirements for cottonwood seedling recruitment – an integrative model. Wetlands. 18: 634-645.

McBain and Trush. 1997. Trinity River Maintenance Flow Report, Prepared for Hoopa Valley Tribe, Hoopa, CA.

Montgomery, D.R. and J.M. Buffington. 1997. Channel-reach morphology in mountain drainage basins. GSA Bulletin. May. V. 109, no. 5.

Placer County Water Agency (PCWA). 2006. Middle Fork American River Project (FERC Project No. 2079). 2005 Physical Habitat Characterization Study Report-Supporting Document G.

____. 2007a. Middle Fork American River Project (FERC Project No. 2079). 2006 Physical Habitat Characterization Study Report-Supporting Document G.

____. 2007b. Middle Fork American River Project (FERC Project No. 2079), Pre-Application Document (PAD), Submitted to FERC on December 13, 2007.

____. 2011a. AQ 9 – Geomorphology Technical Study Report (2008). Available in PCWA's Application for New License – Supporting Document B.

____. 2011b. AQ 1 – Instream Flow Technical Study Report. Available in PCWA's Application for New License – Supporting Document B.

____. 2011c. AQ 9 – Geomorphology Technical Study Report (2010). Available in PCWA's Application for New License – Supporting Document B.

____. 2011d. AQ 10 – Riparian Resources Technical Study Report. Available in PCWA's Application for New License – Supporting Document B.

Reiser, D.W. and T.C. Bjornn. 1979. Influence of forest and rangeland management on anadromous fish habitat in northwest America. USDA Forest Service, Pacific Northwest.

Rosgen D.L. 1996. Applied river morphology. Wildland Hydrology. Pagosa Springs, Colorado.

Ruediger, R. and J. Ward. 1996. Abundance and function of large woody debris in central Sierra Nevada streams. Tech. Bull. 20. FHR current, fish habitat relationships. May 1996.

Schmidt, L. J.; Potyondy, J. P. 2004. Quantifying channel maintenance instream flows: an approach for gravel-bed streams in the Western United States. Gen. Tech. Rep. RMRS-GTR-128. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 33 p.

Watermark Engineering, Inc. 1999. Scour and Evaluation at MF American River below Ralston Afterbay.

____. 2004. Update of Scour and Evaluation at MF American River below Ralston Afterbay.

Wilcock, P. R. and J. C. Crowe. 2003. Surface-based transport model for mixed-size sediment. Journal of Hydraulic Engineering 129(2): 120–128.

TABLES

Table 7.7-1. Summary of Channel Gradients in the MFP Streams and Rivers.

River Mile	Gradient	Reference Points
Duncan Creek		
RM 0.0 to 1.1	10.10%	Middle Fork American River confluence to 1.1 miles upstream
RM 1.2 to 1.9	2.90%	
RM 1.9 to 3.1	4.50%	Big Bar
RM 3.1 to 5.6	3.10%	Lower Glenn Mine
RM 5.6 to 6.5	6.00%	Below Rd 96 Bridge crossing
RM 6.5 to 7.4	1.40%	Rd 96 Bridge crossing
RM 7.4 to 8.6	3.80%	Duncan Creek Diversion
North Fork Long Canyon		
RM 0.0 to 0.9	4.10%	
RM 0.9 to 1.4	1.90%	Mining tailings
RM 1.4 to 2.3	5.10%	
RM 2.3 to 3.1	3.40%	North Fork Long Canyon Creek Diversion
South Fork Long Canyon		
RM 0.0 to 0.8	5.20%	
RM 1.0 to 1.6	2.80%	
RM 1.7 to 2.7	1.80%	Lower Meadow Reach
RM 2.8 to 3.3	4.80%	South Fork Long Canyon Creek Diversion
Long Canyon Creek		
RM 0.0 to 4.9	5.50%	
RM 5.0 to 7.1	4.80%	Blacksmith Flat Footbridge; estimated downstream glaciation limit
RM 7.1 to 7.7	1.70%	0.9 mile downstream from Ramsey Crossing
RM 7.8 to 9.5	2.70%	0.9 mile upstream from Ramsey Crossing
RM 9.5 to 11.3	2.30%	Confluence North and South Forks Long Canyon Creek
Rubicon River		
RM 0.0 to 3.6	1.10%	Ralston Afterbay to Long Canyon Creek confluence
RM 3.6 to 22.6	2.10%	Long Canyon confluence to South Fork Rubicon River confluence
RM 22.6 to 27.0	2.00%	South Fork Rubicon River confluence to Parsley Bar
RM 27.0 to 30.3	1.50%	Parsley Bar to Hellhole Reservoir
Middle Fork American River		
RM 0.0 to 24.5	0.50%	North Fork American River confluence to Ralston Afterbay
RM 25.7 to 35.5	2.50%	Ralston Afterbay to Middle Fork Interbay
RM 35.9 to 47.1	4.20%	Middle Fork Interbay to French Meadow Reservoir

Table 7.7-2. Sediment Contribution Summary.

	Debris Slides	Rock Falls	Debris Torrents	Eroding Banks
Duncan Creek	6	3	0	3
North Fork Long Canyon	3	0	0	4
South Fork Long Canyon	0	0	0	3
Long Canyon Creek	1	17	0	0
Rubicon River	12	4	2	6
Middle Fork American River - Bypass Reach[1]	7	6	7	0
Middle Fork American River - Peaking Reach	17	3	4	11
North Fork American River - Peaking Reach	15	0	2	3
Total	**61**	**33**	**15**	**30**

[1]Most of these were mapped along the section of river within the boundaries of the 2001 Star Fire, which burned through the entire area. The higher frequency is likely related to the loss of forest vegetation, although increased visibility of the hillslopes due to the open vegetative canopy after the fire may have enhanced the identification of debris torrents in this area compared to other areas that were not burned.

Table 7.7-3. Bypass and Peaking Reach Montgomery-Buffington Channel Types.

Upstream Station	Downstream Station	Incremental Distance (mi)	Montgomery-Buffington Channel Type
Duncan Creek			
9.5	9.1	0.4	Bedrock/Step-Pool
9.1	8.7	0.4	Plane-Bed
8.7	7.4	1.3	Step-Pool/Plane-Bed
7.4	6.1	1.3	Plane-Bed
6.1	4.5	1.6	Step-Pool/Plane-Bed
4.5	4	0.5	Bedrock/Step-Pool
4	3.1	0.9	Bedrock/Cascade
3.1	2.5	0.6	Step-Pool/Plane-Bed
2.5	1	1.5	Bedrock/Step-Pool/Cascade
1	0.2	0.8	Step-Pool/Cascade
0.2	0	0.2	Bedrock
North Fork Long Canyon Creek			
3.1	1.75	1.35	Step-Pool/Plane-Bed/Pool-Riffle
1.75	1.6	0.15	Bedrock
1.6	1.4	0.2	Plane-Bed
1.4	0.3	1.1	Step-Pool/Plane-Bed/Pool-Riffle
0.3	0	0.3	Bedrock
South Fork Long Canyon Creek			
3.3	3.2	0.1	Step-Pool/Plane-Bed
3.2	3.1	0.1	Bedrock
3.1	2.7	0.4	Step-Pool/Plane-Bed
2.7	1.8	0.9	Plane-Bed/Pool-Riffle
1.8	1.6	0.2	Bedrock
1.6	0.1	1.5	Step-Pool/Plane-Bed
0.1	0	0.1	Bedrock
Long Canyon Creek			
11.4	10.8	0.6	Plane-Bed/Step-Pool
10.8	10.5	0.3	Plane-Bed
10.5	8.3	2.2	Plane-Bed/Step-Pool
8.3	7.4	0.9	Bedrock/Step-Pool
7.4	7	0.4	Plane-Bed/Step-Pool
7	6.7	0.3	Bedrock
6.7	2	4.7	Bedrock/Step-Pool
2	0	2	Step-Pool

Table 7.7-3. Bypass and Peaking Reach Montgomery-Buffington Channel Types (continued).

Upstream Station	Downstream Station	Incremental Distance (mi)	Montgomery-Buffington Channel Type
Rubicon River			
0.3	2.1	1.8	Forced Pool-Riffle
2.1	3.3	1.2	Forced Pool-Riffle/Plane-Bed
3.3	3.9	0.6	Forced
3.9	8.6	4.7	Forced Pool-Riffle/ Cascades
8.6	9.7	1.1	Step-Pool/Cascade
9.7	15	5.3	Forced Pool-Riffle/ Cascades
15	15.2	0.2	Bedrock
15.2	21.9	6.7	Forced Pool-Riffle/ Cascades
21.9	22.5	0.6	Bedrock/Step-Pool
22.5	24.7	2.2	Forced Pool-Riffle/ Cascades
24.7	27.4	2.7	Forced Pool-Riffle/Plane-Bed
27.4	30.3	2.9	Plane-Bed
Middle Fork American River			
47.2	44.2	3	Bedrock/Step-Pool
44.2	42	2.2	Plane-Bed/Forced Pool-Riffle
42	40.8	1.2	Plane-Bed/Step-Pool
40.8	40	0.8	Bedrock
40	38.4	1.6	Step-Pool/Cascade
38.4	38	0.4	Bedrock
38	37.4	0.6	Step-Pool/Cascade
37.4	36.5	0.9	Bedrock
36.5	36	0.5	Step-Pool/Cascade
36	35.6	0.4	Interbay
35.6	34.8	0.8	Forced Pool-Riffle/ Cascades
34.8	34.2	0.6	Plane-Bed/Forced
34.2	33.4	0.8	Step-Pool/Cascade
33.4	33	0.4	Bedrock
33	29.8	3.2	Step-Pool/Forced Pool-Riffle
29.8	27.8	2	Plane-Bed/Forced Pool-Riffle
27.8	26.1	1.7	Forced Pool-Riffle/ Cascades
26.1	25.7	0.4	Plane-Bed/Pool-Riffle
25.7	24.7	1	Oxbow
24.7	10.8	13.9	Pool-Riffle
10.8	9.6	1.2	Forced Pool-Riffle/ Cascades
9.6	0	9.6	Pool-Riffle

Table 7.7-4. Responsiveness Rating for the MFP Streams and Rivers.

	Channel Response		
	High	**Moderate**	**Low**
Duncan Creek	1.7	3.4	9.4
North Fork Long Canyon Creek	2.7	0	0.5
South Fork Long Canyon Creek	0.9	2	0.4
Long Canyon Creek	0.3	3.2	7.9
Rubicon River	6.8	2.4	21
Middle Fork American River below Oxbow Powerhouse	23.5	0	1.2
Middle Fork American River above Oxbow Powerhouse	5.2	1.2	14.7
Total	**41.1**	**12.2**	**55.1**

Table 7.7-5. Summary of Flows Required to Move 25% of Suitable Gravels[1] within the High Calibration Flow Wetted Channel.

Site	Transect #	Unit Type	Impaired and Unimpaired Hydrology Recurrence Intervals (cfs)					25% Gravel Initiation Flow (cfs)		
			Hydrology Node	Q1.5 Unimpaired	Q1.5 Impaired	Q2.0 Impaired	Q5.0 Impaired	Measured Site Average Q25%	Measured Transect Q25%	Regression Q25%[2]
D8.3[3]	T1[4]	Pool	800.804	253	90	164	774	425	--	149
	T2[4]	Pool		253	90	164	774		--	
	T3	Pool		253	90	164	774		425	
NFLC1.9	T10[5]	Step Pool	817.819	50	19	32	225	11	--	29
	T15	Pool Tail		50	19	32	225		14.5	
	T18	Run		50	19	32	225		8	
SFLC2.3	T10	Pool Tail	820.822	77	29	44	396	36	27	40
	T13	Pool Tail		77	29	44	396		55	
	T19	Run		77	29	44	396		25	
LC9.0	T1[5]	Run	825.828	202	181	216	1,144	100	--	197
	T4	Pool Tail		202	181	216	1,144		180	
	T10	Low Gradient Riffle		202	181	216	1,144		80	
	T16	Pool tail		202	181	216	1,144		40	
R25.7	T2	Pool Tail	832.835	2012	87	173	1,922	500	500	500 [6]
	T21	Pool Tail		2012	87	173	1,922		500	
R20.9	T1	Pool tail	834.836	2259	322	745	4,479	530	260	678
	T6	Run		2259	322	745	4,479		1100	
	T15	Pool Tail		2259	322	745	4,479		230	
R3.5	6	Pool Tail	842.815	3234	1168	2,415	11,341	2300	1100	2198
	10	Pool Tail		3234	1168	2,415	11,341		2100	
	15	Pool		3234	1168	2,415	11,341		3700	
MF44.7	T2	Pool DS body	530.802	965	25	34	632	343	330	343 [6]
	T7	Pool DS body		965	25	34	632		475	
	T16	Pool body		965	25	34	632		225	
MF36.2	T10	Pool Tail	806.810	1324	466	771	1,758	763	530	702
	T11	Pool		1324	466	771	1,758		1500	
	T15	Run		1324	466	771	1,758		260	
MF26.2	2D-T6	Run	813.845	1938	369	584	2,970	568	675	532
	T4[7]	High Gradient Riffle		1938	369	584	2,970		--	
	T14	Pool Tail		1938	369	584	2,970		460	
MF14.1	Full Site	Various	860.863	6483	3383	7,332	19,789	5372	5372	6674
MF4.8	Full Site	Various	866.868	6,590	3476	7,467	20,241	8000	8000	6797

[1]Suitable for rainbow trout spawning according to the MFP RBT spawning substrate HSC.

[2]Predicted flow to move 25% of gravels based on Q2.0 impaired regression (Figure G-1, Appendix G, AQ 1 - TSR [PCWA 2011b]).

[3]Used representative bulk gravel sample from Duncan 6.3 site to characterize gravel at this site.

[4]Gravels movement occurs at extremely high flows greater than the modeled flow range.

[5]Substrate sizes in bulk gravel sample at this location larger than suitable for RBT spawning.

[6]Measured data used at these sites, Q2.0 impaired regression not used. The Q2.0 impaired recurrence interval flows at this site are relatively low. Gravel movement at these sites is most likely initiated by lower frequency (Q5.0) large spill events.

[7]Gravels present at this site were outside of target high calibration wetted channel for this transect.

Table 7.7-6. Average Number of Days Gravel Motion is Initiated by Water Year Type[1].

Site / Release Location	Gravel Initiation of Motion (cfs)[2]	Water Year Type	Existing Conditions[3]			
			Total # of Days	Average # of Days[4]	Event Year Average # of Days[5]	Number of Years[6]
Small Streams						
Duncan Creek	149	Wet	128	13	13	10 / 10
		Abv Normal	14	2	4	4 / 6
		Blw Normal	3	1	2	2 / 6
		Dry	1	0	1	2 / 5
		Critical	0	0	0	1 / 6
		Total	**146**	**---**	**---**	**19 / 33**
North Fork Long Canyon Creek	29	Wet	401	40	45	9 / 10
		Abv Normal	5	1	2	3 / 6
		Blw Normal	6	1	2	4 / 6
		Dry	3	1	2	2 / 5
		Critical	1	0	1	1 / 6
		Total	**416**	**---**	**---**	**19 / 33**
South Fork Long Canyon Creek	40	Wet	490	49	54	9 / 10
		Abv Normal	13	2	7	2 / 6
		Blw Normal	7	1	2	4 / 6
		Dry	2	0	2	1 / 5
		Critical	1	0	1	1 / 6
		Total	**513**	**---**	**---**	**17 / 33**
Long Canyon Creek	197	Wet	278	28	28	10 / 10
		Abv Normal	20	3	4	5 / 6
		Blw Normal	4	1	4	1 / 6
		Dry	2	0	1	2 / 5
		Critical	0	0	0	0 / 6
		Total	**304**	**---**	**---**	**18 / 33**
Middle Fork American River below French Meadows Dam						
MF44.7[5]	343	Wet	107	11	13	8 / 10
		Abv Normal	24	4	12	2 / 6
		Blw Normal	0	0	0	0 / 6
		Dry	0	0	0	0 / 5
		Critical	0	0	0	0 / 6
		Total	**131**	**---**	**---**	**10 / 33**
MF36.2	702	Wet	179	18	18	10 / 10
		Abv Normal	9	2	2	4 / 6
		Blw Normal	2	0	2	1 / 6
		Dry	2	0	1	2 / 5
		Critical	0	0	0	0 / 6
		Total	**192**	**---**	**---**	**17 / 33**

Table 7.7-6. Average Number of Days Gravel Motion is Initiated by Water Year Type(continued)[1].

Site / Release Location	Gravel Initiation of Motion (cfs)[2]	Water Year Type	Existing Conditions[3]			
			Total # of Days	Average # of Days[4]	Event Year Average # of	Number of Years[6]
Middle Fork American River below Middle Fork Interbay Dam						
MF26.2	532	Wet	493	49	49	10 / 10
		Abv Normal	15	3	3	6 / 6
		Blw Normal	0	0	0	0 / 6
		Dry	4	1	2	2 / 5
		Critical	0	0	0	0 / 6
		Total	**512**	**---**	**---**	**18 / 33**
Rubicon River below Hell Hole Dam						
R25.7[5]	500	Wet	192	19	21	9 / 10
		Abv Normal	14	2	14	1 / 6
		Blw Normal	2	0	2	1 / 6
		Dry	0	0	0	0 / 5
		Critical	0	0	0	0 / 6
		Total	**208**	**---**	**---**	**11 / 33**
R20.9	678	Wet	281	28	28	10 / 10
		Abv Normal	22	4	4	5 / 6
		Blw Normal	1	0	1	1 / 6
		Dry	1	0	1	1 / 5
		Critical	0	0	0	0 / 6
		Total	**305**	**---**	**---**	**17 / 33**
R3.5	2,198	Wet	201	20	20	10 / 10
		Abv Normal	22	4	4	6 / 6
		Blw Normal	1	0	1	1 / 6
		Dry	1	0	1	1 / 5
		Critical	0	0	0	0 / 6
		Total	**225**	**---**	**---**	**18 / 33**
Middle Fork American River below Ralston Afterbay						
MF14.1	6,674	Wet	110	11	11	10 / 10
		Abv Normal	9	2	2	6 / 6
		Blw Normal	1	0	1	1 / 6
		Dry	1	0	1	1 / 5
		Critical	0	0	0	0 / 6
		Total	**121**	**---**	**---**	**18 / 33**
MF4.8	6,797	Wet	110	11	11	10 / 10
		Abv Normal	9	2	2	6 / 6
		Blw Normal	1	0	1	1 / 6
		Dry	1	0	1	1 / 5
		Total	0	0	0	0 / 6
		Critical	**121**	**---**	**---**	**18 / 33**

[1]AQ 1- TSR, Table G-1 (PCWA 2011b).
[2] Flow required to initiate motion of 25% of the gravel substrate.
[3]Historical hydrology (1975-2007).
[4]Total number of event days / number of years in water year type.
[5]Total number of event days / number of years with events in water year type.
[6]Number of years with events / total number of years in water year type.

Table 7.7-7. V* Measurement Results 2006 and 2007.

Stream	Pool Number	River Mile	Avg Length (ft)	Avg Width (ft)	Pool Bed Surface Area (ft^2)	Avg Residual Pool Volume (ft^3)	Avg Fines Thickness (ft)	Avg Fines Surface Area (ft^2)	Avg Volume Fine Sediment (ft^3)	Calculated V*
Duncan Creek										
Duncan Creek	1	6.16	72	7	504	1638	<0.1	trace	trace	<0.001
	2	6.53	45	30	1350	1350	0.0	0.0	0.0	0.000
	3	6.47	51	1	68	119	0.2	3.0	0.6	0.005
	4	6.41	45	30	1350	6075	0.0	0.0	0.0	0.000
	5	6.37	51	12	612	1224	0.1	3.0	0.3	0.0002
	6	6.35	54	6	324	486	<0.1	trace	trace	<0.001
	7	6.34	78	8	624	624	<0.1	trace	trace	<0.001
	8	6.3	39	45	1755	3510	<0.1	trace	trace	<0.001
	9	6.28	54	18	972	1944	0.2	16.0	3.2	0.002
	10	6.2	60	8	480	720	0.0	0.0	0.0	0.000
									Weighted 2007 V*	**0.0002**
Long Canyon Creek										
North Fork Long Canyon Creek	1	2.03	30	12	360	270	0.3	30.0	9.0	0.025
	2	1.96	48	21	1008	2016	0.3	15.0	3.8	0.004
	3	1.94	55	7	385	385	0.2	5.0	0.8	0.002
	4	1.93	36	6	198	119	0.0	0.0	0.0	0.000
	5	1.9	10	13	130	65	0.1	1.0	0.1	0.001
	6	1.88	36	11	396	317	0.1	1.0	0.1	0.0003
	7	1.86	60	12	720	540	0.1	4.0	0.4	0.001
	8	1.84	19	8	152	76	0.2	4.5	0.9	0.006
	9	1.81	35	11	385	193	0.0	0.0	0.0	0.000
	10	1.79	39	6	234	94	<0.1	trace	trace	<0.001
									Weighted 2007 V*	**0.004**
South Fork Long Canyon Creek	1	2.59	19	13	247	198	<0.1	trace	trace	<0.001
	2	2.59	47	12	564	282	0.0	0.0	0.0	0.000
	3	2.57	87	21	1827	2375	0.2	85.3	12.8	0.007
	4	2.53	39	19	741	741	0.0	0.0	0.0	0.000
	5	2.45	113	16	1808	2712	0.1	50.0	5.0	0.003
	6	2.36	60	20	1200	1201	0.0	0.0	0.0	0.000
	7	2.34	90	18	1620	1620	<0.1	trace	trace	<0.001
	8	2.29	53	13	689	482	0.0	0.0	0.0	0.000
	9	2.26	95	18	1710	855	0.4	15.0	6.0	0.004
	10	2.23	100	18	1800	900	<0.1	trace	trace	<0.001
									Weighted 2007 V*	**0.002**
Long Canyon Creek	1	9.09	63	17	1071	3481	0.0	0.0	0.0	0.000
	2	9.08	20	20	400	1200	0.0	0.0	0.0	0.000
	3	9.06	57	20	1140	2565	0.0	0.0	0.0	0.000
	4	9	96	42	4032	6048	0.0	0.0	0.0	0.000
	5	8.86	150	45	6750	5063	0.0	0.0	0.0	0.000
	6	8.8	96	75	7200	14400	0.0	0.0	0.0	0.000
	7	8.73	87	20	1740	3828	0.0	0.0	0.0	0.000
	8	8.61	42	51	2142	6426	<0.1	trace	trace	<0.001
	9	8.6	90	12	1080	2160	<0.1	trace	trace	<0.001
									Weighted 2007 V*	**0.000**
Rubicon River										
Hell Hole Reservoir to South Fork Rubicon River	1	25.91	429	63	27027	101351	0.8	275	220	0.002
	2	25.81	228	45	10260	12825	0	0	0	0.000
	3	25.71	213	45	9585	16774	0.1	200	20	0.001
	4	25.63	246	63	15498	42620	0.5	2000	1000	0.023
	5	25.46	204	30	6120	7650	0	0	0	0.000
	6	25.37	138	60	8280	35190	0.1	300	30	0.001
	7	25.28	114	36	4104	7182	0.0	0	0	0.000
	8	25.06	357	45	16065	40163	0.1	10	1	0.00002
	9	25.01	138	27	3726	7825	<0.1	trace	trace	<0.001
									Weighted 2007 V*	**0.005**

Table 7.7-7. V* Measurement Results 2006 and 2007 (continued).

Stream	Pool Number	River Mile	Avg Length (ft)	Avg Width (ft)	Pool Bed Surface Area (ft^2)	Avg Residual Pool Volume (ft^3)	Avg Fines Thickness (ft)	Avg Fines Surface Area (ft^2)	Avg Volume Fine Sediment (ft^3)	Calculated V*
Rubicon River (continued)										
South Fork Rubicon River to Ralston Afterbay	1	21.17	243	54	13122	52488	1.5	150	225	0.004
	2	21.05	447	69	30843	138794	1.0	6000	6000	0.043
	3	20.9	60	45	2700	2700	0.0	0	0	0.000
	4	20.78	240	69	16560	53820	0.1	1125	113	0.002
	5	20.74	165	36	5940	17820	0.0	0	0	0.000
	6	20.64	216	57	12312	24624	<0.1	trace	trace	<0.001
	7	20.45	534	60	32040	16020	0.0	0	0	0.000
	8	20.25	315	63	19845	89303	0.0	0	0	0.000
	9	3.55	204	51	10404	20808	2.0	50	100	0.005
	10	3.48	534	78	41652	179104	<0.1	trace	trace	<0.001
	11	3.32	255	93	23715	213435	0.8	144	108	0.001
	12	3.18	360	66	23760	95040	<0.1	trace	trace	<0.001
	13	3	372	75	27900	97650	<0.1	trace	trace	<0.001
	14	1.6	330	66	21780	87120	0.8	400	320	0.005
	15	1.48	390	60	23400	198900	1.5	16200	24300	0.081
	16	1.14	300	71	21240	233640	0.1	2100	210	0.001
	17	0.91	285	75	21375	101531	<0.1	trace	trace	<0.001
									Weighted 2007 V*	**0.019**
	18	0.7	258	76	19608	58282	0.3	5460	1638	**0.030**
Middle Fork American River (MFAR)										
French Meadows Reservoir to Middle Fork Interbay	1	45	81	30	2430	7290	0.3	30	9	0.001
	2	44.92	51	30	1530	3060	<0.1	trace	trace	<0.001
	3	44.9	87	36	3132	3132	0.2	56	11	0.004
	4	44.9	87	24	2088	3132	0.3	11	3	0.001
	5	44.89	45	36	1620	6480	0.0	0	0	0.000
	6	44.89	69	45	3105	7763	0.2	10	2	0.0002
	7	44.86	114	36	4104	5130	0.8	455	364	0.071
	8	44.83	69	33	2277	3416	0.0	0	0	0.000
	9	44.8	69	33	2277	3416	0.3	114	34	0.010
	10	44.79	45	33	1485	4455	0.1	45	5	0.001
	11	36.25	177	65	11417	42241	<0.1	trace	trace	<0.001
	12	36.2	117	34	3978	11934	0.0	0	0	0.000
	13	36.18	102	33	3366	6732	<0.1	trace	trace	<0.001
	14	36.16	36	57	2052	8208	<0.1	trace	trace	<0.001
	15	36.11	219	45	9855	44348	<0.1	trace	trace	<0.001
									Weighted 2007 V*	**0.003**
	16	36.06	168	50	8400	11797	0.2	895	179	0.020
	17	35.98	221	55	12155	7263	0.3	1150	345	0.030
									Weighted 2006 V*	**0.027**
Middle Fork Interbay to Ralston Afterbay	1	29.4	164	52	8528	23368	0.1	5220	522	0.020
	2	29.3	208	40	8320	2600	0.1	830	83	0.030
	3	29.25	175	33	5775	12343	0.4	102	41	0.003
	4	29.2	106	63	6678	1080	0.2	395	79	0.070
	5	26.08	173	58	10034	12269	0.2	2280	456	0.040
	6	25.94	268	46	12328	16722	0.2	2880	576	0.030
									Weighted 2006 V*	**0.025**
	7	26.69	165	45	7425	18563	<0.1	trace	trace	<0.001
	8	26.36	150	39	5850	23400	0.0	0	0	0.000
	9	26.29	147	42	6174	16670	0.0	0	0	0.000
									Weighted 2007 V*	**0.000**
Below Ralston Afterbay	1	14.8	1155	96	110880	388080	0.1	2880	288	0.003
	2	14.35	270	75	20250	70875	0.3	220	66	0.003
	3	14.25	660	81	53460	294030	0.1	3116	312	0.006
	4	13.9	825	150	123750	618750	0.4	8800	3520	0.028
	5	13.6	819	75	61425	307125	0.1	180	18	0.0003
	6	4.6	420	120	50400	705600	0.5	7200	3600	0.071
	7	4.2	942	90	84780	763020	0.2	2100	420	0.005
	8	3.7	822	99	81378	732402	0.2	6105	1221	0.015
									Weighted 2007 V*	**0.002**

Table 7.7-7. V* Measurement Results 2006 and 2007 (continued).

Stream	Pool Number	River Mile	Avg Length (ft)	Avg Width (ft)	Pool Bed Surface Area (ft^2)	Avg Residual Pool Volume (ft^3)	Avg Fines Thickness (ft)	Avg Fines Surface Area (ft^2)	Avg Volume Fine Sediment (ft^3)	Calculated V*
Comparison Streams										
North Fork American River	1	31.6	1017	120	122040	549180	0.0	0	0	0.000
	2	31.5	1200	90	108000	432000	5.0	1200	6000	0.014
	3	30.7	705	105	74025	740250	3.0	5000	15000	0.020
	4	30.4	840	90	75600	151200	0.0	0	0	0.000
	5	29.6	810	90	72900	200475	0.0	0	0	0.000
									Weighted 2007 V*	**0.010**
North Fork of the Middle Fork American River	1	2.9	146.2	53	7749	5086	0.2	1800	360	0.07
	2	2.85	176	47	8272	5332	0.1	1840	184	0.03
	3	2.75	75	35	2625	3455	0.2	610	122	0.03
									Weighted 2006 V*	**0.046**

Table 7.7-8. Fine Sediment Content of Potential Spawning Gravel Samples.

Location	Instream Unit No.	Habitat Type[1]	River Mile	Spawning Gravel (SG)	Gravel		Gravel Following Winnowing[2]	
					Cumulative Percent Finer than 1 mm	Cumulative Percent Finer than 6.4 mm	Cumulative Percent Finer than 1 mm	Cumulative Percent Finer than 6.4 mm
Instream Flow Study Streams								
Duncan Creek								
D6.3	203	MCP	6.2	1	0.5%	10.0%	0.3%	6%
	193	MCP	6.3	2	0.2%	22.0%	0.2%	13%
	188	STP	6.36	3	0.4%	16.0%	0.3%	9%
	188	STP	6.36	4	1.0%	17.0%	0.7%	10%
Long Canyon Creek								
North Fork Long Canyon Creek (NFLC1.9)	109	STP	1.94	1	4.6%	31.0%	3.1%	18%
	103	LSP	1.98	2	6.4%	33.0%	4.3%	19%
	93	SRN	2.06	3	4.9%	22.0%	3.3%	13%
	93	SRN	2.06	4	4.2%	20.0%	2.8%	12%
South Fork Long Canyon Creek (SFLC2.3)	97	MCP	2.34	1	7.4%[3]	32%[3]	5%[3]	19%[3]
	93	LSP	2.39	2	9.5%	22.0%	6.4%	13%
	77	SRN	2.53	3	4.7%	20.0%	3.1%	12%
	77	SRN	2.53	4	2.1%	24.0%	1.4%	14%
Long Canyon Creek (LC9.0)	136	RUN	8.84	1	0.9%	10.0%	0.6%	6%
	134	MCP	8.88	2	9.3%	21.0%	6.2%	12%
	131	LGR	8.98	3	1.6%	16.0%	1.1%	9%
	131	LGR	8.98	4	4.2%	29.0%	2.8%	17%
	126	STP	9.08	5	2.4%	20.0%	1.6%	12%
Rubicon River								
R25.7	820	MCP	25.91	1	2.7%	8.0%	1.8%	5%
	820	MCP	25.92	2	3.9%	10.0%	2.6%	6%
	807	LSP	25.63	3	2.7%	22.0%	1.8%	13%
	795	LGR	25.2	4	6.9%	34.0%	4.6%	20%
R20.9	679	MCP	20.87	1	3.3%	25.0%	2.2%	15%
	665	RUN	20.51	2	6.9%	34.0%	4.6%	20%
	662	MCP	20.4	3	10.6%	42.0%	7.1%	24%
	662	MCP	20.4	4	6.7%	35.0%	4.5%	20%
R3.5	81	MCP	3.31	1	4.0%	18.0%	2.7%	10%
	81	MCP	3.31	2	3.9%	15.0%	2.6%	9%
	76	MCP	3.12	3	5.6%	27.0%	3.8%	16%
	71	LSP	3.02	4	3.5%	30.0%	2.3%	17%
Middle Fork American River								
MF44.7	728	STP	44.94	1	7.0%	32.0%	4.7%	19%
	721	MCP	44.86	2	8.1%	29.0%	5.4%	17%
	721	MCP	44.86	3	10.6%	38.0%	7.1%	22%
	717	MCP	44.8	4	7.5%	32.0%	5.0%	19%
MF36.2	694	RUN	36.17	1	2.1%	31.0%	1.4%	18%
	694	RUN	36.17	2	1.1%	36.0%	0.7%	21%
	694	RUN	36.17	3	4.1%	39.0%	2.7%	23%
	690	MCP	36.11	4	3.5%	19.0%	2.3%	11%
	690	MCP	36.11	5	3.3%	26.0%	2.2%	15%

Table 7.7-8. Fine Sediment Content of Potential Spawning Gravel Samples (continued).

Location	Instream Unit No.	Habitat Type[1]	River Mile	Spawning Gravel (SG)	Gravel		Gravel Following Winnowing	
					Cumulative Percent Finer than 1 mm	Cumulative Percent Finer than 6.4 mm	Cumulative Percent Finer than 1 mm	Cumulative Percent Finer than 6.4 mm
Instream Flow Study Streams								
MF26.2	334	HGR	26.32	1	8.1%	26.0%	5.4%	15%
	330	HGR	26.32	2	2.8%	17.0%	1.9%	10%
	327	POW	26.18	3	7.6%	37.0%	5.1%	21%
	327	POW	26.18	4	7.9%	37.0%	5.3%	21%
MF14.1	187	LGR	14.5	1	4.8%	32.0%	3.2%	19%
	187	LGR	14.5	2	3.9%	19.0%	2.6%	11%
	183	LSP	14.2	3	5.5%	37.0%	3.7%	21%
	177	SRN	13.64	4	5.8%	18.0%	3.9%	10%
MF4.8	83	SRN	4.72	1	12.1%	33.0%	8.1%	19%
	83	SRN	4.72	2	14.7%	31.0%	9.8%	18%
	81	MCP	4.61	3	9.1%	15.0%	6.1%	9%
	79	MCP	4.44	4	5.0%	20.0%	3.4%	12%
Comparison Streams								
North Fork American River (NF31.3)	*	MCP	31.25	1	3.1%	17.0%	2.1%	10%
	*	LGR	30.7	2	12.4%	32.0%	8.3%	19%
	*	LGR	30.7	3	14.1%	33.0%	9.4%	19%
	*	LGR	30.5	4	3.5%	19.0%	2.3%	11%
North Fork of the Middle Fork American River (NFMF2.3)	*	MCP	2.87	1	1.2%	16.0%	0.8%	9%
	*	POW	2.78	2	3.0%	25.0%	2.0%	15%
	*	MCP	2.74	3	1.1%	19.0%	0.7%	11%
	*	MCP	2.74	4	1.2%	22.0%	0.8%	13%

[1]MCP:mid channel pool; STP:step pool; LSP:lateral scour pool; SRN:step run; RUN:run; LGR:low gradient riffle; HGR:high gradient riffle; POW:pocket water

[2]The criteria for successful spawning is: the percentage finer than 1 mm should be less than 14% and the percentage finer than 6.4 mm should be less than 30%.

[3]Does not contain fine sediment content from surface sample

"*" Instream unit number not applicable

Table 7.7-9. Particle Size Results for Potential Spawning Gravel Samples.

Location	Instream Unit No.	Habitat Type[1]	River Mile	Spawning Gravel (SG)	Geometric Mean (mm)	D_{84} (mm)	D_{50} (mm)	D_{16} (mm)
Instream Flow Study Streams								
Duncan Creek								
D6.3	203	MCP	6.2	1	15.9	37.7	16.1	7.6
	193	MCP	6.3	2	11.6	26.1	11.6	5.2
	188	STP	6.36	3-R	16.2	40.7	18.4	6.1
	188	STP	6.36	4-R	17.6	50.0	22.3	6.0
Long Canyon Creek								
North Fork Long Canyon Creek (NFLC1.9)	109	STP	1.94	1	12.9	99.4	11.8	2.6
	103	LSP	1.98	2	10.0	39.2	12.5	2.3
	93	SRN	2.06	3-R	11.4	51.1	15.0	2.1
	93	SRN	2.06	4-R	17.6	53.5	27.3	4.1
South Fork Long Canyon Creek (SFLC2.3)	97	MCP	2.34	1[2]	11.5	54.5	17.1	2.0
	93	LSP	2.39	2	16.3	64.9	27.5	9.0
	77	SRN	2.53	3-R	16.8	62.1	22.7	3.9
	77	SRN	2.53	4-R	13.8	42.6	17.7	3.7
Long Canyon Creek (LC9.0)	136	RUN	8.84	1	32.2	105.5	38.8	9.2
	134	MCP	8.88	2	17.4	61.6	33.2	2.3
	131	LGR	8.98	3-R	25.6	107.8	28.8	2.3
	131	LGR	8.98	4-R	14.4	57.3	18.3	2.7
	126	STP	9.08	5	13.9	36.0	18.5	4.6
Rubicon River								
R25.7	820	MCP	25.91	1-R	17.0	39.9	18.7	8.9
	820	MCP	25.92	2-R	16.4	41.2	18.5	8.3
	807	LSP	25.63	3	16.5	55.5	24.2	3.7
	795	LGR	25.2	4	10.0	39.1	15.1	1.9
R20.9	679	MCP	20.87	1	11.7	34.6	15.6	3.3
	665	RUN	20.51	2	9.2	37.6	11.7	1.9
	662	MCP	20.4	3-R	6.1	20.7	7.5	1.5
	662	MCP	20.4	4-R	8.1	26.1	9.5	2.2
R3.5	81	MCP	3.31	1-R	19.5	67.9	28.2	5.0
	81	MCP	3.31	2-R	16.0	42.7	19.4	6.6
	76	MCP	3.12	3	12.8	52.9	15.1	3.2
	71	LSP	3.02	4	9.3	28.5	10.0	3.3
Middle Fork American River								
MF44.7	728	STP	44.94	1	9.7	35.7	14.1	2.0
	721	MCP	44.86	2-R	9.6	32.9	15.2	1.8
	721	MCP	44.86	3-R	9.7	34.3	14.0	2.0
	717	MCP	44.8	4	7.4	29.0	10.0	1.4
MF36.2	694	RUN	36.17	1-R	9.0	33.5	9.7	3.6
	694	RUN	36.17	2-R	8.4	21.9	7.9	3.4
	694	RUN	36.17	3	11.1	65.5	9.6	2.8
	690	MCP	36.11	4	15.2	50.9	25.0	3.1
	690	MCP	36.11	5	12.3	39.6	16.0	3.3
MF26.2	334	HGR	26.32	1	11.5	38.5	18.1	2.1
	330	HGR	26.32	2	18.5	52.6	26.4	5.5
	327	POW	26.18	3-R	7.3	24.4	8.9	1.9
	327	POW	26.18	4-R	8.5	41.4	10.2	1.8

Table 7.7-9. Particle Size Results for Potential Spawning Gravel Samples (continued).

Location	Instream Unit No.	Habitat Type[1]	River Mile	Spawning Gravel (SG)	Geometric Mean (mm)	D_{84} (mm)	D_{50} (mm)	D_{16} (mm)
Instream Flow Study Streams								
MF14.1	187	LGR	14.5	1-R	10.9	39.8	16.5	1.9
	187	LGR	14.5	2-R	17.5	54.0	26.1	4.5
	183	LSP	14.2	3	9.0	38.1	9.4	2.1
	177	SRN	13.64	4	21.2	63.7	39.0	5.0
MF4.8	83	SRN	4.72	1-R	9.9	46.6	16.1	1.3
	83	SRN	4.72	2-R	10.1	44.3	18.6	1.1
	81	MCP	4.61	3	16.4	46.1	22.9	6.8
	79	MCP	4.44	4	16.0	49.7	27.8	4.2
Comparison Streams								
North Fork of the Middle Fork American River (NFMF2.3)	*	MCP	31.25	1	9.9	18.2	10.6	5.8
	*	LGR	30.7	2-R	10.8	30.3	12.7	3.7
	*	LGR	30.7	3-R	11.1	25.0	12.2	5.2
	*	LGR	30.5	4	14.6	61.8	13.6	4.6
North Fork American River (NF31.3)	*	MCP	2.87	1	15.1	40.7	19.9	5.5
	*	POW	2.78	2	8.6	31.1	12.7	1.6
	*	MCP	2.74	3-R	7.8	28.0	11.3	1.3
	*	MCP	2.74	8-R	25.5	100.1	41.7	3.9

[1]MCP:mid channel pool; STP:step pool; LSP:lateral scour pool; SRN:step run; RUN:run; LGR:low gradient riffle; HGR:high gradient riffle; POW:pocket water

[2]Does not contain material from surface sample

* = Instream unit number not applicable

R = Replicate side-by-side sample

Table 7.7-10. Total Number of Days that Scouring Flows[1] Occurred between 1975 and 2007.

Site / Release Location	Flow (cfs)	Water Year Type	Existing Conditions			
			Total # of Days	Average # of Days[2]	Event Year Average # of Days[3]	Number of Years[4]
Small Streams						
Duncan Creek	774	Wet	14	1	3	5 / 10
		Abv Normal	1	0	1	1 / 6
		Blw Normal	0	0	0	0 / 6
		Dry	0	0	0	0 / 5
		Critical	0	0	0	0 / 6
		Total	**15**	**---**	**---**	**6 / 33**
North Fork Long Canyon Creek	225	Wet	16	2	3	6 / 10
		Abv Normal	0	0	0	0 / 6
		Blw Normal	0	0	0	0 / 6
		Dry	0	0	0	0 / 5
		Critical	0	0	0	0 / 6
		Total	**16**	**---**	**---**	**6 / 33**
South Fork Long Canyon Creek	396	Wet	16	2	3	6 / 10
		Abv Normal	0	0	0	0 / 6
		Blw Normal	0	0	0	0 / 6
		Dry	0	0	0	0 / 5
		Critical	0	0	0	0 / 6
		Total	**16**	**---**	**---**	**6 / 33**
Long Canyon Creek	1,144	Wet	15	2	3	6 / 10
		Abv Normal	0	0	0	0 / 6
		Blw Normal	0	0	0	0 / 6
		Dry	0	0	0	0 / 5
		Critical	0	0	0	0 / 6
		Total	**15**	**---**	**---**	**6 / 33**
Middle Fork American River below French Meadows Dam						
MF44.7	632	Wet	22	2	4	6 / 10
		Abv Normal	0	0	0	0 / 6
		Blw Normal	0	0	0	0 / 6
		Dry	0	0	0	0 / 5
		Critical	0	0	0	0 / 6
		Total	**22**	**---**	**---**	**6 / 33**
MF36.2	1,758	Wet	21	2	4	6 / 10
		Abv Normal	0	0	0	0 / 6
		Blw Normal	0	0	0	0 / 6
		Dry	0	0	0	0 / 5
		Critical	0	0	0	0 / 6
		Total	**21**	**---**	**---**	**6 / 33**
Middle Fork American River below Middle Fork Interbay Dam						
MF26.2	2,970	Wet	18	2	3	6 / 10
		Abv Normal	0	0	0	0 / 6
		Blw Normal	0	0	0	0 / 6
		Dry	0	0	0	0 / 5
		Critical	0	0	0	0 / 6
		Total	**18**	**---**	**---**	**6 / 33**

Table 7.7-10. Total Number of Days that Scouring Flows[1] Occurred between 1975 and 2007 (continued).

Site / Release Location	Flow (cfs)	Water Year Type	Existing Conditions			
			Total # of Days	Average # of Days[2]	Event Year Average # of	Number of Years[4]
Rubicon River below Hell Hole Dam						
R25.7	1,922	Wet	13	1	3	5 / 10
		Abv Normal	1	0	1	1 / 6
		Blw Normal	0	0	0	0 / 6
		Dry	0	0	0	0 / 5
		Critical	0	0	0	0 / 6
		Total	**14**	**---**	**---**	**6 / 33**
R20.9	4,479	Wet	16	2	3	6 / 10
		Abv Normal	0	0	0	0 / 6
		Blw Normal	0	0	0	0 / 6
		Dry	0	0	0	0 / 5
		Critical	0	0	0	0 / 6
		Total	**16**	**---**	**---**	**6 / 33**
R3.5	11,341	Wet	15	2	3	6 / 10
		Abv Normal	0	0	0	0 / 6
		Blw Normal	0	0	0	0 / 6
		Dry	0	0	0	0 / 5
		Critical	0	0	0	0 / 6
		Total	**15**	**---**	**---**	**6 / 33**
Middle Fork American River below Ralston Afterbay						
MF14.1	19,789	Wet	19	2	3	6 / 10
		Abv Normal	0	0	0	0 / 6
		Blw Normal	0	0	0	0 / 6
		Dry	0	0	0	0 / 5
		Critical	0	0	0	0 / 6
		Total	**19**	**---**	**---**	**6 / 33**
MF4.8	20,241	Wet	19	2	3	6 / 10
		Abv Normal	0	0	0	0 / 6
		Blw Normal	0	0	0	0 / 6
		Dry	0	0	0	0 / 5
		Critical	0	0	0	0 / 6
		Total	**19**	**---**	**---**	**6 / 33**

[1]For this analysis, a 'scouring flow' was a flow that exceeded the impaired Q5 (5-year recurrence interval) flow.

[2]Total number of scour days / number of years in water year type.

[3]Total number of scour days / number of years with scour events in water year type.

[4]Number of years with scour events / total number of years in water year type.

Table 7.7-11. Summary of Historic Sediment Removal Activities at MFP Diversion Pools and Medium Reservoirs (through 2009).[1]

Year	Month[2]	Loose, Uncompacted Volume of Sediment Removed (cubic yds)
Duncan Creek Diversion Pool (period of record 1997-2009)		
1988	-	Sediment removal occurred in this year, however, no information on the volume of sediment removed is available
1998	Aug	4,500
2007	Sept	1,570
Total		**6,070**
Frequency of Sediment Removal Activities:		**once every 7.3 years**
Volume Removed per Maintenance Activity[2]		**3,035 cubic yards**
Average Annual Volume Removed		**416 cubic yards/year**
Average Annual Spawning Gravel Volume Removed		**148 cubic yards/year**
North Fork Long Canyon Diversion Pool (period of record 1980-2009)		
1980	-	Sediment removal occurred in these years, however, no information on the volume of sediment removed is available
1982	-	
1986	-	
1988	-	
1990	-	
1992	-	
1995	-	
1997	-	1,600
2004	Sept	400
2006	Sept	1,370
Total		**3,370**
Frequency of Sediment Removal Activities: 10 times between 1980-2009 (30 years)		**once every 3 years**
Average Volume Removed per Maintenance Activity[2]		**1,123 cubic yards**
Average Annual Volume Removed		**374 cubic yards/year**
Average Annual Spawning Gravel Volume Removed		**75 cubic yards/year**
South Fork Long Canyon Diversion Pool (period of record 1980-2009)		
1980	-	Sediment removal occurred in these years, however, no information on the volume of sediment removed is available
1982	-	
1986	-	
1988	-	
1995	-	
1997	-	2,500
2006	Sept	2,850
Total		**5,350**
Frequency of Sediment Removal Activities: 7 times between 1980-2009 (30 years)		**once every 4.3 years**
Average Volume Removed per Maintenance Activity[2]		**2,675 cubic yards**
Average Annual Volume Removed		**622 cubic yards/year**
Average Annual Spawning Gravel Volume Removed		**386 cubic yards/year**
Middle Fork Interbay (period of record 1987-2009)		
1987	Oct	25,000
1988	Oct	35,000
1997	Feb	16,000
2000	Oct	68,000
Total		**144,000**
Frequency of Sediment Removal Activities: 4 times between 1987-2009 (23 years)		**once every 5.8 years**
Average Volume Removed per Maintenance Activity[2]		**36,000 cubic yards**
Average Annual Volume Removed		**6,207 cubic yards/year**
Average Annual Spawning Gravel Volume Removed		**1,303 cubic yards/year**

Table 7.7-11. Summary of Historic Sediment Removal Activities at MFP Diversion Pools and Medium Reservoirs (through 2009) (continued).[1]

Year	Month[2]	Loose, Uncompacted Volume of Sediment Removed (cubic yds)
Ralston Afterbay (period of record 1969-2009)		
1969	-	Sediment removal occurred in this year, however, no information on the volume of sediment removed is available
1981	Oct	10,000
1984	Oct	13,000
1985	Oct	12,000
1986	Mar	45,000
1986	Oct	80,000
1989	Oct	35,000
1994	Sept	77,000
1997	Feb	65,000
2002	Oct	101,000[3]
Total		**438,000**
Frequency of Sediment Removal Activities:		**once every 4.6 years**
Average Volume Removed per Maintenance Activity[2]		**48,667 cubic yards**
Average Annual Volume Removed		**10,580 cubic yards/year**
Average Annual Spawning Gravel Volume Removed		**2,645 cubic yards/year**

[1]Source: AQ 9 – Geomorphology TSR (2011d; SD B).

[2]Includes only the years with known sediment volumes.

[3]Volume equals 45,000 cubic yards compacted, in-place sediment at Indian Bar; and 29,000 cubic yards compacted, in-place sediment at

Table 7.7-12. MFP Sediment Disposal Areas.

Disposal Areas
Duncan Creek Diversion Sediment Disposal Area
North Fork Long Canyon Crossing Sediment Disposal Area
Middle Fork Interbay Sediment Disposal Area
Ralston Ridge Sediment Disposal Area

Table 7.7-13. Particle Size Composition Summary for Diversion Pools.

	Sand <2 mm	Fine Gravel 2-8 mm	Medium Gravel 8-45 mm	Coarse Gravel 45-64 mm	Cobble 64-256 mm	Boulder/Bedrock >256 mm
North Fork Long Canyon Diversion Pool						
Sample 1	66%	16%	17%	0%	0%	0%
Sample 2	69%	19%	12%	0%	0%	0%
Sample 3	87%	9%	3%	0%	0%	0%
Sample 4	65%	25%	11%	0%	0%	0%
Sample 5	34%	27%	39%	0%	0%	0%
Sample 6	37%	23%	30%	10%	0%	0%
Sample 7	70%	18%	10%	3%	0%	0%
Combined Average	**61%**	**20%**	**17%**	**2%**	**0%**	**0%**
South Fork Long Canyon Diversion Pool						
Sample 1	19%	24%	45%	12%	0%	0%
Sample 2	24%	21%	49%	6%	0%	0%
Sample 3	25%	17%	47%	11%	0%	0%
Sample 4	12%	8%	53%	16%	11%	0%
Sample 5	17%	13%	57%	14%	0%	0%
Combined Average	**19%**	**17%**	**50%**	**12%**	**2%**	**0%**

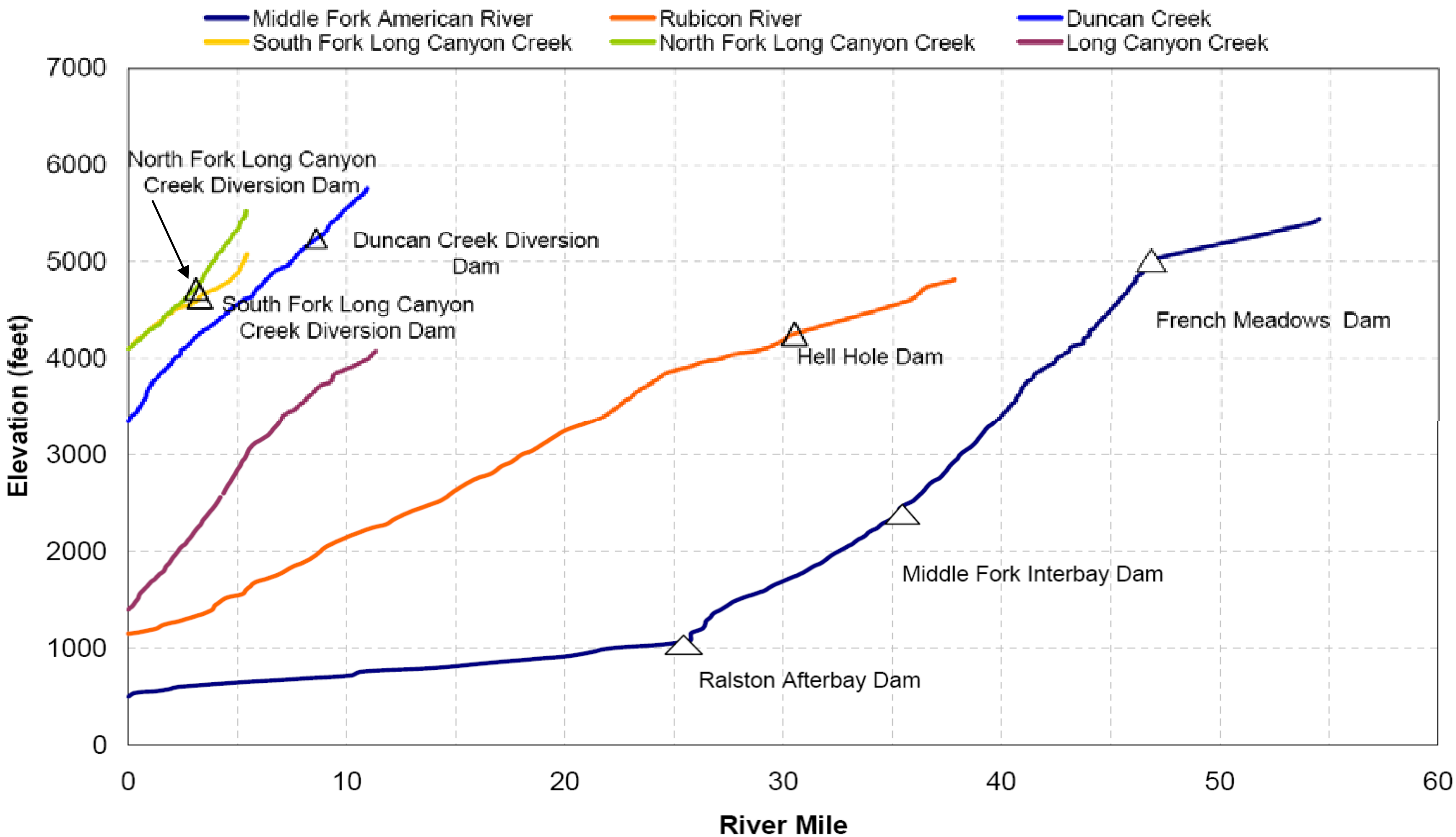
Table 7.7-14. Large Woody Debris within Project Reservoirs and Diversions.

Location	Minimum Length for Large Woody Debris Classification (ft)[1]	Observation Method	Estimated Count (Pieces counted or density of LWD)	Potential for Hillslope Recruitment	Maintenance Practices
Hell Hole Reservoir	50	Boat and walking	40-50 pieces total. Few in Upper Hell Hole Reservoir, 5 pieces behind dam face, most were along northern shoreline at high water mark	Yes, observed along the northwest side of the lower reservoir	Wood on the spillway and dam is collected and burned on site, on average once every five years
French Meadows Reservoir	15	boat, driving along road, and walking	Visual estimate of approximately 1 piece of LWD per every 200-300 feet of shoreline	Yes, active erosion was observed on the shoreline, mostly along the downstream margins of the reservoir	LWD is primarily left in place
Middle Fork Interbay	35	walking	None in reservoir. One piece immediately downstream of reservoir.	Potentially downstream of dam	Woody debris is flushed through the spillway gates, on average once every five years
Ralston Afterbay	120	driving along road and walking	None	Yes, dense vegetation on steep hillslopes surrounding reservoir	Woody debris is flushed through the spillway gates, on average once every five years
Duncan Diversion Pool	22	walking	6 pieces	No	Smaller woody debris is removed from the trash rack, on average once every five years
South Fork Long Canyon Creek Diversion Pool	15	walking	None	No	Smaller woody debris is removed from the trash rack, on average once every five years
North Fork Long Canyon Creek Diversion Pool	15	walking	3 pieces	No	Smaller woody debris is removed from the trash rack, on average once every five years

[1]Minimum width for LWD was 1 ft.

FIGURES

Figure 7.7-1. Middle Fork Project River Longitudinal Profiles.



MAPS