EXECUTIVE SUMMARY OF

THE 2006 UPDATE TO THE CLEAR CREEK GRAVEL MANAGEMENT PLAN

Prepared for:

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INTRODUCTION

The September 2006 Update to the Clear Creek Gravel Management Plan builds upon and repeats many of the investigations originally described in the 2000 Clear Creek Gravel Management Plan by McBain and Trush. This executive summary reduces the technical data contained in the 2006 Update into a more succinct and accessible form. The first section of this executive summary discusses the pertinent findings from the 2006 update. The second part addresses questions raised on behalf of CVPIA following a review of the 2006 update. Citations, site maps, statements of assumptions and supporting data appear in the master document.

Notable revisions to the master document as of April 2007:

1. Table 4-1: *Clear Creek Gravel Injection Volumes* has been revised per WSRCD 2007 calculations and is included in this document. This revision does not affect the time estimate to recharge Reach One

PART ONE: PROJECT SUMMARY

Background

The reduction in habitat quality associated with flow reduction and the elimination of coarse sediment supply in Clear Creek below Whiskeytown Reservoir is most pronounced in the stream segment from Whiskeytown Dam to Clear Creek Road (Reaches One and Two). In these two reaches, habitat degradation has been addressed by gravel injection sites at Whiskeytown Dam (since 1998) and below NEED Camp Bridge (since 2005). The injections represent a flow-based strategy, requiring high flows to distribute the gravel throughout the system. During the ten years since injections began, only four gravel-mobilizing flows (greater than 2,000 cfs) have occurred. These flows (spills) were storm related, not planned spills: the outlet works at Whiskeytown are capable of releasing only up to 1,200 cfs.

Below Clear Creek Road, the stream exits its upper gorge and enters a more alluvial setting. Reaches Three and Four were additionally impacted by gold mining and gravel extraction. Tributary streamflow and sediment contribution are greater in the lower mainstem, but channel downcutting, fine sediment impacts and reduced floodplain connectivity contribute to a complex mosaic of undesirable effects. Restoration efforts in the lower reaches include: gravel injection, channel modification, gravel pit filling, and floodplain lowering.

The 2006 Update focused on assessing channel conditions (relative to how well the injections were functioning) by examining sediment transport, performing geomorphic investigations and by evaluating each gravel injection. Data collected and analyses performed represent an empirical approach and no extensive modeling was performed.

Sediment Transport

In order to evaluate gravel injection efforts against the backdrop of the ambient sediment transport regime, we sought to develop a provisional sediment budget for Clear Creek below Whiskeytown Dam. A subset of tributaries and mainstem stream segments were gaged for streamflow and continuous 15-minute discharge records were produced for Water Years 2005 and 2006. We were unable to enumerate all linkages in the Clear Creek System but were able to develop a useful (and preliminary) sediment budget, summarized as follows:

- Sediment flux out of Reach One remains unknown.
- Annual sediment discharges for Igo and at Reading Bar are virtually identical, as the bedrock gorge below Igo contributes little sediment and the Placer Road gravel injection has not yet reached Clear Creek Road at Reading Bar.
- Clear Creek appears to achieve complete routing of suspended sediment through Reaches One and Two, though relatively little is present.
- The South Fork of Clear Creek delivers more suspended sediment per square mile than all of the other (measured) tributaries, indicating it may be more highly impacted than the others.
- Suspended sediment production increases through the lower mainstem. Discharges increase from 3,100 tons/yr at Igo to 7,020 tons/yr at Phase 3A, much of which is likely due to the actively eroding Saeltzer Dam deposit. However, a further increase to 9,750 tons per year at Phase 4 indicates additional fine sediment sources are active below Phase 3A.
- On average, at least 11,900 tons of coarse sediment once passed the Whiskeytown Dam site each year.
- Tributaries contribute very little coarse sediment to Clear Creek.
- No mainstem reaches achieve complete routing of coarse sediment.
- Mainstem mean-annual bedload discharges increased from Igo (985 tons/yr) to Phase 3A (4,200 tons/yr) but fell off below Phase 3A to 992 tons/yr indicating a coarse sediment sink above Phase 4. Further, most of the bedload reaching Phase 4 appears to be sand.

Geomorphic Investigations

We emphasized monitoring areas where GMA has collected data previously, allowing examinations of change within various time periods between 2000 and 2006. The primary objective was to capture the downstream extent of injected gravel deposition and the secondary objective was to assess other geomorphic changes, namely channel incision or aggradation. Repeat survey data collected included cross sections, thalweg profiles and topography – some of which were used for volume change comparisons. The 2004 surveys describe channel conditions following WY2003 winter storms and sustained Glory Hole spill (4,550 cfs at Igo). The most substantial intervening flow was the December 30, 2005, peak flow (4,400 cfs at Igo). Some surveys isolate the effect of the 2006 Glory Hole event of 2,050 cfs in Reach One. Only the most relevant survey data are presented (by reach) here.

- **Reach One:**

Near Dog Gulch, the leading edge of injected Whiskeytown gravel aggraded up to one foot and translated downstream slightly into the head of the deep bedrock pool. While the deepest point in this pool appears unchanged in the thalweg profile, cross sections through the pool reveal up to three feet of fill in places and the pool tail may have aggraded 0.7 feet. These data describe the leading edge of the Whiskeytown injection, which was last mobilized by the 1,800 cfs Glory Hole spill in April 2006. Surveys below Dog Gulch reveal little change from the spill.

- **Reach Two:**

The only surveys conducted in Reach Two were topographic surveys of the Placer Road gravel injection and a short thalweg profile downstream of the injection in 2006 and is discussed in the next section.

- **Reach Three:**

For Reach 3A, two-mile thalweg profiles were surveyed from Clear Creek Road to the Saeltzer Dam site. Gravel injection (enhanced by the WY2006 storms) filled pools 1,000 feet below the Clear Creek Road injection 2-3 feet deep.

- **Saeltzer Dam:**

The first major flow event following the Saeltzer Dam removal was the winter/spring of WY2003, during which up to 67,000 yds^3 of stored sediment were excavated from the reach above Saeltzer. The channel incised up to a maximum of seven feet over more than a mile. WY2006 showed another 4,500 yds^3 of sediment were excavated since 2004. The low gradient reach through Renshaw Riffle aggraded up to two feet following dam removal. Roughly 13,300 yds^3 of deposition appears to have come from Saeltzer Dam between 2001 and 2004.

- **Reach Four:**

Above Phase 3A, surveys reveal a headcut migrating up from the upstream end of the restoration reach which was heavily scoured following the WY2003 storms and spill. Gravel injections above Phase 3A appear to have at least partially moved through the floodway restoration project, filling some areas that showed scour until 2006. The thalweg profile downstream of Phase 3A describes up to 1,500 feet of channel that is incising above Sunrise Bend.

Gravel Injection Evaluations

Over 100,000 tons of gravel have been injected in Clear Creek at nine sites since 1996. Most of the injections are recruitment piles requiring high flows to distribute the gravel. The Reading Bar and Phase 3A restoration sites utilized both recruitment piles and direct placement methods. Our goal in evaluating existing injections was to ascertain how much gravel was entrained per given flow event and how far it traveled.

- **Reach One:**

Despite the low frequency of high flows below Whiskeytown, Reach One has measurably benefited from gravel injection as indicated by the increase in spawning area in the upstream 25% of the reach. While the Whiskeytown injection traveled 3,300 feet to the Dog Gulch pool during the 1998 event, subsequent events apparently have not yet achieved complete routing through this pool. Assuming the Dog Gulch Pool is on the threshold of complete routing, a simple translation rate analysis (employing a suite of hydrologic and geomorphic assumptions – discussed later) suggests it will take another 28 years to recharge Reach One and connect with the NEED Camp injection.

- **Reach Two:**

The NEED Camp injection has been mobilized by two flow events (2,050 and 800 cfs) which transported injected gravel to the same pool 900 feet downstream, indicating complete routing has not been achieved through this pool. Applying the translation rate analysis (feet per year) to Reach Two indicates this injection will take 64 years to reach the Placer Road injection. Below Placer Road, where we have documented 2,800 feet of travel over six years, it will take 17 more years to recharge the channel to Clear Creek Road.

- **Reach Three:**

Injected gravels at the Clear Creek Road site appear to have traveled approximately 1,000 feet in three years and the leading edge need travel only 1,100 feet to connect with the Reading Bar point-bar placement. However, the channel is not "recharged" more than a few hundred feet below the Reading Bar injection. Less than 1,000 feet downstream is the section of channel that is actively re-adjusting its bed slope in response to the Saeltzer Dam removal. Employing the translation rate analysis, and assuming the small Reading Bar injection to be negligible, it will take 28 years for the Clear Creek Road injection to reach the bedrock sill at the lip of Saeltzer Gorge above the City of Redding injection. The channel appears to be fully charged with gravel in the gorge above the City of Redding injection.

- **Reach Four:**

The downstream extent of the City of Redding injection could not be clearly discerned against the backdrop of Saeltzer-liberated sediment. A sediment sink has been filling at a cut-off channel that re-enters approximately 2,400 feet downstream of the injection. However, approximately 3,000 feet downstream of the site, active gravel bars transition to vegetated, less active bars. If we assume this transition to be the downstream extent of "recharge," the translation rate is 300 feet per year and it will take another 27 years to travel the remaining 8,100 feet to the injection above Phase 3A. However, since this reach is closer to (or has met) the threshold of alluviation, gravel could translate downstream as bar-forms faster than it would in winnowed reaches.

Summary

Sediment deficit estimates range from roughly one half to over one million tons. Approximately 100,000 tons of spawning gravel have been injected into Clear Creek, though continuity has not yet been established. How does the deficit relate to future injection volumes? The coarse sediment deficit must be considered with respect to the existing flow regime. Clear Creek may be a million tons "in the hole," but adding a million tons without re-instating the flow regime associated with the historic condition would not likely achieve the desired "equilibrium" state. We are targeting a new condition in which a smaller channel (equipped with less water and less gravel) functions according to the *same processes* that were impaired by impoundment, channel modification and gravel mining.

Considerable uncertainty exists surrounding the "how much and for how long to attain re-charge" question. The CCDAM channel sub-model (Alexander 2006) was unable to answer this question. Our data indicate that to recharge Reach One, injecting at Whiskeytown alone will require over twice the volume (90,000 tons) over a much longer time span than direct placement. Injecting gravel near the leading edge will accelerate downstream progression. However, without channel modification or riffle supplementation, it is likely that some degraded sub-reaches will not store gravel but will sluice it through.

Over 4,200 tons/year pass the gaging station above Phase 3A and the (un-restored) channel is still downcutting, implying annual bedload transport rates are too low to create and maintain desired channel conditions. Roughly 3,400 tons per year are injected at Saeltzer Gorge, so we know this is not enough and/or we have not yet achieved full routing.

The question of how much to inject once full routing is attained is less difficult to answer: we agree with the McBain and Trush suggestion for putting in a volume equal to that excavated, especially at Reach 1. CCDAM suggests an annual average of 6,900 to 9,800 tons per year as an annual average injection after full sediment routing is restored (Alexander 2006).

The importance of high flows as the driver for sediment transport would be difficult to overstate. The approximate threshold necessary for injected gravel immobilization is 2,000 cfs (McBain and Trush 2001), and for channel bed mobilization is 3,000 cfs. In 41 years, only 46 days at Whiskeytown and 82 days at Igo have exceeded the 2,000 cfs threshold required for injection mobilization. Only four such events have occurred since gravel injections began in 1996. Clearly, restoration efforts related to sediment transport in Clear Creek would benefit greatly from more frequent gravel-mobilizing flows.

Recommendations

We see two approaches (or, ideally a combination of both): (1) single-point injections as are currently being implemented, but coupled with more frequent high flows, or (2) the "injection plus transfusion" advocated in the 2001 report. The first approach is currently being evaluated under the CALFED Environmental Water Program proposal. The focus here is on the second.

Reach 1:

- Continue Whiskeytown injections as flows permit. After this site is charged and is waiting for the next high flow, subsequent allocations should go to the (pending) injection sites down to the lower NEED Camp injection.

Reach 2:

- Continue NEED Camp and Placer Road injections: maximize volume and replenish at every opportunity.
- The CALFED panel on gravel augmentation recommends fewer, larger additions over frequent small additions.
- Investigate the potential for injecting at the Igo gaging station to recharge the reach between the gaging station and Placer Road.

Reach 3A:

- Continue Clear Creek Road injection.
- Continue Reading Bar Injection until gravel from Clear Creek Road site begins to charge the Reading Bar site, then use Reading Bar to charge the leading edge if required.
- Explore potential for new gravel injection locations downstream of Reading Bar.

Reach 3B:

- Continue City of Redding injection, but at a lower priority than Reach 1.
- Assess the cut-off meander bend to determine impact and utility of City of Redding injections.
- Investigate new injection sites, especially in the Renshaw Riffle area.

Reach 4

- Above Phase 3A, place injected gravels as riffle supplementations, eventually all the way across the channel and covering all exposed claypan.
- Assess channel downcutting; evaluate options including floodplain lowering and/or grade control structures.

Basin-wide

- Explore developing reach-level, predictive hydraulic and sediment transport models to assess the potential for sediment transport/storage.

- *Monitoring recommendations are omitted from this summary – see master document.*

PART TWO: PRELIMINARY PREDICITIONS

Purpose

Following review of the 2006 update, numerous questions of a predictive nature arose:

1. How much gravel would have to be added to the system to "recharge" the sediment-depleted channel and achieve full sediment routing?
2. How long would this take?
3. How much would this cost?
4. Where and how would this gravel be placed in the channel?
5. What are the consequences of receiving or not receiving higher flows (such as might be procured by the Environmental Water Program -- EWP)?
6. How much gravel would have to be added per year to maintain instream habitat conditions once full routing is achieved?

Not enough information is available to accurately answer each of these questions. However, lacking a better predictive tool, we make the following ***educated guesses*** based upon translation analysis and insights gained from the investigations performed for the 2006 update. Tables follow this section.

Relevant Background Conditions and Assumptions

1. Extremely high shear stresses associated with steep, confined gorges tend to transport (not store) gravel. However, impoundment-related flow impairment may cause such reaches to function as sinks.
2. In Reach One, injections mobilize at lower thresholds than we previously assumed.
3. Translation rate analyses assume:
    a. Injections continue at the same rate and size distribution,
    b. Subsequent flow regime is similar to that during which original assessment was made,
    c. The leading edge is not still filling a void, rather it is on the verge of equilibrium, and
    d. Transport capacity and channel conditions below the leading edge are similar to those above.
    e. When one injection reaches the next, the downstream site is discontinued and injection continues at the site above but at the rate assigned to the downstream site.

Predictions

How much gravel would have to be added to the system to "recharge" the sediment-depleted channel and achieve full sediment routing? How long would this take and how much would it cost?

Table 1 describes a simple translation rate analysis using observed periods for gravel injections. Employing the assumptions listed above yields approximately 468,000 tons over 68 years to achieve recharge to Phase 3A. We know the channel to be down-cutting above and below Phase 3A. If we were to inject 2,000 tons per year (a guess) above Phase 3A (to address downcutting and the degraded condition of the channel between Phase 3A and the mouth) over the 30 years it will take the City of Redding injection to reach Phase 3A, it will take 528,000 tons to recharge Clear Creek to the Sacramento River (Table 2). Applying a period-averaged rate of $30/ton yields a cost of $15.8 million.

Clearly, these numbers are very rough and a variety of factors could alter this estimate, including but not limited to:

1. The translation rate for Reach Two is limited to the first 900 feet of the gorge, whose channel-type is not exactly representative for the remainder of the gorge. Reach Two may require much more gravel than is estimated here.
2. The translation rate observed for the Clear Creek Road injection may not be applicable to the more alluvial setting encountered in the Saeltzer Dam-adjusted reach.
3. The channel between Saeltzer and Phase 3A may be much closer to recharge than implied here.
4. The degraded channel below Phase 3A may require much higher injection rates than the 2,000 tons/yr suggested here.

The factors mentioned above could even cancel one another out. Given such uncertainty, the half million tons (which happens to approximate the assumed deficit) should be regarded as a guidance figure, indicating that we have a long way to go to reach recharge.

Where and how would this gravel be placed in the channel?

Half a million tons over 68 years is derived from the present day injection scenario, which is a flow-based strategy. Both the time to achieve recharge and the volume required could be dramatically reduced by maximizing opportunities to place gravel directly in the channel. Reach One has extensive design plans in place to recharge the entire length with in-situ placement. Reach Two however, remains a "black box" of uncertainty and virtually no access exists above Igo to place gravel directly in the channel. Short of helicopter placement (very expensive) the only way to shorten the time to recharge Reach Two is by maximizing Reach One injections, coupled with more frequent high flows.

In-channel injection options in the lower reaches should be explored. Numerous restoration opportunities (injection, floodplain lowering, channel modification, utilization of tailings as injection gravel) exist below Clear Creek Road. The more gravel we place directly in the channel at more places, the less gravel we will have to place over time and the shorter the time to recharge will be.

What are the consequences of receiving or not receiving higher flows (such as might be procured by the Environmental Water Program -- EWP)?

The numbers predicted in the previous section assume no higher flows, so one consequence is that it will take half a million tons of gravel over 68 years to recharge Clear Creek. Another potential consequence is that Reach Two will function as a much larger sink than we have predicted here. In this case (no EWP flows), one strategy would be to recharge Reach One to the greatest extent possible, leaving Reach Two as a "sacrifice" reach and allocating more gravel to other sections of stream where it might realize greater benefit (such as near the Igo gaging station or at Clear Creek Road). The lower watershed (with its greater below-dam drainage area) would be less impacted by not receiving EWP flows.

If EWP flows were implemented (assuming a twenty four to thirty hour 3,000 cfs peak flow bench every two years), and assuming maximum injection rates at multiple points in Reach One, the time to recharge both Reach One and Reach Two could be greatly reduced.

How much gravel would have to be added per year to maintain instream habitat conditions once full routing is achieved?

The theory that (once full routing is achieved) gravel volumes injected at Whiskeytown would have to approximate the amount of gravel exiting the downstream end of the system assumes gravel-mobilizing flows begin at the dam and carry through the system. Since winter storm accretion may greatly increase the disparity in transport rates between Reach One and the lower watershed, and since the tributaries are unable to contribute a gravel supply commensurate with their cumulative flow increase, some gravel injection will be required in the lower watershed (such as Clear Creek Road) to accommodate the imbalance.

We do not yet know what the net flux out of a fully charged Clear Creek would be. However, (employing the range of values presented in the *Summary* section above), we know 4,000 tons per year is too little. Therefore, it seems that once the system is charged, we should continue to inject at least what we have been injecting at Whiskeytown (2,300 tons/yr), coupled with something like 6,000 tons per year at some downstream sites, for a total of at least 8,000 tons per year. If channel incision or fossilization of riffles continues in the lower reaches, this rate should be increased.

TABLE 1: Translation Rate Analysis for Estimating Time and Volume to Re-Charge Clear Creek Sub-Reaches

Injection Site	Distance to Leading Edge (feet)	Total Reach Length (feet)	Timespan (years)	Translation Rate (ft/yr)	Injected Volume (tons)	Injection Rate (tons/yr)	Distance Remaining (feet)	To	Time Remaining (years)	Volume Remaining (tons)
Whiskeytown	3000	11720	10	300	23,257	2326	8720	Lower NEED	29	67,600
Lower NEED	900	28800	2	450	3602	1801	27900	Placer Rd.	62	111,662
Placer Injection.	2800	9958	5	560	13201	2640	7158	Clear Cr. Rd.	13	33,747
Clear Cr. Rd.	1000	10700	7	143	3003	429	9700	Saeltzer Dam	68	29,129
City of Redding	3000	11250	11	273	36952	3359	8250	Abv. Phase 3A	30	101,618
Above Phase 3A			2		1729	865				
										343,757

TABLE 2: CUMULATIVE INJECTION TOTALS TO ACHIEVE RECHARGE TO SACRAMENTO RIVER

Reach	Tons	Years	
Whiskeytown to NEED	67,600	29	
NEED to Placer	52349	29	1st period
	59313	33	after WT reaches NEED (assume WT rate drops to 1801 t/yr)
Placer to CC Rd	33747	13	
CC Rd to Saeltzer	5484	13	1st period
	23646	55	after Placer reaches CC Rd (assume Placer rate then drops to 429 t/yr)
City of Redding to 3A	101618	30	
	343,757		
	-2574		minus the 6 years it would take for CC Rd to reach Saeltzer after Placer has arrived at CC Rd
	126477		plus the 38 years of injection at COR until CC Rd reaches Saeltzer
	60000		plus 30 years at 2,000 t/y at Phase 3A
	527,659		**TO ACHIEVE COMPLETE ROUTING TO SACRAMENTO RIVER**

TABLE 4-1
LOWER CLEAR GREEK GRAVEL INJECTION TOTALS
(revised with input from WSRCD April 2007)

Placement site	Quanity (tons)	Cu. Yd. Equivalent (1.5 ton/cy)	Placement dates	Sponsor
Whiskeytown Dam	4498	2999	1/27/98-2/10/98	CVPIA
	3500	2333	7/13/99-7/19/99	CVPIA
	3500	2334	7/13/00-7/17/00	CVPIA
	2500	1667	2/1/01-2/27/01	CVPIA
	4258	2839	8/11/04-8/25/04	CVPIA
	2000	1334	6/15/05-6/30/05	CVPIA
	3000	2000	1/23/07 - 1/31/07	BOR
	23,257	**15,505**		
Need Camp	1001	667	9/13/05-9/30/05	CVPIA
	2601	1734	8/17/06-8/29/06	BOR
	3,602	**2,401**		
Placer Bridge	3001	2001	12/12/00-12/26/00	CVPIA
	3000	2000	5/17/01-5/18/01	CVPIA
	1500	1000	15-02-2003	CVPIA
	300	200	15-02-2003	CVPIA
	2999	1999	8/13/03-8/20/03	CVPIA
	4999	3333	6/16/04-6/24/04	SWRCB
	4003	2669	6/15/05-6/30/05	SWRCB
	19,802	**13,201**		
Clear Creek Rd Bridge	1001	667	8/11/03-8/15/03	CVPIA
	1000	667	6/24/04-6/25/04	SWRCB
	1002	668	6/15/05-6/30/05	SWRCB
	3,003	**2,002**		
Reading Bar	1000	666	8/11/03-8/15/03	CVPIA
	1,000	**666**		
City of Redding	4500	3000	7/9/96-7/24/96	BLM
(Includes Saeltzer Dam)	3000	2000	9/20/96-9/30/96	USFWS
	3500	2334	9/19/97-9/24/97	CVPIA
	4501	3000	12/10/98-12/16/98	CVPIA
	4501	3001	10/4/99-10/11/99	CVPIA
	4500	3000	7/7/00-7/19/00	CVPIA
	7001	4668	6/5/01-6/14/01	CVPIA
	2500	1667	9/4/03-9/15/03	CVPIA
	948	632	9/4/03-9/15/03	CVPIA
	2001	1334	6/27/04-6/30/04	SWRCB
	36,952	**24,635**		
Phase 3A	1729	1153	8/17/05-8/23/05	SWRCB
	1,729	**1,153**		
LCC Floodway	11721	7814	Aug-02	CALFED
	11,721	**7,814**		
Phase 2B exchange	1404	936	8/29/02-9/11/02	RCD/westside
	1,404	**936**		
TOTAL GRAVEL	**102,469**	**68,313**	**1996 to 2007**	