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Distribution of bed sediment on Clear Creek after  
removal of Saeltzer Dam

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# Distribution of bed sediment on Clear Creek after removal of Saeltzer Dam

## Abstract

Saeltzer Dam was removed from Clear Creek in October 2000 to restore ten miles of upstream habitat access to spring run chinook salmon and steelhead trout. Since the dam removal, an estimated 50,000 cubic yards of sediment has eroded from the banks and channel at the former dam site. Some of the eroded sediment has been deposited downstream on Renshaw's Riffle, a stretch formerly known for its spawning habitat, aggrading the bed up to 2.5 ft. To evaluate characteristics of the sediment deposition, we performed roughly 60 pebble counts and created a facies map for a 1.43 mi stretch downstream of the former dam site. We created maps in ArcMap GIS using the data to depict changes in gravel bar location, the d50 (the size at which 50% of the pebbles are finer) and the composition of percent-finer-than-8 mm material for each pebble count along the length of our study area. Five pebble counts were performed at transects in Renshaw's Riffle, at sites with existing cross-sectional data. We found that finer-than-8 mm sediments comprise over 20% of the substrate in parts of the riffle. An earlier facies map was created in 2001 by visual assessment, but we were unable to compare our results due to incompatible methods. We hope the pebble count serves as an easily replicable method from which to compare future surveys of the area.

## **Distribution of bed sediment on Clear Creek after removal of Saeltzer Dam**

Alicia Gilbreath and Z Clayton-Niederman

May 18, 2005

### **Summary**

Saeltzer Dam was removed from Clear Creek in October 2000 to restore ten miles of upstream habitat access to spring run chinook salmon and steelhead trout. Since the dam removal, an estimated 50,000 cubic yards of sediment has eroded from the banks and channel at the former dam site (Miller and Vizcaino, 2004). Some of the eroded sediment has been deposited downstream on Renshaw's Riffle, a stretch formerly known for its spawning habitat, aggrading the bed up to 2.5 ft. To evaluate characteristics of the sediment deposition, we performed roughly 60 pebble counts and created a facies map for a 1.43 mi stretch downstream of the former dam site. We created maps in ArcMap GIS using the data to depict changes in gravel bar location, the d50 (the size at which 50% of the pebbles are finer) and the composition of percent-finer-than-8 mm material for each pebble count along the length of our study area. Five pebble counts were performed at transects in Renshaw's Riffle, at sites with existing cross-sectional data. We found that finer-than-8 mm sediments comprise over 20% of the substrate in parts of the riffle. An earlier facies map was created in 2001 by visual assessment, but we were unable to compare our results due to incompatible methods. We hope the pebble count serves as an easily replicable method from which to compare future surveys of the area.

## **I. Introduction**

Recently, dam removal has gained popularity as a method for restoration, particularly where dams block former salmon spawning habitat. Creeks naturally experience geomorphic changes in response to dam removal; changes which may or may not improve spawning habitat downstream of the dam site. Specifically, if the sediment trapped behind dams is not removed prior to dam removal, it can be mobilized and displaced downstream. When the water table lowers due to dam removal, riparian vegetation along the bank may die, leaving unstable soil that may erode and lead to downstream deposition. In both cases, if that deposition drops fine sediment on previously good spawning grounds, it can have negative consequences for salmonid egg survival. Substrates with fine sediment above 20 percent may severely limit spawning potential (Bjornn and Reiser 1991). Conversely, deposition of gravels may serve to create new spawning riffles (Brown, 2004).

Mapping bed material is important for understanding the stream's geomorphology and the habitat quality for spawning fish and other organisms. Sediment often deposits on creek beds in distinct textural patches, or facies (Buffington and Montgomery, 1999). Facies mapping allows for analysis over the length of the reach, by showing a gradient or pattern. Alternatively, facies mapping can provide spatial comparison between reaches, between rivers, or temporal comparison for a specific reach. For example, before and after facies maps may show how given flows mobilize different sediment sizes.

For our study, we created a facies map of a 1.43 mi stretch downstream of a former dam on Clear Creek in Northern California. We spent six days using the pebble count method to characterize each facies.

## II. Site Description and Background

Clear Creek, which drains 278 square miles, is a west bank tributary to the Sacramento River, joining the Sacramento just south of Redding (Fig. 1). Whiskeytown Reservoir impounds Clear Creek, eliminating the coarse sediment contribution to Lower Clear Creek and diverting over 80% of the natural flow into the reservoir (NRCS, 1999). Lower Clear Creek runs 18 miles to the Sacramento River, draining 49 sq mi along the way. Average monthly flows downstream of Whiskeytown Dam range from 50-650 cfs (USGS Gauge 11372000: Clear Creek near Igo CA, Monthly Streamflow Statistics).

Clear Creek has been severely degraded over the years by human land use practices (Brown, 2004). In particular, mining activities have been heavy on Clear Creek ever since Major Reading discovered gold there in 1848. Historic dredge-mining for gold and gravel has altered the channel form. In some areas, the stream is straight and highly entrenched; in others, multiple flow channels exist (NRCS, 1999).

Today several agencies are involved in restoration efforts on Clear Creek, including Western Shasta Resource Conservation District, GMA, BLM, USGS, USFWS, PRBO, CALFED, and others. In the last decade, these efforts have included a major rehabilitation project on the Lower Clear Creek Floodway<sup>1</sup>, increasing the minimum instream flow, spawning gravel augmentation, erosion control projects, and the removal of Saeltzer Dam (Brown, 2004).

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<sup>1</sup> The rehabilitation is being implemented by Western Shasta Resource Conservation District (WSRCD) and funded primarily by CALFED, with additional resources coming from Bureau of Reclamation and Bureau of Land Management (see [http://www.westernshastarc.org/26\\_21.html](http://www.westernshastarc.org/26_21.html)). Rehabilitation includes filling of gravel pits, and constructing functional floodplains.

### *Removal of Saeltzer Dam, 2000*

The McCormick-Saeltzer Dam, built in 1912 to divert water for local agriculture, also impacted the creek environment. Located 6 miles from the confluence with the Sacramento, at about 15 ft high and 200 ft long, the dam trapped sediment from moving downstream and blocked fish from upstream migration. In 2000, Saeltzer Dam was removed, primarily to provide fish access to ten miles of upstream habitat (Brown, 2004). At that time, approximately 25,000 cubic yards of sediment trapped behind the dam was removed to prevent mobilization and deposition downstream.

### *Key Findings from Previous Studies: Post dam-removal geomorphology on Clear Creek*

Previous work on Clear Creek includes long profiles surveyed in 2001 (Stillwater), 2003 (GMA), March 2004 (GMA), and Oct-Dec 2004 (GMA), cross sections surveyed in 1999 (McBain and Trush), 2003 (GMA), and 2004 (GMA), a facies map created in 2001 (Stillwater), and two papers written by previous students of this course (Miller & Ferry, 2003, and Miller & Vizcaino, 2004). Specifically, we found long profiles extending in both directions from the former dam site (Fig. 2), a long profile for the Renshaw Riffle stretch (Fig. 3), and 5 cross sections spaced roughly 200 feet apart at Renshaw's Riffle (Figs. 4 and 5). This review provides background information on the geomorphologic changes taking place to the creek.

Erosion: An initial survey after the first season of low winter flows indicated no significant changes in the channel morphology (Stillwater, 2001). However, subsequent higher peak flows have led to significant changes. In a more recent study, Miller and Vizcaino observed an active headcut from the dam site to 1000 feet upstream of the former dam site, 50-60

ft of lateral erosion at the former reservoir site, and a total estimated erosion of roughly 50,000 cubic yards from the former reservoir site (2004).

2001 Facies Map: An earlier facies mapping that included our stretch was completed in September 2000 and May/June 2001 by Stillwater Sciences.<sup>2</sup> The grains size characterization was completed using a different method. Discussion with Stillwater gave us a general idea of the method used. The author developed and described five categories of sediment composition: FiMeGR – fine and medium sized gravel, MGR – mixed gravel, MGRs – same as MGR except embedded in sand, GRCO – mixed gravel and small cobble, and COGR – small cobble and mixed gravel (see Fig. 6 for further descriptions of each category). In addition, Stillwater conducted eleven pebble counts in this mapping process, at least one for each of the above categories (see Fig. 6 for d50s and d84s for each pebble count).

The 2001 facies map categorized most of our study reach as MGR (mixed gravel) or MGRs (mixed gravel embedded in sand). The author found that at the major bend, the composition became more mixed, adding small GRCO and FiMeGR facies in addition to the MGR and MGRs facies types. There were small sand patches throughout the reach.

Long Profiles: The long profile from the downstream end of Saeltzer Gorge to below Renshaw's Riffle (Fig. 2) shows that incision and deposition alternated along the channel until about one third of the way into our project stretch, at which point the aggradation remains at roughly 2 ft through the end of Renshaw's Riffle. After Renshaw's Riffle aggradation tapers for almost 1000 ft before jumping back up. At Renshaw's Riffle (Fig. 3), the aggradation progresses downstream in a step-wise fashion over the years. Between 2001 and 2003, there is aggradation of 0.5-1.0 ft all the way through to point B, with the aggradation being heavier on the upstream of point A. Between 2003 and March 2004, there is some aggradation upstream of point A,

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<sup>2</sup> John Wooster (Stillwater Sciences) provided these dates via email correspondence 5/02/05.



although the bulk of it takes place between points A and B. From March 2003 to Oct-Dec 2004, the aggradation generally occurs downstream of point B.

Cross Sections: The changes seen in the cross sections range from over three feet of aggradation at the most upstream cross section (Fig. 5, XS 283+20) in the riffle to an incision area almost a foot deep in the most downstream cross section (Fig 5, XS 273+65). The most uniform area of aggradation across the creek occurs in cross section 280+25 (Fig. 5), where there is roughly two ft of aggradation over the entire cross section.

Hydrograph: The hydrograph (Fig. 7) shows daily stream flows on Clear Creek downstream of Whiskeytown dam. The annual peak flow for 2000, the year following the dam removal, was 1220 cfs, the second lowest peak flow in past two decades. Since that year, however, the creek has had higher flows. The 2001 water season hit 2470 cfs, 2002 saw a peak of 4550cfs, and 2003 reached 3680 cfs. This current water year (2004) has had a mean daily high of 1490 cfs. The highest flow on record was 24,500 in 1955. More recently, the flow in the 1996 water year reached nearly 16,000 cfs, a return interval of 13 years.

### **III. Methods:**

Our primary fieldwork took place in two phases. The first phase, spanning five days of fieldwork between December 2004 and February 2005, included pebble counts and facies mapping of 64 patches on a 1.4 mile stretch downstream of the former Saeltzer Dam. After compiling this data, and in conjunction with analysis of the previous studies, we identified the need to fill in the gaps from our earlier work. This second phase of our fieldwork involved locating the 5 cross section survey sites along Renshaw's Riffle and conducting pebble counts at each cross section.

### *Description of Facies Mapping*

Sediment often deposits on creek beds in distinct textural patches, or facies (Buffington and Montgomery, 1999). Patches can include well or poorly-sorted grains, as long as they have consistent sorting over the entire patch. Facies mapping involves identifying the location and size of each patch, and then characterizing each patch based on its grain size (Buffington and Montgomery, 1999). By weighting each pebble count by its patch area, it is possible to find the reach-average grain size, as well as make comparisons between patches (Buffington and Montgomery, 1999).

The pebble count is a common method used to characterize a patch's grain size distribution. There are various techniques, but a pebble count generally involves selecting a sample of pebbles representative of the grain distribution over the entire patch and categorizing these pebbles into predetermined size categories. A sample of 100 stones is reported to consistently reproduce accurate median grain sizes ( $d_{50}$ ), though accurate results for the tail ends of the distribution may require up to 400 stones per sample (Kondolf et al., 2003).

### *Field Data Collection – Phase I: Facies Mapping*

We created a facies map of 64 patches for a 1.4 mile stretch downstream of the former Saeltzer Dam. To do this, we identified patches of similar sediment composition on the creek bed and adjacent gravel bars. We visually determined these patches and, in retrospect, used a minimum patch size of about 60 sq ft. For each unique patch identified, we counted minimum of 100 pebbles randomly distributed over the entire patch to characterize the grain size distribution. There were a few areas in the creek that were too deep to take a pebble count on. For these, we

qualitatively assessed the grain size distribution by comparing the reach to other reaches we surveyed.

### *Field Data Collection – Phase II: Renshaw’s Riffle Pebble Counts*

Using annotated aerial photographs (Stillwater), we located the 5 cross section survey sites along Renshaw’s Riffle and conducted pebble counts at each cross section<sup>3</sup>. Additionally, at each site we sketched in plan view the various patches along the path of each cross section and photographed most of the sites. This work allowed us to map the sediment composition and distribution character at exactly known locations on the creek.

### *Analysis of Field Data*

In order to understand the distribution of sediment within the different patches, we graphed the d50, d84, and cumulative-percent-finer-than-8mm material for each pebble count we conducted. Then we drew our field-sketched facies map onto orthorectified aerials<sup>4</sup> in the ArcMap GIS program and created a table with the attribute data (d50, d84, percent-finer-than-8 mm) for each mapped polygon/facie. Using ArcMap, we created graduated color maps for each attribute, illustrating changes in the d50, d84, and percent-finer-than-8mm along our study reach.

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<sup>3</sup> These cross sections were marked by rebar (iron spikes) with blue tape. Graham Matthews of GMA believes this blue tape may be from the original McBain and Trush surveys

<sup>4</sup> We orthorectified the aerials we used (2003) to previously orthorectified aerials (2004) obtained by Shiloe Braxton at the Western Shasta Resource Conservation District.

### *Gravel Bar Analysis*

We also orthorectified the aerials (McBain and Trush, 1997) used for the 2001 facies mapping study, and mapped in GIS the gravel bars existing at that time. This allowed us to make a gross comparison of the changes in gravel bar sizes and locations between the 1997 and 2003<sup>5</sup>.

## **IV. Results**

### *Gravel Bar Changes*

The total area of gravel bars just downstream of the dam removal has increased by over 50% from roughly 95,600 ft<sup>2</sup> in 1997 to 151,400 ft<sup>2</sup> in 2003 (Fig. 8). The number of patches went from 6 to 13. The big bend has most of the gravel bars, where some gravel bars have completely shifted from one side of the creek to the other.

### *Facies Mapping*

The d50 facies mapping (Fig. 9) in ArcMap GIS is categorized into 7 classes using the standard classes: less-than-8, 8, 11, 16, 22, 32, and 45 mm. None of the patches measured had d50s greater than 64mm. The color scheme for this map shows the patches with smaller d50s in light yellow and the patches with larger d50s in darker blue. We found that 70 percent of the total area (not including sand bars) of patches measured has a d50 between 16 and 32mm. Ninety-three percent of the total area has a d50 between 16 and 45mm. The mean d50 across all patches, weighted by patch size area, was 27mm (see Table 1 for summary).

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<sup>5</sup> 2003 is the year of the aerials we used in our facies mapping. 2003 aerials provided by the Western Shasta Resource Conservation District.

The d84 patches were also calculated, but the map is not included. We found that the mean d84 weighted by patch size was 49mm. Ninety-five percent of the total area had d84s between 32 and 90mm, 51 percent of the total area falling in the 45 to 64mm category.

The percent-finer-than-8mm-material (PFTEM) map (Fig. 10) is categorized into 7 patch types; those where PFTEM is less than 5 percent, 5-10 percent, 10-15 percent, 15-20 percent, 20-30 percent, 30-50 percent, and 50-100 percent. On the map, those patches composed of lesser amounts of finer-than-8mm sediments are shaded darker blue, while those with greater amounts of finer-than-8mm sediments are shaded in yellow, according to the above classifications. When we did not include the area categorized as sand bars, we found that 57 percent of the total area measured had less than 5% finer than 8mm, and 93percent of the total area had a PFTEM of less than 10% (see Table 2 for summary).

*Renshaw’s Riffle: site- specific results*

At Renshaw’s Riffle, the cross sectional data indicates significant deposition and in a stepwise fashion over time. In our study, we found up to 24 percent of that sediment is finer than 8 mm. Pebble count results and qualitative details about the bed material at each cross section are provided in Figures 11-15. Below is a table of the tabulated results for the pebble counts at each cross section:

<b>Cross Section</b>	<b>283+20</b>	<b>280+25</b>	<b>277+55</b>	<b>275+55</b>	<b>273+65</b>
% <8 mm	21%	24%	15%	17%	14%
D50	12	17	23	21	23
D84	24	32	41	43	32

Plotted together (Fig. 16), the five pebble counts show that the upstream two cross-sections have a greater percentage of fines than the three cross sections further downstream. The uppermost cross section has a noticeably finer grain size distribution than the other four, as seen by the d50 and d84.

Our sketches at each cross section indicate that on the left bank, roughly 4-7 feet into the creek tends to be dominated more by sand than in the center regions of the creek. The right side is more varied with sand, vegetation, and simply bedrock wall (see Pictures at the end of the Appendix for examples of bank vegetation and substrate).

Comparing our pebble counts of Renshaw's Riffle in February with those in April, we found similar results for the d50 and d84, but differences in the percent of fines. In February, we described the entire area as one facies with a d50 of 19 mm, a d84 of 33 mm, and 9% of the sediment at finer-than-8 mm. The April average across all five cross sections results in a d50 of 19 mm and a d84 of 34 mm, but 18% finer-than-8 mm in composition.

## **V. Discussion**

The long profile and cross sectional data that we gathered prior to our own fieldwork indicated up to three feet of aggradation in the reach of the creek that we mapped. This provides motivation for creating a facies map in which to understand the sediment distribution throughout the creek.

Our analysis of changes in location and size of gravel bars shows that there has been heavy activity in the streambed and banks since dam removal. New deposition is likely due to either the erosion taking place upstream, or the gravel injections occurring upstream (see Fig. 1 for locations of gravel injection sites), or some combination of the two. Differences in flow can

also affect the area of gravel bar exposure. However, it is unlikely in this case because the flows were similar; 183 cfs in the 1997 aeriels and 159 cfs in the 2003 set of aeriels.

The full facies mapping revealed a differential distribution of the variation between facies. In the bend area of the upstream half of our study reach, patches were generally smaller, had slightly higher levels of fines, and often abutted patches with significantly different sediment composition. On the other hand, in the straight stretch downstream of the bend, the patches are larger and there is much less diversity between the patches. These results are not surprising because the bend provides a more varied environment in terms of velocity, flow depth, and shear stress on the bed; differences which cause sediment to organize into distinct textural patches (Buffington and Montgomery, 1999).

The pebble counts we performed in the Renshaw's Riffle area in February yielded similar results to those we performed at the five cross section locations in the second phase of our study, with the exception that the percent-finer-than-8 mm category in April was double that of February. Looking at the hydrograph since the February count reveals that there was a flow of nearly 1500 cfs in March, which might explain movement of some sediment. Doubling from 9 to 18% finer-than-8 mm by way of a 1500 cfs flow does not seem likely (though sediment mobilization is outside of the scope of this paper). It is possible that our first count may have simply been in a location that did not adequately represent the entire facies, and so was counted too low. However, the 9% count was markedly lower than *any* of the five pebble counts performed in April. This discrepancy brings forth a question about the soundness of the method in determining the percent-finer-than-8 mm category: how many pebbles must be counted in order to get an accurate representation? Research has shown that one hundred pebbles is enough to get accurate d50s, but that more than one hundred is needed for accuracy at the tail ends of the

distribution (Kondolf et al., 2003). While we do not want to disregard our February results, our April results averaged together may be a more accurate representation. This is because the entire Renshaw's Riffle stretch is fairly homogenous<sup>6</sup>, and while we counted a total of only 100 stones in the patch in February, we counted a total of 500 stones in the patch in April. This larger sample size would be more likely to produce accurate results at the tail ends of the distribution.

It is difficult to say whether these levels of fine sediment at Renshaw's Riffle are problematic for salmon. The grain size requirements of salmonids differ during different spawning stages. Fine sediment deposition onto redds can lower the intergravel flow and decrease the dissolved oxygen to the eggs, as well as affect the fry ability to migrate to the surface (Kondolf, 2000). Studies that relate fine sediment levels to incubation and emergence success show a range of results. For Chinook salmon, studies ranged from 15-40 percent as the maximum percentage of grains finer than 6.35 mm that would produce 50 percent emergence of salmonids (Bjornn, 1969, Tappel and Bjornn, 1983, and McCuddin, 1977, *all in*: Kondolf, 2000). These studies suggest that the levels of fine sediment we found at Renshaw's Riffle may be problematic, but we cannot be certain from this facies mapping effort alone.

Another important factor regarding salmon spawning and fine sediment is that when salmon lay their eggs, they winnow the fine sediment out of the gravel, so what may be measured as unsuitable may become suitable after this winnowing if the underlying gravel is adequate (Kondolf, 2000). This highlights a possible disadvantage of a surface pebble count, because it does not consider the size of sediment underneath the surface, which may also hinder spawning (Kondolf and Wolman 1993).

Ideally, we would have liked to compare our results to the earlier facies map created in 2001. Our results, based on individual pebble counts, seemed more specific than the 5-category

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<sup>6</sup> In February, we assessed it as a single patch with similar grain-size distribution



method used in the earlier map, so we attempted to reinterpret our results into the five categories. We did not follow through with this comparison, however, because we had a difficult time understanding results in the earlier work. Specifically, the descriptions for each category did not seem to align with the pebble counts for each of the facies types. For example, COGR has an estimated d50 of 80 mm, whereas the d50s for the three pebble counts of that facies type were 62 mm, 44 mm, and 47 mm. Also, it was difficult to draw distinctions between the categories based on the pebble count results alone. For example, under GRCO, one of the pebble counts had a d50/d84 of 58/86 mm, whereas one of the counts for MGRs was 56/93 mm, and a COGR count was 47/83. If one of our pebble counts was 52/85 mm, we would not be able to confidently place it into any one category over another. Therefore, we abandoned our effort to make the comparison. (see Fig. 6 for details about the earlier method).

We do not mean to imply that the earlier work is inconsistent. All we know is that we do not understand the method well enough to make quantitative comparisons. It would be a valuable future effort to work out this challenge. The difficulty of comparison does highlight for us the importance of having a replicable method of study, and/or a set of metadata that thoroughly describes the method and explains any apparent discrepancies.

#### **IV. Conclusion**

It appears that the stream channel is still in active modification four years after the removal of Saeltzer Dam. We can see this through the changing long profiles, cross sections and the changing gravel bar locations and sizes. Given that the highest flow since dam removal was 4,550 cfs in 2002, a return interval of 2 years, we can expect even more changes with higher flows. The five-year flood has a flow of roughly 10,000 cfs.

The pebble count surveys will provide a baseline that can be used for further research and study. Our pebble count method serves as an easily replicable method to which future pebble counts may be compared. This characterization of a 2.3 km stretch should provide many areas for further comparison, which may be important for understanding the process and timing of spawning habitat regeneration after dam removal. Future analysis that applied the Stillwater method of facies mapping to a standard pebble count assessment could provide a valuable comparison to pre-dam facies mapping, since it appears that little changes occurred to the streambed between dam removal and that mapping.

Our GIS analysis may be a useful first step for future analysis. The GIS allows for the visualization of the spatial data in a way that can more easily show trends over the extent of the stretch. The GIS also provides an easy way to query the data and to calculate areas based on specific characteristics. In addition it gives the ability to compare the facies mapping over time. Finally, the GIS acts as a database for the storage and retrieval of data.

This facies mapping may serve as a tool from which to better understand the habitat conditions for salmonids and other organisms in the creek. There are proposals to increase Clear Creek mid-range flows as a way of mobilizing fine sediment. Our data could serve as a baseline from which to assess the need for, and monitor the success of, increased flows. There are also gravel injections along Clear Creek and this facies study may help to show the movement of that gravel along the creek bed.

#### **Acknowledgements:**

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Figures:

Cross Sections and Long Profiles provided by: Graham Matthews

Cross Sections: 1999 (McBain and Trush)

2003, 2004 (Graham Matthews and Associates)

Long Profiles: 2001 (Stillwater Sciences)

2003, March 2004, Oct-Dec 2004 (Graham Matthews and Associates)

Aerials:

1997 aerials provided by Stillwater Sciences, taken by McBain and Trush

2003 and 2004 aerials provided by Shiloe Braxton at the Western Shasta Resource  
Conservation District

Hydrograph:

USGS Gauge 11372000: Clear Creek near Igo CA

<http://waterdata.usgs.gov/nwis>