Comparison of predicted and observed geomorphic changes following the removal of Saeltzer Dam

Task 6 Deliverable Report

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1 Introduction

As part of an extensive effort to restore salmonid habitat to Clear Creek, CA, the U.S. Bureau of Reclamation (USBR) removed Saeltzer Dam in November 2000 to provide an additional 10 miles (16 km) of potential habitat for salmonids upstream of the former dam site. The potential downstream impacts associated with dam removal, particularly the fate of sediment from behind the dam, were not well understood. Extensive sediment deposition could potentially have detrimental effects to downstream aquatic habitat. To analyze the downstream movement of sediment following the removal of Saeltzer Dam, Stillwater Sciences modified a sediment transport model developed for the removal of Marmot Dam on the Sandy River, Oregon\(^1\). The goals of the modeling were to assess potential geomorphic and ecological effects of sediment deposition and elevated total suspended solids (TSS) levels in Clear Creek and to improve our understanding of sediment transport following dam removal, in general.

Based upon consultation with our review team, Stillwater Sciences designed a monitoring program to test the model and to assess sediment movement before and after dam removal. The monitoring studies consisted of:

- cross sections surveyed at regular intervals from the upstream end of Corkscrew Riffle (river mile [RM] 5.5) to just upstream end of the restoration site (RM 3.75) with a focus on Corkscrew and Renshaw riffles;
- channel bed texture mapping and pebble counts from RM 5.5 to RM 2.2; and
- topographic surveys of the reservoir deposit upstream of Saeltzer Dam.

In this report, we compare the modeling predictions of coarse sediment and sand deposition to the field monitoring results downstream of Saeltzer Dam.

Clear Creek is a gravel-bedded river that flows into the Sacramento River south of Redding, California. Saeltzer Dam, a small diversion dam built in 1912, was located 6.2 miles upstream of the confluence with the Sacramento River (RM 6.2). Prior to sediment excavation, the reservoir behind the 15-ft (4.6 m) high, 200-ft (61 m) long concrete dam was filled with sediment. Whiskeytown Dam, built in the 1963, is located about 10 miles (16 km) upstream of Saeltzer Dam. Whiskeytown Dam controls flows in Clear Creek, but tributaries downstream of the dam contribute flow during storms. Flow from the tributaries, however, tends to be very flashy.

Following the sediment transport modeling and initial field surveys, we convened a second meeting with our review team to review the modeling results and examine the dam site. Observations during the site visit and additional survey data on bedrock from the reservoir area, indicated the volume of sediment available for transport from the reservoir was 80 percent less than the volume used in the modeling\(^2\) (Figure 1). Based on surveys conducted by the USBR following sediment excavation from the reservoir, we estimate that only 5,900 yd\(^3\) (4,500 m\(^3\)) of sediment are available for downstream transport. (This assumes a depth of 1.6 ft (0.5 m), length of 1,500 ft (450 m) from the excavation to the bedrock control [BR-1 in previous models], and an average (bankfull width of 70 ft [20 m]). This volume of sediment is too small to be modeled and to discern a difference from background sediment transport conditions.\(^3\)

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\(^1\) Marmot Dam has yet to be removed.
\(^2\) The volume of sediment used in the modeling was based on the assumption that the bedrock was up to 13 ft (4 m) below the surface of the reservoir (Figure 1).
2 Sediment Transport Model

Stillwater Sciences developed numerical models to simulate the removal of the Marmot Dam on the Sandy River, Oregon. A detailed description of the model, including its derivation and assumptions, is provided in Cui and Wilcox (2000) and is attached as Appendix A. The model consists of a stand-alone gravel model based on Parker’s (1990) gravel transport equation and a gravel-model-dependent sand transport model based on Brownlie’s (1981) bed material transport equation. Cui and Wilcox (2000) was peer-reviewed prior to publication to ensure that it met rigorous scientific standards. Peer review comments were provided in the June 1, 2001 deliverables package.

2.1 The Zero Process

As discussed in Appendix A (Cui and Wilcox, 2000), a “zero process” is generally required for long-term, large-scale sediment transport simulation. The purpose of the zero process is to generate a starting point for the modeling and to evaluate input parameters. The process recognizes the imperfection of the numerical model, as well as the database used to run the model. In the zero process, the model is run repeatedly under a reference condition in which input data, such as slope, channel width, and discharge, are the same as that used for the dam removal simulation but neither Saeltzer Dam nor any sediment pulse from the reservoir deposit are considered. If raw input data are used without modification, however, the model typically will not produce quasi-equilibrium results at reference conditions. The goal of the zero process is to run the model and modifying certain input parameters until the model produces quasi-equilibrium results, i.e., the river experiences aggradation and degradation at different reaches through time, but overall, long-term aggradation or degradation is limited.

Modeled reference conditions represent background sediment transport and deposition in the absence of Saeltzer Dam and its impounded sediment. We used the daily discharge record at USGS Clear Creek Igo station (USGS Station No. 11372000) from October 1, 1989 through September 30, 1999 (Figure 2) for the zero process and subsequent modeling runs. Based on field measurements, we assumed that average channel width was 85.3 ft (26 m) upstream of the dam, 49.2 ft (15 m) in the gorge, and 65.6 ft (20m) further downstream. We assumed that the channel surface grain size distribution was a composite of the distributions from pebble counts conducted by Stillwater Sciences between RM 5.8 and RM 3.7 (Figure 3). The gravel transport rate identified from the zero process ranged between 0.003 to 11,000 tons/yr (Figure 4). The zeroed long profile and the surveyed thalweg profile are shown in Figure 5. To demonstrate that the zeroed profile is in quasi-equilibrium, we ran the model for 10 years with the discharge record shown in Figure 2 and channel aggradation and degradation were minimal (Figure 6).

The background grain size distribution and transport rate for sand and silt (sediment finer than 2 mm) in Clear Creek is unknown. We assumed a background sand and silt concentration of 100 mg/l to test channel response. The background sand and silt grain size distribution is assumed to be the same as the sand and silt grain size distribution in the reservoir deposit used for the dam removal run. The thickness of sand deposition at selected locations is shown in Figure 9. Fine sediment deposition was predicted only in isolated locations where scour holes occurred in the initial river bed. A subsequent run in which these scour holes were removed eliminated this fine sediment deposition, suggesting that there is little sand deposition in Clear Creek under pre-dam conditions. Deposition in isolated local scour holes, however, may occur.

2.2 Model Inputs
Stillwater Sciences identified several bedrock controls upstream of the dam. Model runs were conducted that assumed two alternative bedrock controls. The lowermost control (BR-1) is located about 0.4 miles (650 m) upstream of the dam (Figure 8). An additional control (BR-2) is located about 1.1 miles (1.8 km) upstream of the dam.

When developing the model, we assumed that, in the short-term, and without a large flow, BR-1 would act as the primary bedrock control and that erosion of the reservoir deposit would not propagate beyond BR-1. In the long-term, however, we assumed that the channel may cut through the right bank. In this case, BR-2 would act as the bedrock control, and erosion would propagate further upstream. Since we did not have information on the location and depth of bedrock beneath the reservoir deposit when our modeling was conducted, we assumed a parabolic curve connecting BR-1 to the bedrock control at the dam site (Figure 1). Following the site visit conducted after excavation of sediment from the reservoir, we concluded that due to the large amount of bedrock in the reservoir reach, BR-1 would act as the upper control. We, therefore, limit our presentation in this report to the “best case” model results, where BR-1 is the upper control on erosion of the reservoir. Model runs included a 1-year run with a constant discharge of either 1,200 cfs, 600 cfs, or 400 cfs, and a 1-year run with discharge beginning with a flood event on January 8, 1995.

The grain size distribution of the reservoir deposit was estimated from bulk sample data provided by URS Corporation (2000). A total of 37 samples were collected to characterize the grain size distribution of the reservoir deposit (Figure 9). Because most of the samples were collected in the vicinity of the dam, where grain size is finer, the grain size distribution of the reservoir deposit as a whole was likely somewhat coarser. We assumed that 40 percent of the reservoir deposit was finer than 2 mm (Figure 9). No vertical stratification was assumed because of the height of the dam was relatively small.

2.3 Model Predictions

Because of the lack of sediment upstream of the dam site, we limit our discussion in this report to predicted locations of sediment deposition in the best case scenario with BR-1 as the bedrock control using the hydrograph from October 1, 1989 to September 30, 1999. The model results for this scenario are shown in Figures 10 and 11. The model predicted coarse sediment deposition of up to 7 ft (2 m) over the ten-year run. Coarse sediment deposition extended from the dam site to RM 4.0 and decreased in magnitude downstream (Figures 10 and 11). Because there were no peak flows greater than 1,000 cfs in the first three years in the model run, the initial predicted sediment transport rates were low. Sediment was not deposited in Corkscrew Riffle (RM 5.8) until three years after dam removal. The model predicted no sand deposition due to the removal of Saeltzer Dam. Predicted sand deposition (Figure 12) is identical to the reference run, and is likely the result of abrupt changes in slope.

The best-case modeling results overestimate the volume of sediment remaining upstream of Saeltzer Dam by at least a factor of five. These modeling results, therefore, overstate the amount of sediment deposition following dam removal. Based on the site visit following excavation of sediment from the reservoir, we believed that there would be no downstream sediment signal associated with the removal of sediment from behind Saeltzer Dam. Although adjustments to cross sections and sediment facies distributions are expected, such changes would occur naturally and would not likely be in response to dam removal.

3 Field Methods
Initial field surveys were conducted in September and November 2000, following consultation with the scientific review team. Post-dam removal surveys were conducted in April and May 2001. The results presented in the following sections were provided to UC-Davis in a separate deliverables package (June 1, 2001), where they are discussed in more detail.

### 3.1 Topographic Surveys Upstream of Saeltzer Dam

Topographic surveys upstream of Saeltzer Dam were initially completed in November 2000, following dam removal and sediment excavation upstream of Saeltzer Dam but prior to high flows. The initial survey from the Saeltzer Dam site to the coffer dam was surveyed by Pace Engineering for the USBR. Stillwater Sciences and John Wooster (a UC-Davis graduate student) surveyed the area from the cofferdam to BR-1 using a total station. In addition to the total station survey, four cross sections were established upstream of the cofferdam. Following dam removal, Stillwater Sciences and John Wooster surveyed the area from the Saeltzer Dam site to the cofferdam in April and May 2001. Upstream of the cofferdam, three of the four cross sections were re-surveyed. The surveyed data were imported into a GIS to create maps that portray surface elevation as interpolated from the surveyed points. These surfaces were used to calculate the change in bed elevation between the two surveys.

### 3.2 Longitudinal Profile Upstream of Saeltzer Dam

Stillwater Sciences subcontracted Del Terra Inc. (Redding, CA) to survey the longitudinal profile from Clear Creek Bridge (RM 8.4) to the former Saeltzer Dam site (RM 6.35). Thalweg elevation and water depth were documented at 160-ft (50-m) intervals and at significant breaks in slope using a GPS. The profile was surveyed in September 2000, with a follow-up survey in May 2001.

### 3.3 Cross Sections

Stillwater Sciences surveyed cross sections from RM 6 to RM 3.75. Twenty-eight cross sections were surveyed in September 2000. Twenty of the 28 cross sections were re-surveyed in April–May 2001. The location of each cross section is given in Table 1. Cross sections in the gorge were initially surveyed using a total station but were resurveyed using an auto-level.
Table 1. Cross section locations, survey method, survey crew, and reoccupation.

<table>
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<tr>
<th>Station</th>
<th>Site</th>
<th>Surveying device</th>
<th>Surveyor</th>
<th>Re-occupied by Stillwater Sciences?</th>
</tr>
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<tr>
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</tr>
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<td>Auto-level</td>
<td>SWS</td>
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<td>SWS</td>
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<td>SWS</td>
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3.4 Channel Bed Texture

Channel bed texture was mapped from RM 5.75 (the upper end of Corkscrew Riffle) to RM 2.25 (approximately 0.75 mile upstream of the ACID siphon). The post-dam removal sediment facies were mapped as an overlay of pre-dam removal sediment facies. Post-dam-removal mapping was conducted in April and May 2001.

3.5 Sand Deposition in Pools

Sand patches in three pools in the gorge reach (RM 6.2 to 5.8) were mapped in September 2000 and again in May 2001. In both surveys, we measured the areal extent and depth of each patch.

4 Results

4.1 Changes Upstream of the Dam

The total station surveys indicate that, while there was topographic adjustment in the reservoir site, only 122 yd$^3$ (93m$^3$) of sediment were transported out of the reservoir reach between January
and May 2001 (Figure 13). No changes in the cross sections upstream of the cofferdam site (RM 6.75) were observed (Appendix B).

4.2 Longitudinal Profile Upstream of the Dam

The longitudinal profile from Saeltzer Dam to Clear Creek Bridge changed slightly following dam removal (Figure 14). These changes occurred in isolated locations and were not due to slope adjustment in response to dam removal.

4.3 Cross Sections Downstream of the Dam

At the majority of cross sections the channel bed did not exhibit significant change. Most of the observed changes occurred in Corkscrew and Renshaw riffles, and 2 pools in the gorge. Extensive redd construction in Corkscrew and Renshaw riffles disturbed the channel bed and altered the channel morphology in these areas. Cross sections 330+00 (the upper end of Nude Beach Pool) and 315+60 (the lower end of the pool above Corkscrew Riffle) exhibited about 3 ft (1 m) of aggradation due to migrating gravel bars. This aggradation occurred on the inside of river bends, where sediment deposition is most likely to occur, but was limited in extent.

4.4 Sediment Facies Mapping

Six sediment facies were identified during the facies mapping. Sediment facies identified included:

- **Sand**
- **FiMeGR**: Fine and medium sized gravel, moderately graded, and rounded. Generally very loose, often found in the 1997 bar/berm deposits. The approximate grain size fraction distribution: fine gravel (2-20 mm), 40%; medium gravel (20-40 mm), 40%; other (mostly large gravel), 20%. Estimated d50 20mm.
- **MGR**: Mixed gravel, well graded, and subrounded and subhydral. Generally paved, usually in the pools or low-gradient riffles as a bed pavement, and on top of active and semi-active alluvial bars. The approximate grain size fraction distribution: fine gravel, 30%; medium gravel, 30%; large gravel (40-64mm), 30%; and cobble (usually only small 64 to 120 mm), 10%. Estimated d50 35 to 40mm.
- **MGRs**: Same as MGR, except embedded with sand.
- **GRCO**: Mixed gravel and small cobble (64 to 120 mm), moderately graded, and rounded. Generally loose, usually in low-gradient riffles and glides. The approximate grain size fraction distribution: mixed gravel (d50 approximately 35mm), 70%; and small cobble (d50 approximately 90 mm), 30%. Estimated d50 65mm.
- **COGR**: Small cobble and mixed gravel, moderately graded, and rounded. Generally quite loose, usually in the high-gradient riffles and pools, and in areas adjacent to eroding cobble bars. The approximate grain size fraction distribution: small cobble (d50 around 90mm), 70%; and mixed gravel (d50 around 35mm), 30%. Estimated d50 80mm.

Small changes in substrate facies were observed throughout the mapped area, but these are not attributable to the removal of Saeltzer Dam because of the small volume of sediment supplied from the reservoir reach.

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3 The cross sections were provided to UC-Davis on June 1, 2001 as the deliverable for Task 6a and are attached as Appendix B.

4 The facies maps were provided to UC-Davis on June 1, 2001 as the deliverable for Task 6b and are not included in this report.
There appeared to be more sand in the streambed, particularly in Renshaw and Corkscrew riffles downstream of newly constructed redds. This sand was likely the result of redd construction and not dam removal. There also seemed to be more sand in the bed in general, although this could be due to the reduced extent of algae during the post-dam removal surveys. The amount of exposed bedrock in the lower river (between stations 224+00 and 212+00 ft) decreased by up to 50 percent. This is likely due to nearby bank erosion or other channel processes not related to dam removal.

4.5 Sediment Deposition in Pools

In September 2000, an estimated 137 yd³ (105 m³) of sand was mapped between Nude Beach Pool (RM 6.2) and the top of Corkscrew Riffle (RM 5.8). In May 2001, the volume of sand had been reduced to 84 yd³ (64 m³), a 61% decrease. Cross sections surveyed across Nude Beach Pool and the pool above Corkscrew Riffle showed little change in topography except for some gravel deposition at two of the cross sections.

5 Comparison of observed and predicted changes downstream of Saeltzer Dam

We do not believe that the modeling results can be used to predict changes following dam removal because the difference between modeled and observed volume of sediment upstream of Saeltzer Dam is too large. These results can, however, be used as an upper bound on the amount of sediment deposition observed following dam removal. The magnitude of coarse sediment and sand deposition observed at cross sections and in facies maps did not exceed model predictions.

Because most of the sediment upstream of Saeltzer Dam was removed during excavation, the model predictions presented in Section 2.3 do not accurately portray expected sediment dynamics following the removal of Saeltzer Dam. Based upon professional judgement, we expect that there would be no observed changes in channel morphology due to the removal of Saeltzer Dam, and none were observed. There were two sites in the gorge where approximately 3 feet (1 m) of gravel deposition were observed along short portions of the cross sections. This aggradation was limited in extent and did not represent a significant aggradational signal.

6 References


Figure 1. Comparison of bedrock elevations used in the sediment transport modeling with actual bedrock elevations following dam removal.
Figure 2. Discharge record at the USGS Clear Creek gauge near Igo (number 11372000) from October 1, 1989 to September 30, 1999.
Figure 3. Grain size distributions of pebble counts, including the composite distribution used in the model.
Figure 4. Predicted background gravel transport in Clear Creek from water year 1990 to water year 1999.
Figure 5. Zeroed longitudinal profile and the surveyed thalweg profile downstream of Saeltzer Dam.
Figure 6. Modeled channel bed elevation for 10 years for the reference condition.
Figure 7. Modeled sand deposition for the reference condition.
Figure 8. Orthorectified aerial photograph of Clear Creek upstream of Saeltzer Dam prior to dam removal indicating locations of potential bedrock controls.
Figure 9. Grain size distributions of the reservoir deposit (URS 2000).
Figure 10. Predicted bed elevations for a 10-year run assuming BR-1 as the bedrock control and using the discharge record from USGS Igo gauge (number 11372000) October 1, 1989 to September 30 1999.
Figure 11. Predicted changes in bed elevation for a 10-year run assuming BR-1 as the bedrock control and using the discharge record from USGS Igo gauge (number 11372000) October 1, 1989 to September 30 1999.
Figure 12. Predicted sand deposition for the first two years of a 10-year run assuming BR-1 as the bedrock control and using the discharge record from USGS Igo gauge (number 11372000) October 1, 1989 to September 30 1999.
Figure 13. Changes observed upstream of Saeltzer Dam between January and May 7 2001.
Figure 14. Longitudinal profiles of Clear Creek, CA from Clear Creek Bridge (RM 8.4) to the former Saeltzer Dam site (RM 6.35).
Appendix A:

Cui and Wilcox Chapter 23, ASCE Manual 110, not attached here.
Appendix B

Cross sections surveyed by Stillwater Sciences in September 2000 and May 2001
Clear Creek Cross-sections 262+60

Elevation above arbitrary datum (ft)

Distance from left end pin (ft)

2001 WSEL (145 cfs)

May 2001
September 2000

F:\SaeltzerRemoval\field data\cross sections\appendix b.xls
Clear Creek Cross-sections 301+30

Elevation above arbitrary datum (ft)

Distance from left bank pin (ft)

2001 WSEL (160 cfs)

May 2001

September 2000

F:\SaeltzerRemoval\field data\cross sections\appendix b.xls
Clear Creek Cross-sections 311+25

Distance from left bank pin (ft)

Elevation above arbitrary datum (ft)

September 2000

May 2001

2001 WSEL (161 cfs)

F:\SaeltzerRemoval\field data\cross sections\appendix b.xls
Clear Creek Cross-sections 312+55A

Distance from left bank pin (ft)

Elevation above arbitrary datum (ft)

- September 2000
- April 2001

2001 WSEL (161 cfs)

F:\SaeltzerRemoval\field data\cross sections\appendix b.xls
Clear Creek Cross-sections 312+55B

Distance from jog pin (ft)

Elevation above arbitrary datum (ft)

- September 2000
- May 2001

2001 WSEL (161 cfs)
Clear Creek Cross-sections 314+50

- Distance from left bank pin (ft)
- Elevation above arbitrary datum (ft)

September 2000

May 2001

2001 WSEL (161 cfs)
Clear Creek Cross-sections 315+60 (Lower Corkscrew Pool)

Distance from left bank pin (ft)

Elevation above arbitrary datum (ft)

2001 WSEL (142 cfs)

- May 2001
- September 2000
Clear Creek Cross-sections 316+00 (Middle Corkscrew Pool)

Distance from left bank pin (ft)

Elevation above arbitrary datum (ft)

2001 WSEL (142 cfs)

May 2001
September 2000
Clear Creek Cross-sections 316+40 (Upper Corkscrew Pool)

Distance from left bank pin (ft)

Elevation above arbitrary datum (ft)

2001 WSEL (142 cfs)

May 2001

September 2000
Clear Creek Cross-sections 332+40 (Middle Nude Beach)

Elevation above arbitrary datum (ft)

Distance from left bank pin (ft)

2001 WSEL (142 cfs)

May 2001
September 2000
Clear Creek Cross-sections 333+00 (Upper Nude Beach)

Distance from left bank pin (ft)

Elevation above arbitrary datum (ft)

2001 WSEL (142 cfs)

May 2001

September 2000

F:\SaeltzerRemoval\field data\cross sections\appendix b.xls
Clear Creek Cross-sections 355+75
Cross-section A upstream of the cofferdam

Distance from left bank pin (ft)

Elevation above arbitrary datum (ft)

May 2001
November 2000

2001 WSEL
Clear Creek Cross-sections 359+60
Cross-section C upstream of the cofferdam

Distance from left bank pin (ft) vs. Elevation above arbitrary datum (ft)

- 2001 WSEL

Data points for May 2001 and November 2000.