



12/13/2018

To: City of Boulder Open Space and Mountain Parks, Marianne Giolitto

From: Deb Hummel and Jessie Olson, Lefthand Watershed Oversight Group

RE: Monitoring to determine effectiveness of post-flood restoration on Left Hand Creek, Boulder County, Colorado

The purpose of this memo is to provide a progress report for review and comment by the City of Boulder Open Space and Mountain Parks (OSMP) regarding an OSMP funded project titled, "Monitoring to determine effectiveness of post-flood restoration on Left Hand Creek, Boulder County, Colorado." This work is being completed by Lefthand Watershed Oversight Group (LWOG). LWOG implemented their Adaptive Management Framework (AMF) to monitor one flood-recovery restoration project site and one control site on OSMP properties. These findings will be further integrated with LWOG's AMF monitoring efforts at 20 additional sites to provide a robust comparison of restored and non-restored reaches throughout Left Hand Creek. Additionally, these assessments will contribute to our annual, "State of the Watershed" report, a holistic report on the health of Left Hand Creek watershed. Both reports are expected to be complete in March of 2019, as discussed in our grant application.

Purpose

The September 2013 floods resulted in dramatic changes to the Left Hand Creek watershed. High peak flow, sediment inputs, and debris inputs caused the creek to migrate and experience deposition, erosion, and loss of riparian vegetation. Recovery efforts have included numerous restoration projects by different entities, including City of Boulder, Boulder County, and LWOG. These restoration projects aimed to increase flood resilience, restore long-term stream health and stability, and improve aquatic and riparian habitat. The purpose of this research was to provide measurable assessments on the performance of these restoration projects as envisioned through LWOG's AMF and to provide OSMP with recommendations for management.

Overview of Methods

Two reaches, one restored and one control, located on OSMP property in Left Hand Canyon were selected for this research. The Upstream Buckingham restored site was completed in May 2017 and is located upstream of Buckingham Park, the control reach (Figure 1). Both study reach end limits were defined during site visitation by OSMP and LWOG staff in August 2018. These reaches were representative of stream characteristics in the area and included at least one pool and one riffle. The outlined tasks for this research included eight different assessments at each site to be completed from August through November 2018. Qualitative assessments on these sites included the Stream Visual Assessment Protocol for the State of Colorado, version two (SVAP), photo monitoring, and LWOG's AMF site monitoring form. Quantitative assessments of geomorphic and ecological parameters included longitudinal profiles, cross sectional profiles, in-stream pebble counts, vegetation surveys, and benthic macroinvertebrate (BMI) surveys. All methods are compiled in LWOG's monitoring methods report (Attachment 2).

Preliminary Results and Discussion

Qualitative Assessment

SVAP and LWOG site monitoring form observations provided an overall characterization of the study reaches. The SVAP score is an average of 16 geomorphic and biological elements individually scored from 0 to 10, 10 being the highest performing condition. The Buckingham Park control reach and Upstream Buckingham restored reach received similar SVAP scores of 8.1 and 7.9, respectively. Both values are within the good stream condition classification ranging from 7.0 to 8.9 (Figure 2). We hypothesized that restored sites would have less flood resilience one year after restoration compared to control sites. These results were in line with our expectation that the Upstream Buckingham site would have a lower overall SVAP score than the control site. Upstream Buckingham scored lower due to vegetation gaps, while Buckingham Park had greater cover and percentage of native species. The SVAP score was an important tool for preliminary reach-wide assessment, but further monitoring efforts were needed to identify and assess geomorphic and biological characteristics between reaches.

We made additional observations using the LWOG site monitoring form. This form was created as a supplement to the SVAP, and includes parameters that measure stream form and function specific to LWOG's AMF and post-flood restoration monitoring efforts. These assessments included wetted channel width and pool depth measurements, and reach-wide observations including: flow, evidence of floodplain activation, deposition, head-cutting, bank instability, and encroachment. Both reaches were observed during low flow with wetted channels ranging from 21 ft to 26.5 ft. Selected pools were greater than 33 inches in depth and fish were observed throughout both reaches. We observed evidence of bank instability at Buckingham Park, while Upstream Buckingham had low levels of herbaceous encroachment within the bankfull channel. The LWOG monitoring form protocol was designed for continued, annual monitoring during high and low flows to identify positive trends toward recovery and possible management triggers that would warrant adaptive management. Bank erosion and evidence of flushing flows (or unnatural encroachment) should be monitored over time to assess bank stability between reaches and the annual changes in herbaceous growth within the stream channel. To supplement these detailed observations, we collected quantifiable data including longitudinal profiles, cross sectional profiles, pebble counts, vegetation surveys, and BMI surveys.

Quantitative Assessment

Both Buckingham and Upstream Buckingham reaches are characterized as canyon streams. Both sample reaches included a pool and riffle. A longitudinal profile was measured along the thalweg of each reach (Figure 3). The lengths of each profile were dependent on sampling equipment and satellite communication. The 375 ft. long profile for Buckingham Park illustrates a continuous riffle followed by a series of step pools and a 125 ft. long pool beginning at 100 ft. cumulative distance. The reach then continues with a continuous riffle. The 750 ft. long profile for Upstream Buckingham illustrates a riffle followed by a 100 ft. pool beginning at 100 ft. cumulative distance. The channel then follows a short step pool complex and a long continuous riffle. At 715 ft. cumulative distance, the long profile illustrates the crest of a second pool. Similarly, the maximum water depth at both pools were greater than 33 inches and deposition of fine sediment was observed.

In addition, cross sectional profiles were surveyed at each pool and downstream riffle and were supplemented with pebble counts and vegetation surveys. Canyon streams are characterized by steep upland banks and these were observed at both sites. However, the channel at Buckingham Park is slightly incised due to additional constraints including Left Hand Canyon Drive and the park adjacent to the right bank (Figure 4). Upstream Buckingham reach is also constrained by Left Hand Canyon Drive on the left bank, but the channel has more access to its floodplain. Additionally, recent activation of the restored floodplain was indicated by rack lines and small wood accumulation. These comparisons and observations suggest that the restoration effort at Upstream Buckingham successfully reconnected the floodplain.

Sediment size and distribution further characterized bankfull substrate at the pool and riffle sites. Theoretically, the median cumulative 50% (D_{50}) sediment distribution corresponds with the substrate particle size (mm), and every particle size less than, that will mobilize at bankfull flushing rates without larger obstruction such as large boulders (Wolman 1954). At the riffle cross sections, the D_{50} particle size was 128 mm at Upstream Buckingham, while the D_{50} particle size at Buckingham Park was 180 mm (Figure 5). Overall, both sample reaches had similar substrate size distribution. The smaller median size at Upstream Buckingham is reflective of a higher relative frequency of cobbles (>64- 256mm), while Buckingham Park had a higher relative frequency of small boulders (>256 mm). In unrestored area, we would expect to have larger debris armoring banks at bankfull width, while restoration efforts may have reduced these larger substrate size classes. The riffle section of Upstream Buckingham may have had higher relative frequencies of smaller substrate compared to Buckingham Park due to restoration efforts.

At the pool cross sections at both sites were similar in sediment distribution. Upstream Buckingham and Buckingham Park pools were composed of 74% and 66% sand (<2 mm), respectively (Figure 6). The pool at Upstream Buckingham is located on a river bend, while the pool at Buckingham Park is within a straight section of stream. Upstream Buckingham may have greater deposition due to slower velocities at the river bend. Lastly, since both pools were greater than 50% sand, it is likely that most of the sand deposition in these pools will mobilize at bankfull flushing rates.

Revegetation throughout the riparian corridor after flood disturbance is critical for bank stabilization and ecological habitat. At a minimum, four vegetation zones were assigned per cross section, these included creekside and upland vegetation plots for each bank. Additional floodplain and upper riparian zones were identified and sampled at the discretion of the surveyors. We found that bare ground comprised 60% or more of vegetation zone plots for both sites (Figure 4). Overall, US Buckingham Park vegetation zones had a higher % stem cover of native herbaceous and woody plants. In contrast, Buckingham Park vegetation zones had higher % stem cover of invasive plants, with the exception of the left bank upland plot along the riffle transect.

Although US Buckingham showed more native stem cover, the percent bare ground was high. LWOOG restoration project sites typically include a maintenance and monitoring warranty of revegetated sites that outlines stem cover thresholds for the first three years post-restoration. From these suggested thresholds, we expect greater than 30% stem cover one year after seeding. After one growing season, the US Buckingham site had 45% or less stem cover, with the majority of plots falling within this warranty. Bare ground at this site was primarily comprised of the wood chip mulch used during reseeding (Figure 7). In comparison, the bare ground at the Buckingham Site was comprised by stream cobble, bedrock, and thatch.

Conclusions and Recommendations

1. Continuation of monitoring

Within LWOOG's AMF, there are methods for quantitative and qualitative monitoring of parameters associated with key watershed functions. The overarching goal is to identify positive trends towards resilience and possible management triggers. The three year timeframe for many flood recover projects is essential for this monitoring framework. Within one year of monitoring, LWOOG has observed a variety of post- restoration responses; some of which have required revegetation efforts and weed control. In addition, comparison between reference, pre, and post- restoration site monitoring is critical for making adaptive management decisions towards restoration trajectories and learn more about restoration efforts and responses over time. The following recommendations highlight some possible management concerns specific to the OSMP monitoring efforts:

2. Monitor flushing flows, encroachment, and stream profile at Upstream Buckingham in comparison with Buckingham Park

The flushing flow rates and restored bankfull channel widths of upper Left Hand Creek are influenced by man-made alterations. Below the James Creek and Left Hand confluence, restored channel widths must account for flow regimes effected by inputs from Left Hand Reservoir and the diversion from South St. Vrain through James Creek. If flushing flow events are inadequate for these restored bankfull channels, then mature riparian vegetation may establish on the exposed alluvial substrate. This encroachment may armor the banks and cause channel incision (Friedman 2018; Gordon and Meentemeyer 2006). Past research has also found that encroachment may be delayed for multiple years following hydraulic alterations (Jalon et al. 2017, unpublished data). While it is unclear if the low levels of herbaceous encroachment at Upstream Buckingham is indicative of a combination of inadequate channel width and altered flushing flow rates, increased encroachment may armor banks and result in channelization or incision. For these reasons, we suggest continued monitoring of riparian encroachment and revegetation in conjunction with flow observations and cross sectional profiles.

3. Reseed floodplain, riparian, and creekside vegetation zones at Upstream Buckingham

Revegetated zones are comprised of high percent bare ground compared to other LWOG project warranty standards. However, it does not appear that weeds are outcompeting native species at the Upstream Buckingham location. We observed low levels of pioneer weed species including sweet clover and invasive thistles in reseeded areas at Upstream Buckingham. Although we expect to see succession in plant communities each growing season, the lack of non-native species at this specific location provides an excellent opportunity to strengthen the native plant community. Due to high percentages of bare ground, we suggest reseeding the floodplain, riparian, and creekside zones as early as spring 2019. By continued monitoring, there is an added benefit of quantifying revegetation with low presence of weeds.

We look forward to providing a more detailed assessment and recommendations for management at these OSMP selected sites and in relationship to the 18 additional LWOG monitoring sites.

References

- Friedman, J.M. 2018. *Potential effects of elevated base flow and midsummer spike flow experiments on riparian vegetation along the Green River* (No. NPS/NRSS/WRD/NRR—2018/1603). National Park Service.
- Garcia de Jalón, D., Martínez-Fernández, V. and González del Tánago, M. 2017. Riparian Vegetation Encroachment Ratios in rivers below large Dams. Unpublished data. In *Geophysical Research Abstracts*. 19:10274.
- Gordon, E. and Meentemeyer, R.K. 2006. Effects of dam operation and land use on stream channel morphology and riparian vegetation. *Geomorphology*. 82(3-4):412-429.
- Wolman, M.G. 1954. A method of sampling coarse river-bed material. *Transactions American Geophysical Union*. 35(6):951-956.

Attachments

1. Figures (included)
2. LWOG Adaptive Management Site Monitoring Methods (see attachment)

Attachment 1. Figures

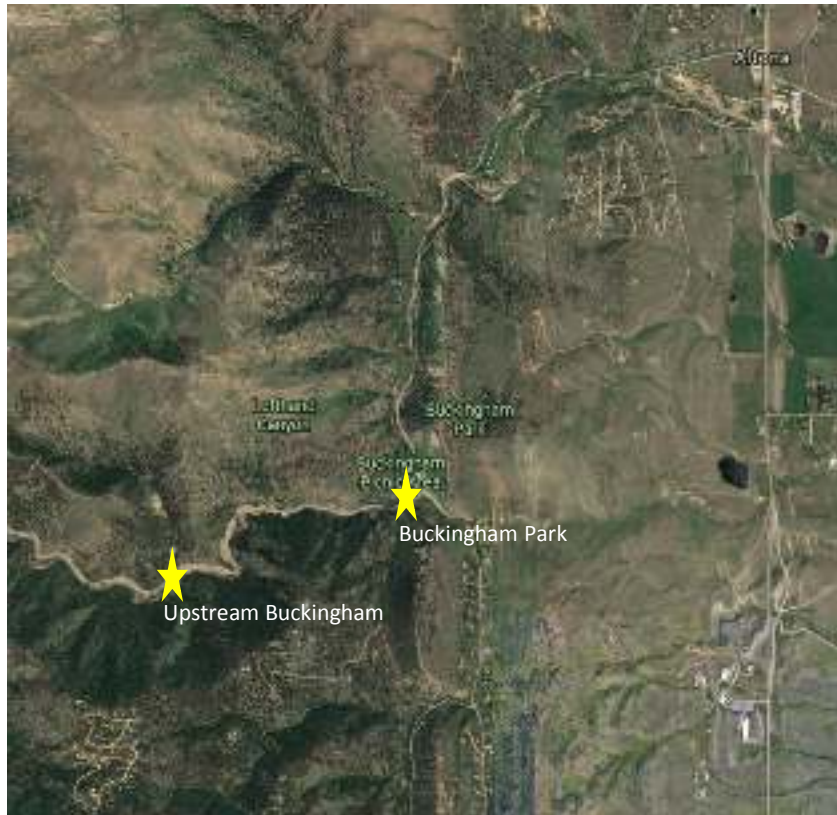


Figure 1. The 2018 sample reach locations for OSMP Buckingham Park and Upstream Buckingham properties on Left Hand Creek, Boulder County, Colorado.

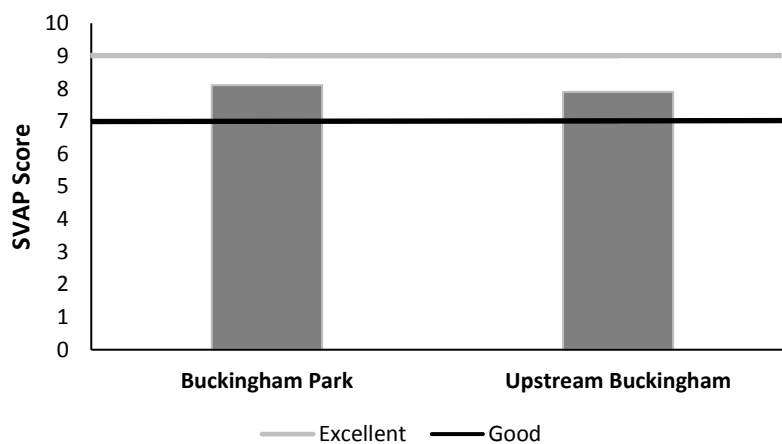


Figure 2. The 2018 overall SVAP scores for Buckingham Park and Upstream Buckingham reaches on Left Hand Creek, Boulder County, Colorado.

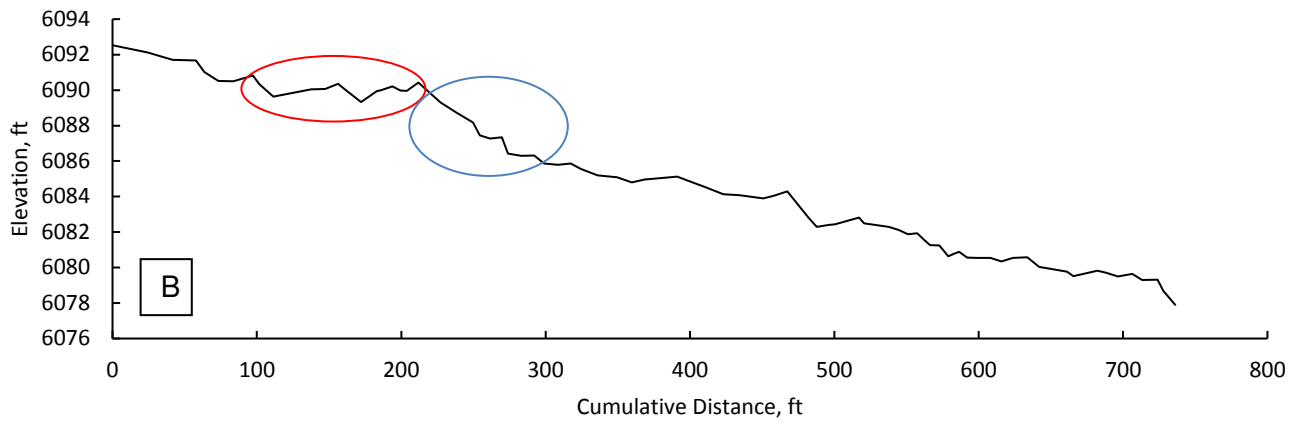
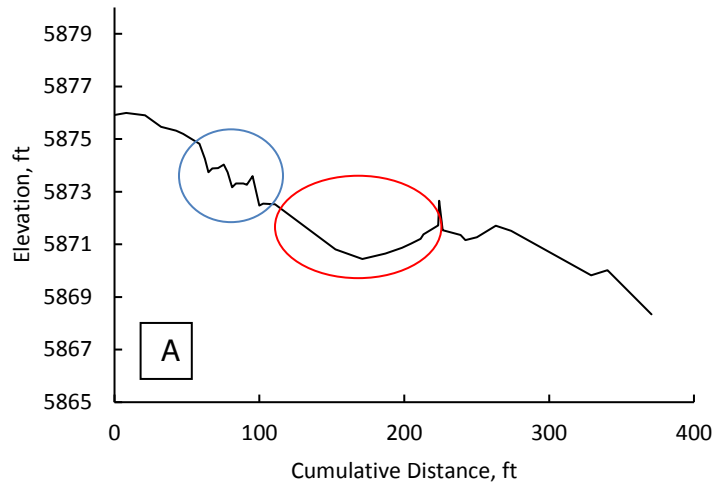


Figure 3. The 2018 longitudinal profiles for A. Buckingham Park and B. Upstream Buckingham sample reaches on Left Hand Creek, Boulder County, CO. Red circle indicates a pool and blue circle indicates a step pool. Cumulative distance for Buckingham Park is abbreviated to scale.

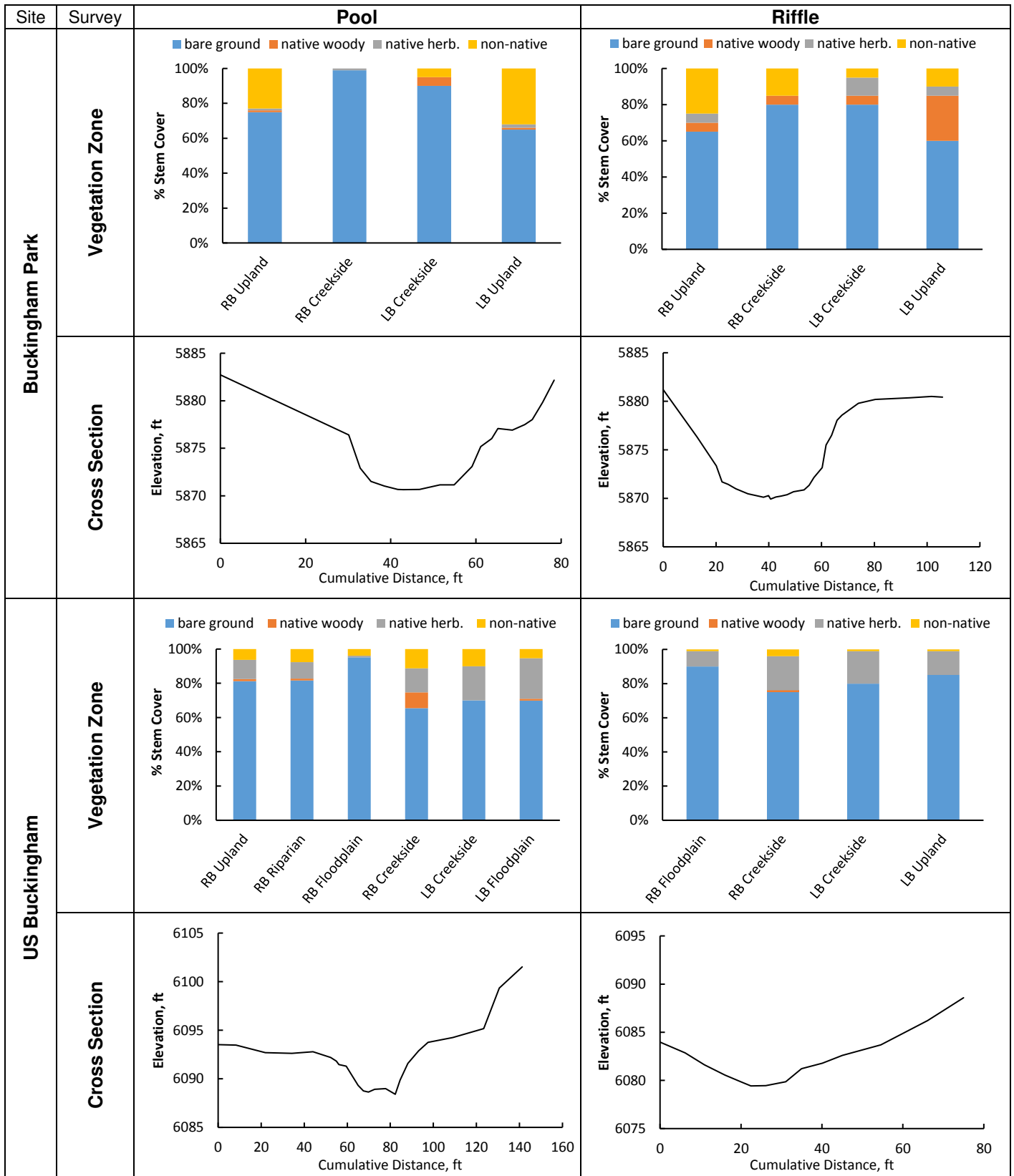


Figure 4. The 2018 pool and riffle survey results for Buckingham Park and US Buckingham sample reaches on Left Hand Creek, Boulder County, Colorado. Composition of the vegetation zone (Upland, Riparian, Floodplain, or Creekside) is illustrated by % stem cover of bare ground, native woody, native herbaceous, and non-native plants. Banks are oriented as if the observer were looking downstream. Cross sections for each pool and riffle are plotted by elevation (ft) and cumulative distance (ft). Profiles are oriented as if the observer were looking upstream. Vegetation Zone charts and Cross Section graphs are directly correlated by cumulative distance, but rather rough estimates.

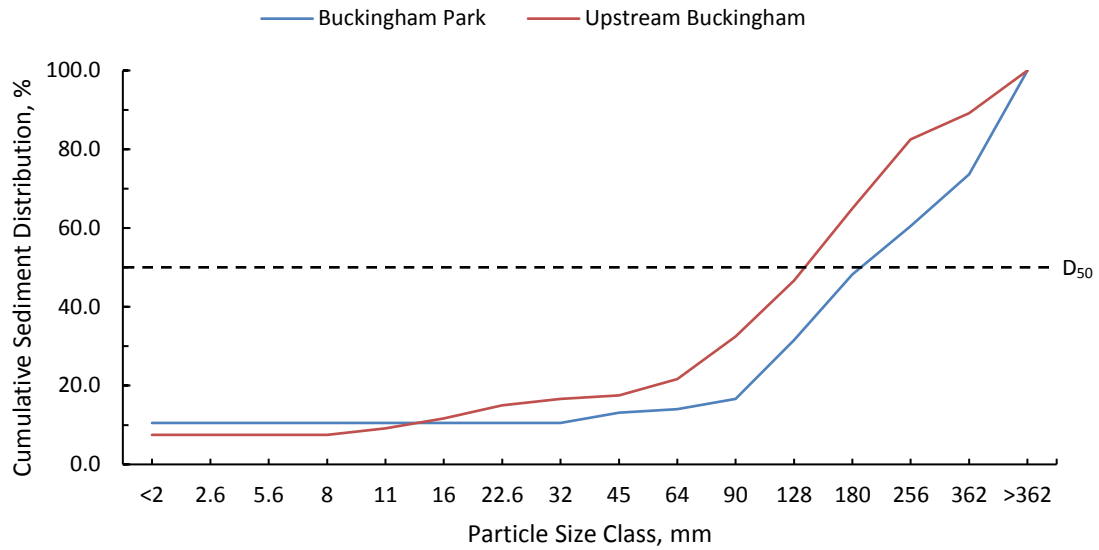


Figure 5. The 2018 particle size class (mm) and cumulative sediment distribution (%) of substrate at the Buckingham Park and Upstream Buckingham riffle cross sections on Left Hand Creek, Boulder County, CO. D₅₀ dashed line indicates the particle size at which 50% of all samples were equal to or less than.

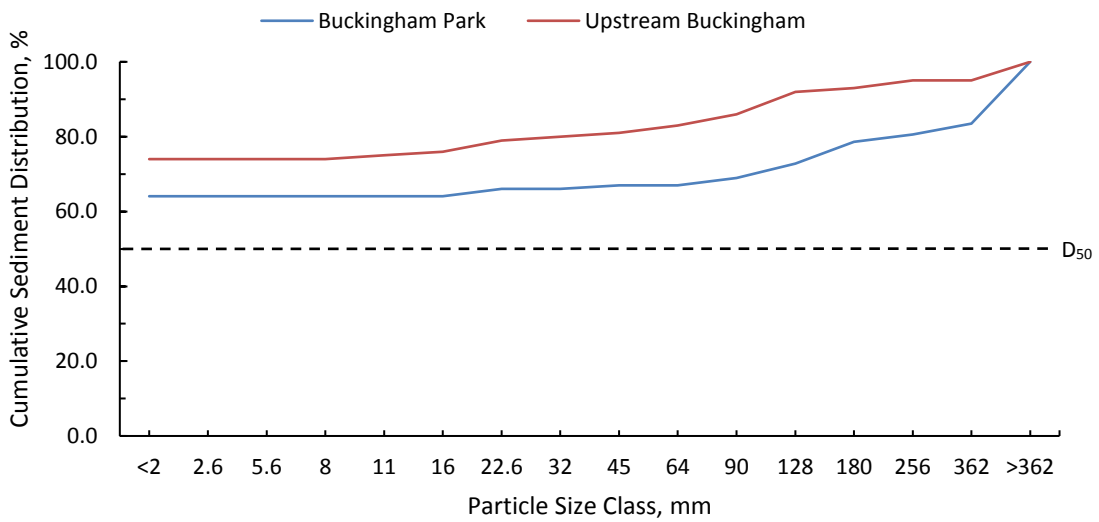


Figure 6. The 2018 particle size class (mm) and cumulative sediment distribution (%) of substrate at the Buckingham Park and Upstream Buckingham pool cross sections on Left Hand Creek, Boulder County, CO. D₅₀ dashed line indicates the particle size at which 50% of all samples were equal to or less than.



Figure 7. Image from 2018 vegetation survey at the Upstream Buckingham riffle site on Left Hand Creek, Boulder County, Colorado. This image was taken from the right bank, floodplain plot. Bare ground is occupied by woodchips.