Post-Dredge Monitoring of Channel Adjustment in a Gravel-Bedded River

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Introduction

The Cedar River has a contributing basin area of 184 square miles and travels 45 miles westward from the Cascade Mountains to Lake Washington in the City of Renton, Washington. The river serves as a drinking water supply for the City of Seattle and is populated by several species of anadromous salmonids, including Chinook, sockeye, coho, and steelhead. The greater Lake Washington basin, including the lower Cedar River (Figure 1), has been highly altered over the past century (Chrzastowski, 1983). These alterations included the lowering of Lake Washington by approximately 9 feet and the abandonment of the lake’s previous outlet channel, the Black River, which flowed southward to the nearby Green River. Historically, the lower Cedar River was located on an active alluvial fan over what is today downtown Renton and discharged directly to the Black River. Since 1912, the Cedar River has been channelized and directed to Lake Washington. Owing to the ongoing sediment delivery from upstream and the depositional nature of this reach, periodic dredging, typically on a decadal timescale, is required to maintain flood conveyance along what is now an economically vital and urbanized corridor (USACE, 1997).

In summer 2016, the lower 1.2 miles of the Cedar River was dredged. Near the upstream dredge extent, the channel gradient was steepened to approximately 0.6% to tie into the existing channel grade. Referred to as the transition zone, it was anticipated that this steepened reach would undergo adjustment through a rotational headcutting process. As requested by stakeholders and required by permitting agencies, a focused monitoring program was implemented in the reach immediately upstream of the dredge project to document channel adjustment and potential impacts to salmonid spawning areas. Presented herein are the methods and findings of monitoring efforts conducted over the course of four flood seasons immediately before and after the 2016 dredging of the lower Cedar River.

Methods

Four monitoring sites were established on the lower Cedar River as part of this study (Figure 1). Three sites were located between River Mile (RM) 1.23 and 1.69 to evaluate conditions immediately upstream of the dredge project. A fourth site, located outside the anticipated area of project influence near RM 2.10, was established as a control site. A key component of the monitoring involved the use of buried scour chains equipped with accelerometers following the methodology of Gendaszek et al (2013).
Scour chains were constructed with HOBO® Pendant™ G Data Loggers (accelerometers) wrapped with lead to counteract buoyant effects, then encased within an 8-cm-long PVC pipe sleeve to provide impact protection (Gendaszek et al, 2013). Three accelerometer units were connected by crimped cable at fixed depths along a single chain and record movement when a unit is exposed by bed scour. Following Gendaszek et al (2013), each accelerometer was set to record its orientation at 20-minute intervals, and movement owing to natural scour or burial forces was determined when the recorded vertical (z) tilt of an accelerometer changed by more than 15 degrees. Accelerometers were attached at depths of approximately 4, 19, and 45 cm (Figure 2), corresponding to the approximate center of the 8 cm PVC sleeve length. The accelerometer placed at the 4 cm depth was intended to measure surface armor layer movement. Depths of 19 and 45 cm below the bed surface correspond to the upper limit of spawning disturbance depth for Sockeye salmon (DeVries, 1997), and the upper and lower limits of spawning disturbance depths for Chinook salmon (Gendaszek et al, 2013). Scour chains were installed vertically into the streambed using a manual hollow-core driver-pipe apparatus. Three scour chains equipped with accelerometers were installed along a transect at each monitoring site spanning the estimated active channel. Scour chains were typically installed during the fall and retrieved the following summer.
In addition to scour chain installation, field data collection included bathymetric surveys and surface bed material sampling. Bathymetric surveys were conducted using a combination of real time kinematic-global positioning system (RTK-GPS) and total station survey equipment. Surveys extended approximately 100 feet upstream and downstream of the established transect at each monitoring site. Survey data were processed to create digital elevation models (DEMs) and evaluate bed level changes between flood season. Sampling of surface bed material was conducted to characterize spatial and temporal variation of grain size distributions at each of the four monitor sites. Samples were collected in the central portion of the channel where scour chains were installed using a traditional random-walk pebble count methodology.

River discharge was obtained from a nearby USGS stream gage (Figure 1, USGS 12119000, Cedar River at Renton, WA). River hydraulics were computed with a one-dimensional HEC-RAS model of the project reach. This model was calibrated and is updated annually with channel geometry data to assess the effects of channel aggradation on flood profiles along the lower Cedar River.

**Results**

River flows during three of the four years monitored were hydrologically uneventful (Figure 3) with peak discharges below the estimated 2-year return period flow of 3,150 cfs (Tetra Tech, 2017). During Water Year (WY) 2016, however, the 2-year flow was approached or exceeded during three separate events, and the maximum peak discharge of 5,460 cfs exceeded the estimated 5-year return period discharge of 4,790 cfs (Tetra Tech, 2017).
Scour monitoring results showed little activity during the first year (WY 2015), with motion of the surface accelerometer (4 cm depth) measured at only four of the 12 chains installed. Motion coincided with a single peak event occurring in early January 2015, at a discharge of 2,630 cfs, and was limited to the upstream two monitoring sites. During the second year of monitoring (WY 2016) higher peak discharges resulted in the motion of a similar number of accelerometers; however, motion was recorded during multiple events, and at intermediate units (17 cm depth). In addition, motion at the two downstream monitoring sites was recorded.

In summer 2016, the lower Cedar River was dredged, and monitoring results from WY 2017 indicate that channel adjustment began shortly after the beginning of the flood season. Immediately upstream of dredge project limit, at the downstream-most monitoring site, motion of the surface accelerometers began in October at a relatively low flow of 1,500 cfs. Further upstream, at the remaining three monitoring sites, motion was recorded at discharges ranging from 1,900 to 2,100 cfs. Channel adjustment was also apparent in the bathymetric survey and bed material data collected. Channel degradation of up to four feet was observed at the downstream monitoring site but decreased in magnitude in the upstream direction. Coarsening of the surface armor layer was also observed. In the second flood season following the dredging (WY 2018), peak flows over 2,000 cfs were achieved, but scour monitors did not record motion. Bathymetric surveys indicated that aggradation was beginning to occur at the downstream

Figure 3. 15-minute Cedar River discharge for Water Years 2015-2018 (USGS 12119000 CEDAR RIVER AT RENTON, WA)
monitoring sites with limited degradation observed upstream. Figure 4 shows average bed profiles from annual surveys of the lower Cedar River and illustrates headcut rotation following the 2016 dredging.

![Graph showing average bed level profiles for the lower Cedar River from 2015 to 2018.](image)

**Figure 4.** Lower Cedar River average bed level profiles surveyed 2015-2018

**Conclusion**

Prior to the 2016 dredging, the lower Cedar River, downstream of RM 1.6, exhibited a forced plain-bed morphology, evidence of alternative bar formation, and a uniform slope of approximately 0.15-percent. Median (D50) particle diameters ranged from 29-60 mm and D90 particles ranged from 78-115 mm. Interestingly, between RM 1.2 and 1.6, grain sizes tended to increase in the downstream direction suggesting selective transport of finer materials in a generally aggrading reach. Under these conditions, scour chain monitoring indicated that incipient motion occurred under flows ranging from 2,000 to 3,000 cfs (1.5- to 2-year return period) and scour depths limited to approximately 0.5 feet (17 cm). The latter is consistent with disturbance depths observed at twice the surface D90 (DeVries, 2002).

As a result of the 2016 dredging, and particularly the grading of a localized over-steepened (0.6-percent) sub-reach between RM 1.1-1.3 (i.e. the transition zone, Figure 4), the channel has adjusted through a process of headcut rotation with relatively symmetric degradation extending upstream and aggradation downstream (Brush and Wolman, 1960). Given the noncohesive gravel-cobble composition of the bed material, this process initiated rapidly and after two flood seasons the channel profile is approaching a slope 0.30-percent. From here, it is anticipated
that the lower Cedar River has responded to the 2016 dredging and will begin to aggrade uniformly.

**Acknowledgements**

The authors would like to thank Andrew Gendaszek (USGS-WA) and Chris Magirl (USGS-AZ) for assistance with initiating this monitoring study, as well as the City of Renton, WA and King County Flood Control District who provided oversight and funding.

**References**


