RECLAMATION

Managing Water in the West

Leavenworth National Fish Hatchery

Icicle Creek Rapid Geomorphic Assessment

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U.S. DEPARTMENT OF THE INTERIOR

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Rapid Geomorphic Assessment:
Icicle Creek, Leavenworth National Fish Hatchery

Purpose

The Leavenworth National Fish Hatchery resides on Icicle Creek near the city of Leavenworth in central Washington State. The Hatchery Channel was constructed to divert high flows around the Historic Channel to protect the fish rearing that originally occurred in the Historic Channel. Fish rearing in the Historic Channel ceased in 1979. More recently, Biological Opinions associated with bull trout and steelhead trout placed limitations on how long water can be diverted down the Hatchery Channel by lowering the radial gates at the inlet structure (Structure 2).

Potential changes to flow regulation through the Historic Channel may alter channel dynamics and geomorphic conditions. The purpose of this report is to provide a rapid, qualitative, geomorphic evaluation of the historic Icicle Creek channel versus the constructed Hatchery Channel given various flow split scenarios.

For purposes of this report, the project area is defined as the historic Icicle Creek channel between Structures 2 and 5 (Figure 1) within Reach 4.

Historic Conditions (Pre Hatchery)

Upstream of the project reach, the Historic Channel is, and historically was, steep, narrow, confined, and characterized by sediment transport. The gradient reduces from over 1 percent upstream of the project reach to roughly 0.18 percent within the project reach. The entrenchment ratio increases by a factor of 4 (from 2.75 to 11 based on GIS measurements from LIDAR), meaning the project reach is much less confined than the upstream reaches. Entrenchment ratio is defined as the flood-prone width divided by the bankfull width and represents an estimate of channel confinement at flood stage. The project reach is, and has been historically, a transitional reach where the conditions change from a narrow, steep valley to a relatively broad, less steep valley. These conditions are similar to those forming alluvial fans whereby the reduced confinement and gradient result in deposition and dynamic channel changes. These types of environments are typically dominated by periods of stability punctuated by infrequent but rapid, episodic channel shifts/avulsions as opposed to consistent channel migration as is seen lower in Icicle Creek (Reach 5). Historic maps of the area near the upstream end of the Historic Channel (approximately upper 1000 feet) show multiple channels fanning out across a relatively broad area with active bars between each suggesting an alluvial fan character.

Alluvial fans, including this historic fan on Icicle Creek, are commonly multi-threaded with a single dominant channel. The dominant main channel would have moved laterally or avulsed episodically during large flood and sediment transport/deposition events. Instream conditions may have varied significantly on the fan from year to year depending on the availability and proximity of instream structure including large woody material (LWM) and the presence of bedrock. Where structure was engaged, pools would have formed and relatively diverse conditions were likely present. In the absence of structure, the instream characteristics would have been relatively homogenous. In all cases, channel forming processes on the fan were dominated by high velocity, high discharge, episodic flood flows. The smaller branch channels on the fan likely received predominantly seasonal high flow and shifted laterally and vertically from year to year.

Immediately downstream of the fan, the multiple channels coalesced into a single-thread channel more similar to downstream reaches (Reach 5). Based on measurements from historic maps, visible relic bank lines, and comparisons with Reach 5, the historic single-thread channel below the alluvial fan likely had a bankfull width between 100 feet (ft) and 135 ft. Bankfull channel geometry was the result of channel forming flows, which typically represent floods between the 1-year and 2-year recurrence interval. Base flows were left to pick a path within the larger bankfull channel. With a relatively broad bankfull channel and low base flows (around 40 cubic feet per second [cfs]), the historic low-flow channel below the fan would have had a relatively high width:depth ratio. The sediment transport regime transitions below the fan from predominantly depositional to balanced (equal deposition and transport). Deposition would drive bar building, bank erosion, and channel migration similar to existing conditions in the lower half of Reach 4. As a result of the Historic Channel function, channel character below the alluvial fan would have been dominated by relatively wide and shallow instream conditions, multiple gravel bars containing little to no mature riparian vegetation, limited overhanging riparian cover, and a coarse substrate bed (likely cobble/boulder transitioning to cobble/gravel). Pools and other bedforms, as within the alluvial fan section, would have formed depending on the availability and proximity of instream structure including LWM, bedrock, and other hard points in the channel and along the banks.

Existing Conditions

The Leavenworth National Fish Hatchery and associated instream structures were built starting in 1939 (ICIF Study, USFWS, 2013). For decades, hatchery operations diverted Icicle Creek flows through a constructed, low-gradient Hatchery Channel while very little flow passed through a regulated concrete weir (Structure 2) into the Historic Channel (Figure 1). The low gradient Hatchery Channel could not efficiently convey sediment, causing deposition within the Hatchery Channel. Test pits excavated by Reclamation in 2009 show up to 4 feet of sand and gravel deposition in the Hatchery Channel. When Structure 2 has been open, much of the bedload sediment was forced through the relatively high-gradient opening at Structure 2 and into the Historic Channel. Three channel-spanning structures (Structures 3, 4, and 5) were used to further manage hatchery operations within the Historic Channel. As a result of the reduced peak flows, multiple channel-spanning structures obstructing sediment transport, and the potential for bedload sediment delivery, deposition occurred within the Historic Channel (predominantly coarse gravel deposition toward the upstream end of the reach near Structure 2 and predominantly sand and fine gravel toward the downstream end near Structure 5). Deposition over time caused bed aggradation enhancing and expanding the braided environment of the alluvial fan creating multiple bars and side channels extending much farther downstream than the historic alluvial fan. The regulated flow regime allowed vegetation to encroach onto the bars, stabilizing the braids resulting in several stable side channels and associated islands. The channel had come into equilibrium with this regulated flow regime.

Structures 3 and 4 were removed in 2003. Fine sediment trapped by these structures remobilized leaving behind a predominantly gravel bed and a broad/shallow channel in this middle section of the Historic Channel. Since the mid-2000s, the gates at Structure 2 have remained open year-round increasing peak flow through the Historic Channel; but flows are still restricted to a maximum of roughly 2,600 cfs (Personal Communication, Steve Croci, USFWS). For comparison, recent gage data show Icicle Creek flows in this area range from a minimum of 44 cfs to a maximum of 19,800 cfs (or higher) with mean annual flow of 624 cfs (ICIF Study, USFWS, 2013). As a response to the removal of structures 3 and 4 and to peak flow increases after Structure 2 gates were kept open, the channel widened up to 10 ft in places (based on historic aerial photo comparison), and a handful of small islands were scoured away. Field observations in July 2014 showed the channel has generally stabilized to a new equilibrium based on Structure 2 remaining open year-round with peak discharge no greater than roughly 2,600 cfs.

Current physical conditions in the Historic Channel observed in July 2014 are analogous to a side channel with limited peak discharge. Channel character is defined by a relatively stable channel with dense riparian vegetation along the banks, little to no gravel bar formation, limited channel migration, maximum instream velocity around 6 feet per second, steep to undercut banks, several split flows and side channels, and ample vegetative cover along the banks.

Potential Future Scenarios

Potential future flow regulation at Structure 2 provides 3 different scenarios:

No change: Maintain existing flow split through Structure 2.

Historic Channel: Under this scenario the Historic Channel character would remain similar to existing conditions described above. With peak flows limited to roughly 2,600 cfs, the Historic Channel would effectively function as a perennial side channel. Bedload would continue to pass into the Historic Channel which, over time, may result in channel aggradation and increased channel dynamics (especially lateral channel migration). This may occur very slowly over several decades, or may occur rapidly following a high-magnitude sediment release from upstream (i.e. debris flow). The channel would continue to function more like a side channel with a low width:depth ratio, undercut banks, and overhanging riparian vegetation. Similar to a spring-fed channel, these unique conditions would occur because peak flows are limited in the Historic Channel (by Structure 2) versus the main Icicle Creek channel (2,600cfs vs 19,000cfs). In other words, the peaks in the hydrograph would be shunted through the Hatchery Channel, and the Historic Channel would receive only relatively consistent flows, much like a spring-fed channel where flow is dominated by consistent groundwater inputs rather than relatively flashy overland runoff. If flows through the Historic Channel are reduced in the future, riparian vegetation would begin to encroach further on the channel narrowing it and creating conditions similar to those following initial hatchery construction described above.

Hatchery Channel: The Hatchery Channel would continue to convey the majority of flood flows and dry out at low flow. Most flood flow and suspended sediment including primarily sand and silt would continue to be transported through the Hatchery Channel to downstream reaches. A very large flood may occasionally scour the bed of the Hatchery Channel, transporting bedload sediment to downstream reaches.

Moderate Increase: Increase peak flow through the historic side channel beyond 2,600 cfs.

Historic Channel: As shown following the increased flow through Structure 2 in in the mid-2000s, any increased flow in the project reach will result in channel adjustment. The most likely channel adjustments would include a wider channel (higher width:depth ratio), coarser substrate (tend more toward cobble), and increased rates of channel movement (bar building and bank erosion). The greater the increase in flow, the more pronounced the adjustment. The Historic Channel would continue to convey low flows, but that flow would be spread out over a wider channel throughout much of the reach with more pronounced bank erosion and bar formation and less overhanging riparian vegetation along the banks more similar to Reach 4 conditions below the hatchery.

Hydraulic modeling completed by Reclamation shows that during large floods, existing conditions result in a backwater in the Historic Channel where it rejoins the Hatchery Channel. Under a split flow scenario as described here, the backwater condition would decrease with more flood water allowed to pass through the Historic Channel (i.e. as flood flows in the Historic Channel approach those in the Hatchery Channel, the hydraulic backwater would be minimized). The larger the backwater, the more potential for deposition within the Historic Channel driving channel widening and/or migration.

Hatchery Channel: The Hatchery Channel would continue to shunt high-flow, but to a lesser degree than under existing (no change) conditions. During floods, the Hatchery Channel and Historic Channel would effectively split flow (depending upon the design), but during low flow, the Hatchery Channel would run dry as it does under existing conditions. Backwater conditions and subsequent deposition would persist within the Hatchery Channel.

Natural Flow Regime: Allow all discharge to pass through the Historic Channel.

Historic Channel: Under a “natural” flow regime, peak flow through the Historic Channel would increase from roughly 2,600 cfs to upwards of 20,000 cfs, which would force rapid channel adjustment primarily by widening the channel to match upstream and downstream geometry. Even without a significant flood, it is likely that the Historic Channel would rapidly (within 1 to 5 years) adjust to the new flow regime. The channel pattern would likely mimic the historic, pre-hatchery planform. The channel would increase from an average bankfull width of roughly 40 to 60 ft to an average width of 100 to 135 ft. An alluvial fan would likely re-form at the location of Structure 2 with a width and length both potentially exceeding 1,000 ft. Increased flow volume and removal of the existing hydraulic backwater would also increase instream velocity and shear replacing the gravel-dominated substrate with cobble (tending toward cobble/boulder in the upper portion of the reach and cobble/gravel in the lower portion). The Historic Channel would function as a mainstem channel characterized by active gravel bars, potential episodic movements/avulsions, less riparian encroachment/cover, higher velocity (especially at high flow), and limited opportunity for relatively low-velocity side channels. Average base flow conditions throughout the project reach would also be affected by the increased width:depth ratio resulting in a wider and shallower channel with reduced amounts of overhanging riparian vegetative cover.

Hatchery Channel: The Hatchery Channel would be dry and/or physically removed, returning the area to the historic relatively high terrace conditions.

Habitat Modeling Considerations

Weighted usable area (WUA) curves are commonly used to estimate habitat changes given variations in hydrology. Most WUA applications include a combination of hydraulic and habitat modeling. By adding more or less water to the model, one can estimate increases or decreases in habitat (i.e. WUA). These models only predict physical and habitat conditions at a snapshot in time and do not account for potential channel adjustment/change, which could be significant. In the case of Icicle Creek, more flow through the Historic Channel will result in coarser bed material, a wider channel, less encroachment of riparian vegetation, fewer perennial side channels, and less overall cover. The existing WUA curves, therefore, are only accurate in describing the “no change” scenario outlined in the previous section. Anticipated changes to channel geometry, bed, and bank conditions would need to be addressed to accurately model the “moderate increase” and “natural flow regime” scenarios. Future habitat modeling of different flow regimes should seek to incorporate anticipated physical changes to the channel geometry, bed, banks, and riparian condition.

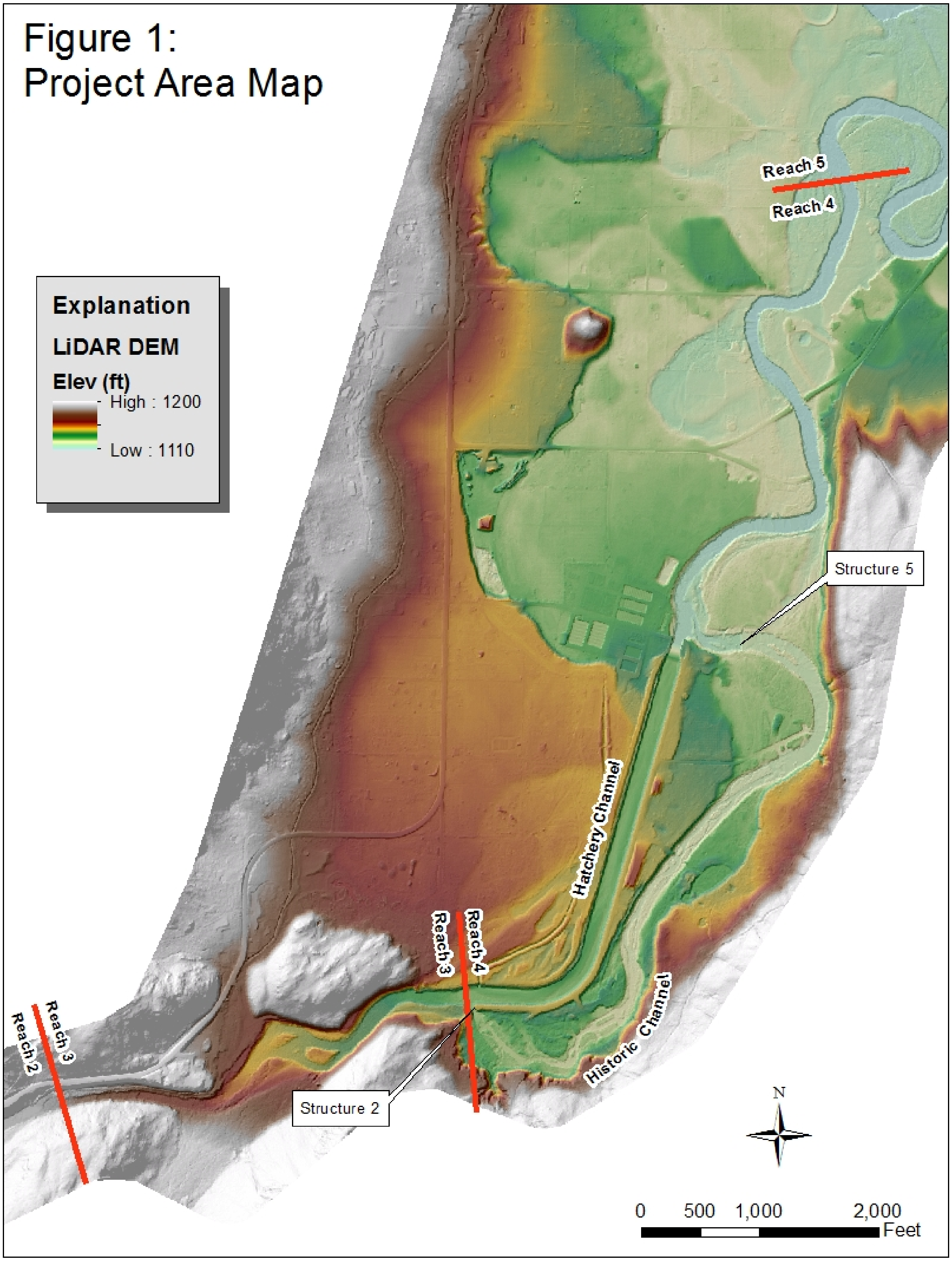

Figure 1. Project Area Map