System Wide Sediment Impacts of CRSO Snake River Dam Removal Alternative

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Abstract

A 2019 Environmental Impact Statement (EIS) was completed to review and update management of the Columbia River System comprised of fourteen federal water regulation projects in Idaho, Montana, Oregon, and Washington. One multiple objective alternative included structural measures for breaching of the four lower Snake River dams (Ice Harbor, Lower Monumental, Little Goose, and Lower Granite). This alternative explored potential impacts of breaching the earthen embankments for these four dams. The analysis included a sediment impact assessment of a two-stage dam removal. This talk will describe the overall dam removal sediment analysis framework and provide Columbia system context for sedimentation results.

A suite of models and analyses were developed to understand system-wide sedimentation processes in the portion of the Columbia River System covered under the Columbia River System Operations EIS with particular focus on the ability to analyze an alternative that included breaching of the Lower Snake River dams. The framework includes 1D mobile bed HEC-RAS, 2D AdH and particle tracking modeling, system-wide 1D HEC-RAS stochastic data analysis for sediment suspension potential and a literature review of sedimentation processes in the affected reaches and notable historic events. This talk will describe how the pieces of the framework work together to inform on system wide sedimentation, major sedimentation findings of the dam removal alternative and provide system context for those findings.

Introduction

Sediment impact analysis for the proposed dam removal alternative was envisioned to be system scale and inclusive of all major sediment processes related to the removal for the timeframe between initiation of pool drawdown and return to a post dam removal quasi-equilibrium condition. Specific objectives for the analysis included:

- Best available quantitative estimates of the volume of reservoir sediment mobilized during removal of the four dams.
- Timing of sediment in motion, including sediment concentrations, and return to quasi-equilibrium in the Snake River.

- Condition of the Snake River following dam removal.
- Sediment Load to McNary Reservoir and McNary Reservoir Deposition
- Sediment Load and Fate Downstream of McNary Dam

Figure *1* shows the four lower Snake River dams in context with the Columbia River watershed and other storage projects in the system. The run-of-river Snake River dams sit upstream of four mainstem Columbia River dams and the Pacific Ocean and downstream of multiple run-of-river and storage dams.

Figure 1: Columbia River Watershed System (Corps, USBR, BPA, 2020).

Sediment Analysis Framework

The team developed a suite of models and analyses to focus on the sediment processes in each of impacted reaches, from the head of Lower Granite reservoir to the Columbia River Estuary.

Snake River

A new one-dimensional HEC-RAS quasi-unsteady mobile bed model of the Lower Snake River and McNary Reservoir was developed to inform the predominately erosion and transport sediment trends during dam draw-down and removal as well as in the longer-term following removal. Data analysis during development of the one-dimensional analysis yielded an estimate of total volume and gradation of material stored within the lower Snake River pools. Between construction and 2010 is estimated to be approximately 180 Mcy. Lower Granite holds the most volume of sediment with 75Mcy, with the remainder distributed throughout the reach. Repeat cross sections throughout the lower Snake River show the location of sediment deposition relative to water surface elevations at typical pool prior to removal and after drawdown (Figure 2). This deposition high above the historical river elevation will be abandoned in place when the reservoirs are drawn down and bypassed. The volume of material estimated to be abandoned above the free-flowing river following dam removal is approximately half of the total deposited sediment. The remaining half (84 Mcy) of the deposited sediment will be in the new free flowing river and floodplain will be subject to river scour and sediment transport.

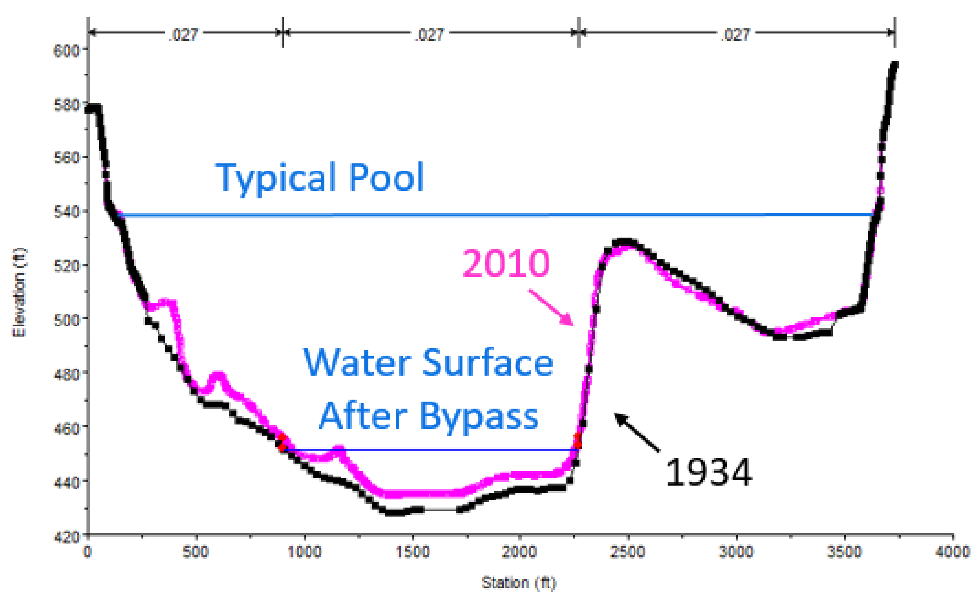

Figure 2: Example cross section comparison showing bed and bank deposition. (Corps, USBR, BPA, 2020)

The one-dimensional model was calibrated to an observed drawdown event and ran for a wet, moderate and dry hydrologic time series. Model results show that rapid scour and resulting high concentrations during the removal years are driven by a large change in hydraulic condition in the river instead of high river flows. Sensitivity testing with respect to flow shows that draw-down and removal peaks and durations are insensitive to the typical range of hydrology during the summer season. This finding runs counter to the typical correlation between flow and sediment concentration, with high flows yielding high sediment loads. Once the draw-down and removals have occurred and the readily available wash load has moved through the Snake River, sediment movement again becomes linked to hydrology and river flows.

It is estimated that it will take from 2-7 years following removal for the coarser sands and gravels stored in the reservoirs to scour down to pre-dam bed elevation throughout the reach and establish a new quasi-equilibrium condition in the Snake River. Sediments stored on the historical floodplain may be accessed by subsequent flood events and be transported downstream. During the period following removal, sediment transport will be correlated to flow, but will be reducing in magnitude and available transportable sediments are scoured from the system. Calculated average annual sediment load rates from the Snake River to McNary Reservoir for the affected environment condition as well as near-term and long-term following dam removal are shown in Table 2.

Table 1: Average Annual Composition and Volume of Snake River Sediment entering McNary Reservoir for a Moderate Future Hydrology. (Corps, USBR, BPA, 2020)

	Affected Environment		**Near-Term** 3 years following removal		**Long-Term** 3-16 years following removal	
	% of Total	Average Annual Vol (Mcy)	% of Total	Average Annual Vol (Mcy)	% of Total	Average Annual Vol (Mcy)
Clay	50%	0.4	36%	4.5	13%	0.5
Silt	50%	0.4	49%	6.2	68%	2.4
Sand	0%	0.0	15%	1.9	19%	0.7
Total	100%	0.8	100%	12.6	100%	3.6

McNary Reservoir

McNary Reservoir is capable of effectively trapping nearly all sand and a portion of silt and clay sized particles. HEC-RAS model output was interrogated to determine trapping rates for the near-term and long-term. It is notable that silt and clay are trapped at higher percentages in the near-term than long-term. This is because the large sediment load to McNary Reservoir associated with dam removal occurs during a low flow period when McNary is a more effective trap. Calculated average annual deposition rates for the affected environment condition as well as near-term and long-term following dam removal are shown in Table 2.

New two-dimensional adaptive hydraulics (AdH) models for McNary and John Day reservoirs were developed to provide hydrodynamic solutions within the reservoirs. AdH output was used in new Particle Tracking Model applications to McNary and John Day reservoirs to track particle deposition within or transport through the reservoirs.

Figure *3* depicts expected deposition locations of Snake River sediments in McNary Reservoir. Modeling predicts that the deposition will be concentrated along the Oregon shore with sands being retained higher in the pool than silts. This Oregon shore biased deposition is consistent with previous bed core sample findings made Beasley et al. 1986.

Table 2: Average Annual Composition and Volume of Snake River Sediment Depositing in McNary Reservoir for a Moderate Future Hydrology. Analysis assumes dam removal occurring at time of EIS publication in 2021 (Corps, USBR, BPA, 2020)

	Affected Environment		**Near-Term** 3 years following removal		**Long-Term** 3-16 years following removal	
	% of Total	Average Annual Vol (Mcy)	% of Total	Average Annual Vol (Mcy)	% of Total	Average Annual Vol (Mcy)
Clay	28%	0.1	22%	1.8	1%	0.0
Silt	72%	0.3	60%	5.1	67%	1.6
Sand	0%	0.0	19%	1.6	32%	0.8
Total	100%	0.4	100%	8.5	100%	2.4

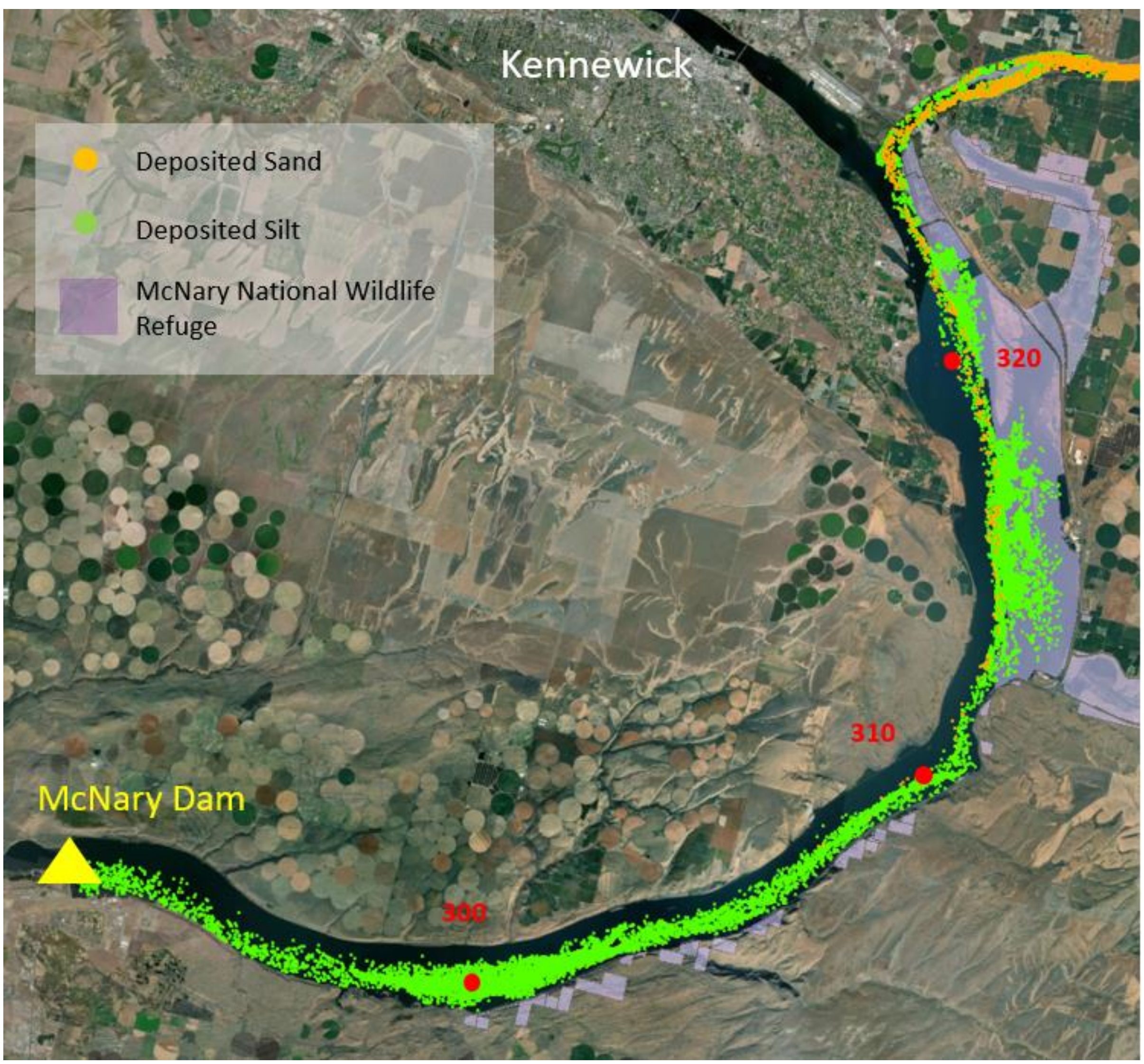

Figure 3: Predicted Deposition Locations in McNary Reservoir for Sand and Silt Sized Particles (from Particle Tracking Model output). (Corps, USBR, BPA, 2020)

Columbia River, McNary Dam to the Estuary

HEC RAS mobile bed model results estimate that approximately 30 to 35 percent of the sediment entering McNary reservoir from the Snake River following dam removal passes McNary Dam into John Day reservoir.

Table *3* shows a breakdown of the composition of the passing sediment along with average annual volumes for the draw down and removal period as well as the long term.

Table 3: Average Annual Composition and Volume of Snake River Sediment passing McNary Dam for a Moderate Future Hydrology. (Corps, USBR, BPA, 2020)

	Affected Environment		**Near-Term** 3 years following removal		**Long-Term** 3-16 years following removal	
	% of Total	Average Annual Vol (Mcy)	% of Total	Average Annual Vol (Mcy)	% of Total	Average Annual Vol (Mcy)
Clay	71%	0.3	70%	2.7	35%	0.4
Silt	29%	0.1	30%	1.1	65%	0.8
Sand	0%	0.0	0%	0.0	0%	0.0
Total	100%	0.4	100%	3.8	100%	1.2

Existing one-dimensional unsteady state HEC-RAS modeling of the Snake River and the Columbia River downstream of the Snake River confluence was used to calculate multiple sediment transport metrics including threshold grain size for 100 percent suspension using the Rouse method. This analysis of the CRSO alternative including dam removal hydraulic conditions for the Columbia River downstream of the Snake River confluence is shown in

Figure *4*.

It is not expected that bed sediments in the Columbia River downstream of McNary Dam will change in the long-term following Snake River Dam removal. McNary effectively traps sand and courser material leaving wash load to move through the system. An analysis of hydraulic conditions and threshold grain size for having a particle being held 100 percent in suspended in the water column shows that reaches downstream of McNary Dam can pass material that makes it through McNary Dam. The downstream Subreach of John Day dam is one notable exception where the grain size threshold for suspension is similar to McNary. The Rouse analysis presented is based on one dimensional hydraulic modeling which speaks to cross section average trends. Localized deposition in currently observed patterns will continue. Areas that are silt bed will continue to be silt bed and areas that are sand or coarser will continue to be sand or coarser.

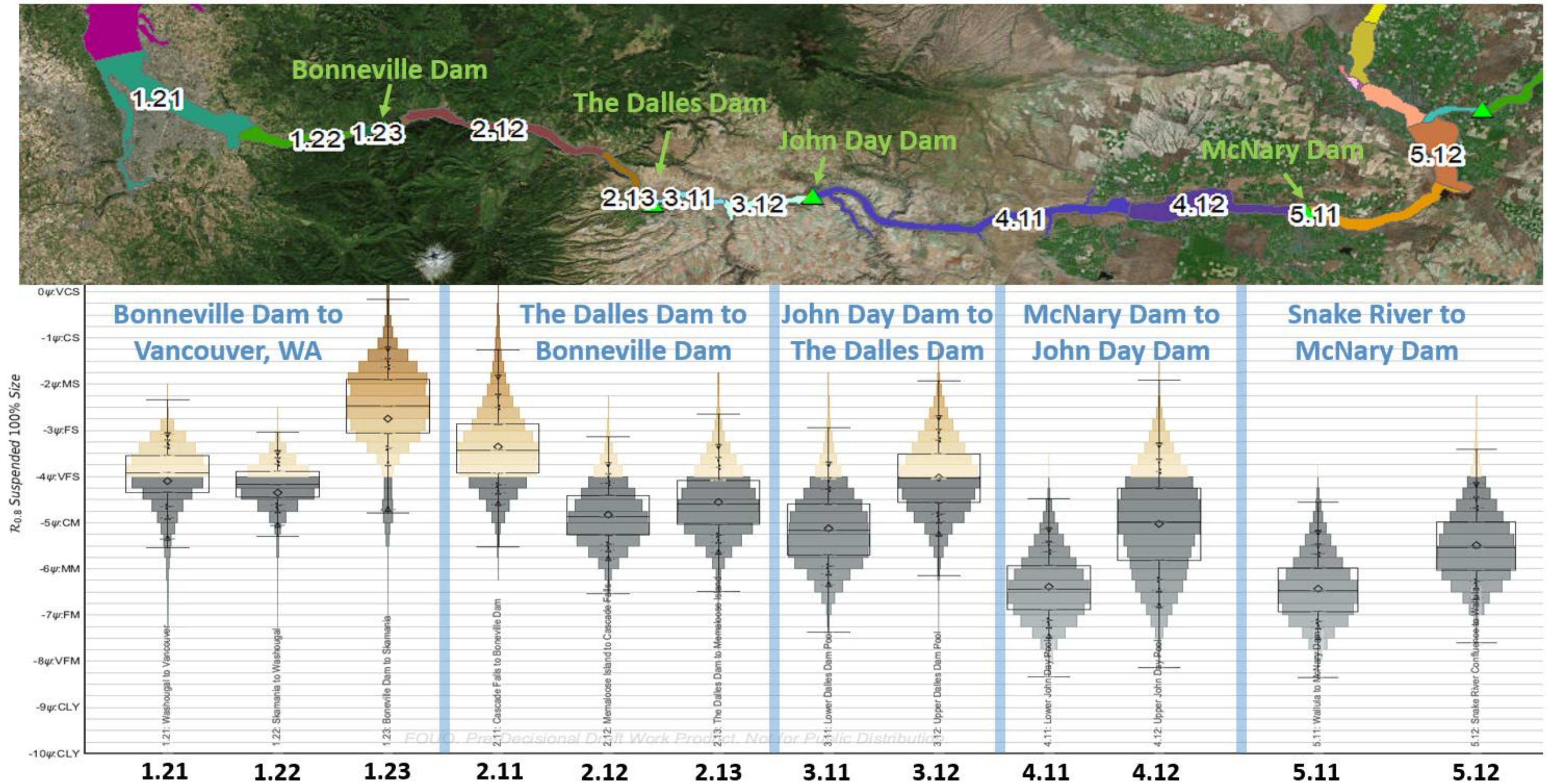

Figure 4: Rouse 100 percent suspended grain size threshold for all daily flows by subreach. (Corps, USBR, BPA, 2020)

Additional Context

Previous studies and datasets within the region were applied for analysis verification and to provide additional information on sediment processes and fate.

Habitat in the Snake River

The resulting habitat condition in the Lower Snake River once the river reaches a quasi-equilibrium condition following dam removal was studied and reported in the Appendix H of the Lower Snake River Juvenile Salmon Migration Feasibility Report/Environment Impact Statement (Corps 2002). The analysis utilizes the 1934 survey data which contains a large amount of information on bed material, bank material, rapid heads and toes, rapid velocities and other observations to classify the geomorphology of the pre-dam condition. New data collection and analysis including the mobile bed HEC-RAS model supports and adds additional information to the 2002 geomorphology analysis. The 2002 study concluded that historic and contemporary discharge records indicate that regulated flow regimes after dam breaching would be competent enough to maintain channel characteristics and riverine processes (e.g., channel bed mobilization) following removal. Bed material and sediment loading data collected since the 2002 report and the new HEC-RAS mobile bed modeling indicate that the transition time to long term habitat types may be faster than estimated in 2002 and may be achieved between 2 and 7 years following removal depending primarily on river flows.

References

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