US Army Corps of Engineers®
Portland District

WILLAMETTE VALLEY SYSTEM OPERATIONS AND MAINTENANCE

FINAL ENVIRONMENTAL IMPACT STATEMENT

APPENDIX C: RIVER MECHANICS AND GEOMORPHOLOGY

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Executive Summary

This appendix provides additional detail on the river mechanics and geomorphology effects assessment methods, assumptions and calculations. The document is composed of two major parts. It includes (1) discussion of the overall analysis methodology and specific metrics, (2) quantitative metric results and a qualitative estimate of the potential impacts to metrics under the No Action Alternative (NAA), seven action alternatives and the near-term operations measure. Relative impacts are compared between the action alternatives and NAA.

THE FOLLOWING INFORMATION HAS BEEN UPDATED FROM THE DEIS AND MOVED FROM DEIS SECTION 3.3 INTO THIS APPENDIX

EIS SUBSECTION NUMBERING WAS NOT MODIFIED FROM THE DEIS TO ASSIST WITH DEIS COMPARISONS

3.3 River Mechanics and Geomorphology

3.3.1 Affected Environment

The Affected Environment pertaining to river mechanics and geomorphology is divided into two descriptions: (1) the rivers downstream of the WVS and, (2) the dams and reservoirs themselves. In this section, river mechanics refers to the flow levels in the river and closely associated phenomena, such as sediment movement. Floodplain geomorphology refers to the geometry and features of the area that interact with the river.

There are many factors that contribute to both descriptions, including the basin geology, hydrology, and riparian vegetation. The river and floodplain both shape and interact with each other. For example, the seasonal variability of flow velocity would erode or deposit sediment and change the shape of the channel and floodplain, leading to changed river velocities in a continuous process.

In the downstream portions of the Willamette River Basin (WRB), riverine processes help shape the morphology of the terrain. The Willamette Valley System (WVS) substantially affects the hydraulics and morphology of rivers in the WRB. During all seasons, dams and reservoirs remove sediment and energy from the system and revetments along the river retard its movement. During the major flood season, peak flows are reduced to decrease damage from flood inundation. All these activities – and others outside of the WVS control – have the effect of reducing the width of the floodplain engaged by the river (Section 1.8, Non-USACE-managed Dams and Reservoirs in the Willamette River Basin).

Reservoir elevations vary throughout the year, changing the ponded storage and shoreline. In winter, these changes result from flood risk management operations. In spring and summer, reservoirs store water for use during the conservation season and are filled up to full pools as conditions allow (Section 3.2, Hydrologic Processes). Water surface elevations in the reservoirs and the outflows from dam outlets have substantial effects on the immediate surroundings.

3.3.1.1 Willamette Valley System

There are approximately 465 River Miles (RMs) along the Willamette River and its regulated subbasins below the WVS. Two subbasins, the Clackamas and Molalla River Subbasins, contain revetments but are not downstream of any WVS reservoirs, so they are 'unregulated' by USACE flood damage reduction storage projects (Section 1.7.2, Revetments and Other Structures for Bank Protection).

The WVS is multipurpose; operational goals change throughout the year based on the season. During the major flood season, the goal is to decrease flood damages by reducing the peak flow downstream of the WVS (Section 3.2, Hydrologic Processes). These operations are readily apparent in the historic record. The WVS was constructed starting in 1942 with Fern Ridge Dam on the Long Tom River and was fully operational for water year 1969.

The peak flows at Albany, Oregon were reduced substantially after 1969. Figure 3.3-1 shows the annual peak from each WY at a long-term flow gaging site on the Willamette River downstream of the WVS reservoirs. Annual observed peak flows are reduced by hydropower regulation, but the USACE also reduces potentially damaging flows from the WVS that are lower than the annual peak flows shown in Figure 3.3-1.

The high flows, both annual peaks and lesser large flows from before construction of the WVS, formed the geomorphic floodplain in the WRB. The amount of energy and peak flows available to the rivers downstream of the WVS has been reduced, and the area of influence around the main channel has narrowed as an effect of flood damage reduction operations. Consequently, the many floodplain terraces, swales, and other geomorphic formations along the Willamette Basin rivers are no longer regularly connected to the channel as they were before construction of the WVS.

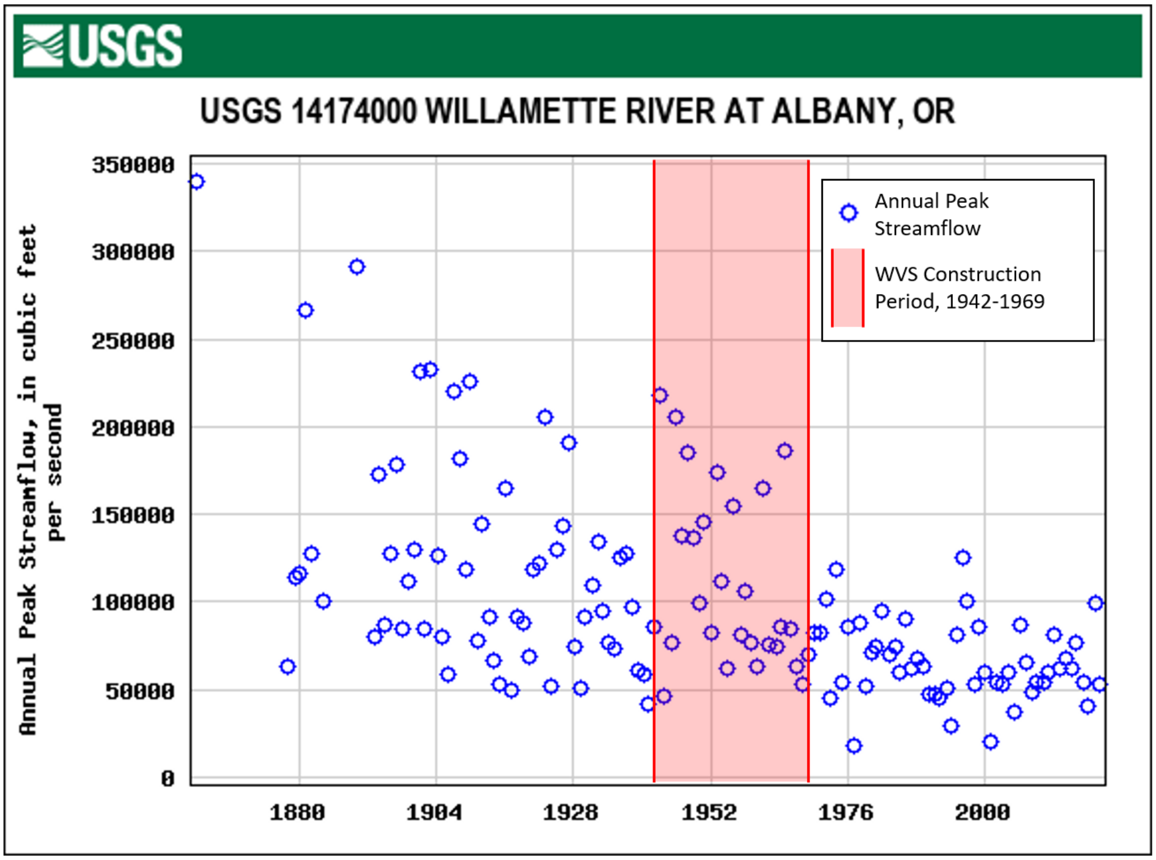

Figure 3.3-1. Annual observed maximum flow at Albany, Oregon.

The rivers are generally steep further upstream toward the headwaters of the WRB. While the Willamette River above Willamette Falls is nearly flat during low water periods, the upper portions of the North Santiam River and McKenzie River have steep average channel slopes of up to 10 feet per mile (Figure 3.3-2). A general geomorphic and hydraulic description of the downstream reaches (Wallick et al. 2013) is discussed below.

All regulated tributaries in the WRB except Blue River, South Fork McKenzie, Fall Creek, and Row River contain constructed bank protection revetments, embankments, or levees. These structures are part of the WVS and generally constrain the movements of river channels (Section 1.7.2, Revetments and Other Structures for Bank Protection).

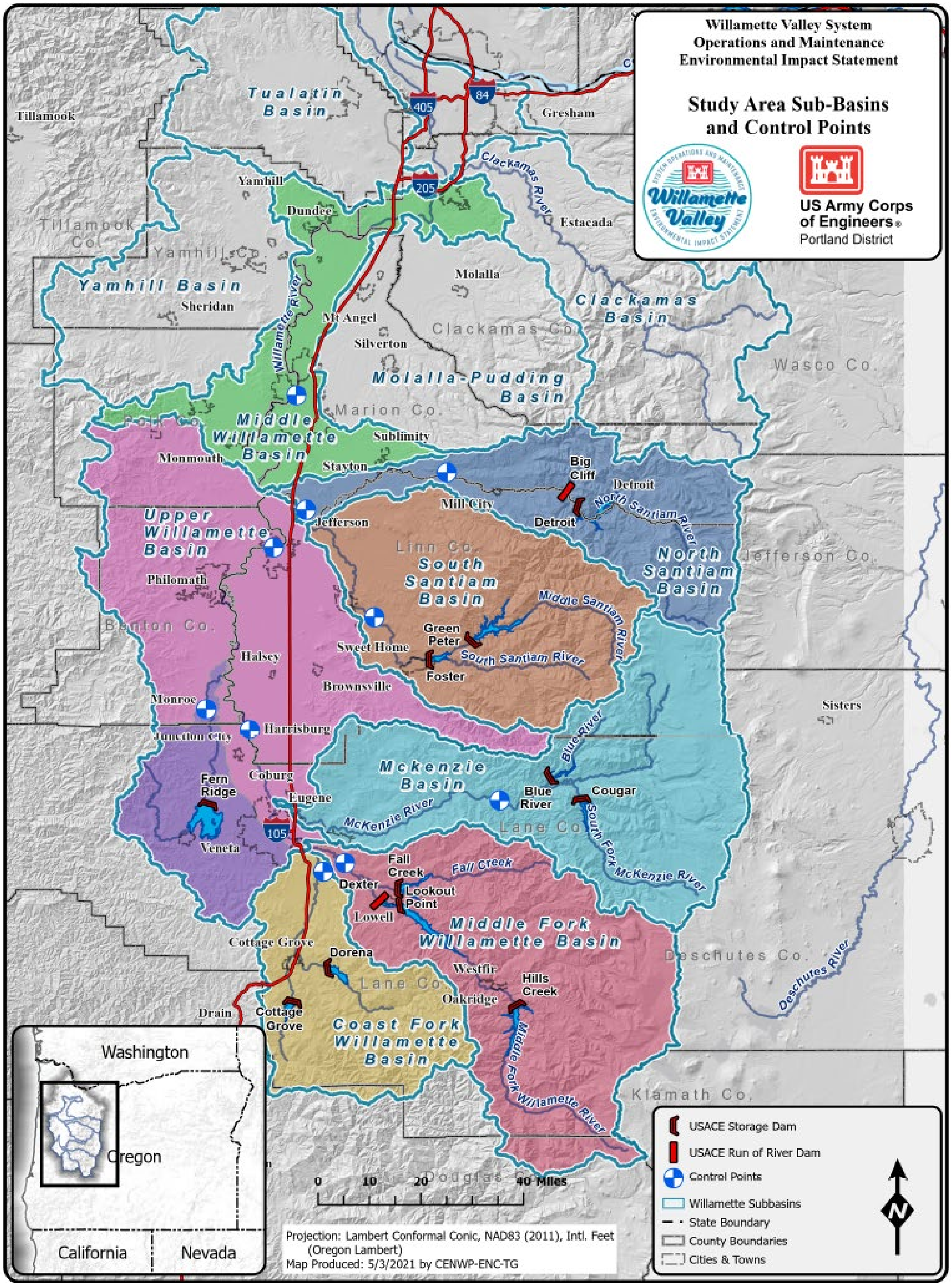

Figure 3.3-2. Willamette River Basins and Willamette Valley System.

3.3.1.2 Willamette River Basin Sediment Movement

Sediment movement in the WRB is substantially altered by the WVS, both in the reservoirs themselves and in the downstream rivers and floodplains due to the construction of revetments and hydrologic modifications for flood damage reduction. Unregulated tributaries within the WRB, upstream of their confluences with USACE regulated rivers, are not affected by WVS. USACE constructed bank protection structures authorized by the 1936, 1938 and 1950 Flood Control Acts exist on the Clackamas, Molalla, and Pudding Rivers. Although not within the WVS for flood control, these structures are associated with flood damage reduction projects within the WRB.

<u>Reservoir Sediment Mechanics</u>

Coarse sediments (sand and gravel) entering a reservoir typically settle out and deposit as a delta in the upstream end of reservoirs and along the upstream river channels as the flow of the river encounters the reservoir pool. Sediment in the delta (commonly referred to as “head-of-reservoir” deposits) can be remobilized farther downstream when the reservoir operating pool lowers (e.g., for seasonal management changes).

In dam projects that operate over a wide range of elevations throughout the year, the upstream extent of reservoir backwater and the location where coarse sediments deposit may shift considerable distances. Reservoirs with large changes in water surface elevation and shallow slopes near the head-of-reservoir would have large coarse sediment deltas. Coarse sediments rarely pass a dam with a pool substantially full of water.

Fine suspended silts and clays tend to transport past the delta and slowly settle out of the water column along the reservoir bottom as a lakebed deposit. Fine sediment would typically travel further in the reservoir: the smallest sediment particles may never reach the bottom of the reservoir and would pass through the dam with the outflow.

Reservoirs with large storage volumes relative to the annual volume of water passing through tend to trap more suspended sediment than reservoirs with small relative storage volumes (Figure 3.3-3). Reservoir geometry can also affect fine sediment trapping: sediment would take longer to travel to the bottom of a reservoir that is relatively long and deep as compared to a similar volume reservoir that is wide and shallow.

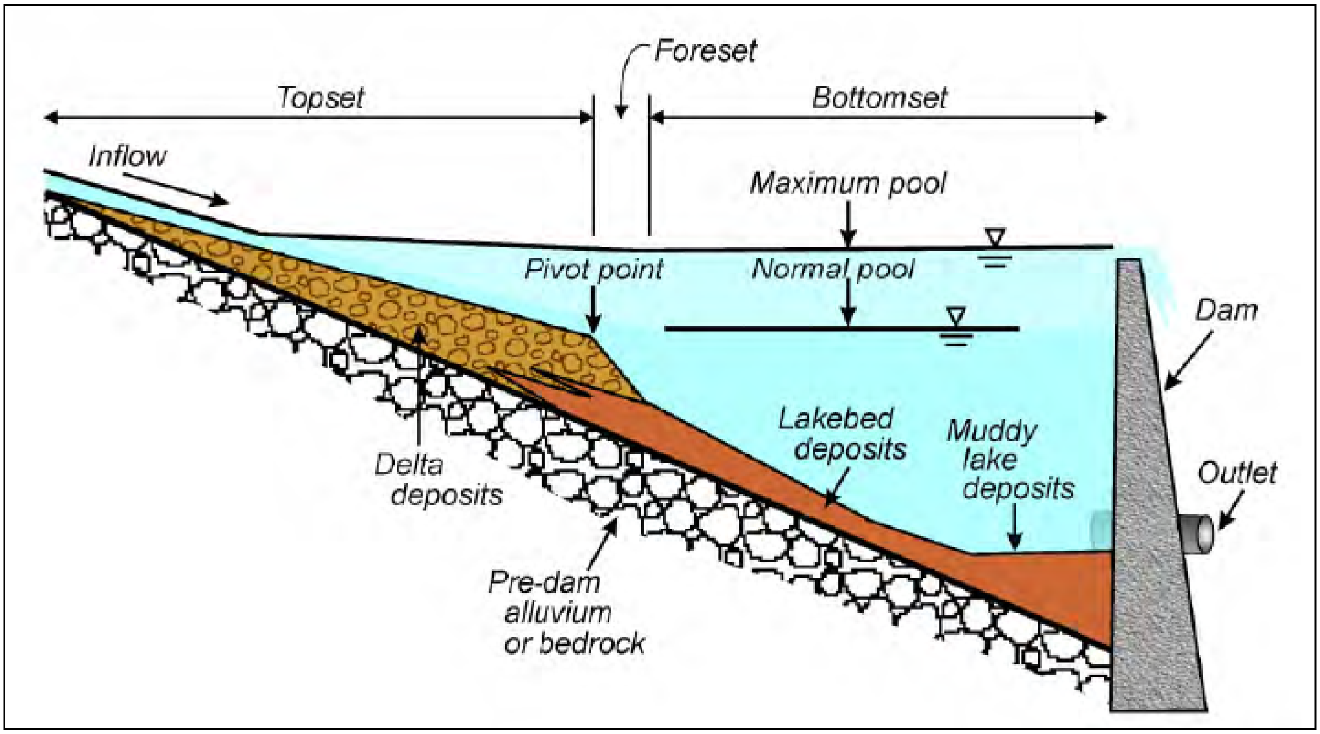

Figure 3.3-2. Idealized Sediment Profile within a Dam-controlled Reservoir.

The estimated median sediment trapping efficiencies for the WVS (excluding the Big Cliff and Dexter Dam reregulating projects) are shown below. These calculations use the WVS PEIS hydrology inflow dataset for storage and inflow volume

Target elevations generate useful comparisons of median trapping efficiency across the WVS as most sediment generated from upstream sources transports into the reservoirs during the flood season flows. More broadly, since trapping efficiency is based on a log-scale comparison of water volumes, the estimated trapping efficiency would not change substantially if the actual amount of impounded water is different than the rule curve[1] target.

<u>**Reservoir Storage Projects**</u>

There are 11 WVS dams that are designed and operated for storage purposes as listed below along with estimated trapping efficiency at each reservoir.

[1] A rule curve is seasonal reservoir elevation targets or restrictions, represented graphically as curves, that guide reservoir operations.

Table 3.3-1. Reservoir Storage Project Setting

Reservoir	***Basin (Figure 3.3-2) and Downstream River Reaches***	***Estimated Sediment Trapping Efficiency***
Blue River Reservoir	Within the McKenzie Basin. Downstream river reach is Blue River, a tributary to McKenzie River.	81 percent
Cottage Grove Reservoir	Within the Coast Fork Willamette Basin. Downstream river reach is the Coast Fork Willamette River.	81 percent
Cougar Reservoir	Within the McKenzie Basin. Downstream river reach is the South Fork McKenzie River, a tributary to the McKenzie River.	91 percent
Detroit Reservoir	Within the North Santiam Basin. Downstream river reach is Big Cliff reservoir, a run-of-river reservoir on the North Santiam River.	91 percent
Dorena Reservoir	Within the Coast Fork Willamette Basin. Downstream river reach is the Row River, a tributary to the Coast Fork Willamette River.	81 percent
Fall Creek Reservoir	Within the Middle Fork Willamette Basin. Downstream river reach is Fall Creek, a tributary to the Middle Fork Willamette River.	82 percent
Fern Ridge Reservoir	Within the Long Tom Basin. Downstream river reach is the Long Tom River.	80 percent
Foster Reservoir	Within the South Santiam Basin. Downstream river reach is the South Santiam River.	67 percent
Green Peter Reservoir	Within the South Santiam Basin. Downstream river reach is the Middle Santiam River which flow into Foster Reservoir.	93 percent
Hills Creek Reservoir	Within the Middle Fork Willamette Basin. Downstream river reach is the Middle Fork Willamette River and Lookout Point Reservoir.	94 percent
Lookout Point Reservoir	Within the Middle Fork Willamette Basin. Downstream river reach is the Middle Fork Willamette River.	88 percent

Note that these values are estimates based on comparing water volumes and not measured sedimentation. Also, as noted above, every reservoir in the WVS traps nearly all coarse sediments (gravels and sands) in the pool (O'Connor et al. 2014). These are included in the values above, and generally the only sediment passing a reservoir would be fines (i.e., silt and clay sized sediments).

Reservoirs Run-of-River

Run-of-river reservoirs are formed by dams that are operated to discharge water downstream at rates that generally match the upstream inflows. Big Cliff, and Dexter dams are run-of-river projects that operate in a small range of pool elevations for daily or weekly hydropower purposes but do not attempt to store water for release in later seasons. Foster Dam is considered both a storage and a run-of-river project in this analysis as it is partially operated to re-regulate the outflows from Green Peter.

THE FOLLOWING FOUR PARAGRAPHS WERE MOVED FROM DEIS SECTION 3.3.2.1.2, ENVIRONMENTAL CONSEQUENCES, STORAGE PROJECT METRICS, AS AFFECTED ENVIRONMENT INFORMATION

Reservoir sedimentation and loss of storage capacity has been historically assumed to be small such that it does not affect operations. Repeat surveys of a subset of the WVS storage projects shows that this assumption is accurate. The 2017 Lookout Point water control manual provides a good summary of the sedimentation study history and system design assumptions:

> The Portland District conducted a sediment sampling program in the Willamette River Basin from 1 December 1948 to 1 July 1951, for the purpose of obtaining factual data on sedimentation rates and bedload movement in this area. As a result of this investigation, it was found that suspended sediment rates and bed-load movement is comparatively low in Willamette River Basin streams. Consequently, loss of reservoir storage in existing reservoirs was estimated as small and would not materially affect storage capacities during the 50-year economic life of these projects (USACE 2015a).

USACE has performed a limited resurvey of WVS reservoirs since the original sedimentation transects were established. Where repeat surveys exist, data support the low overall sediment yield design assumptions. Lookout Point Reservoir was surveyed in 1956 and 2014. Updated rating curves show a 1.0 percent loss in storage capacity below maximum pool with all of the total loss occurring below minimum flood pool.

Dorena Reservoir was surveyed in 1953 and 2017. Updated rating curves show a 4.8 percent loss in storage capacity below maximum pool with approximately half of this loss occurring below minimum flood pool. Fern Ridge Reservoir was surveyed in 1947 and 1993. Reporting identifies a 3.8 percent loss in storage capacity below maximum conservation pool with 80 percent of the loss in storage capacity occurring in the lower half of the pool.

Shoreline erosion of bank sediments along the edges of the reservoir where the water meets the land is a complex process that is influenced by the cumulative effects of: wind and boat wave erosion, reservoir currents, precipitation runoff, freeze-thaw, soil properties, exposure, and vegetation density and type. One commonly observed process is that, during times of extended reservoir drawdown, exposed un-vegetated shoreline soils that were previously saturated are prone to erosion and localized slope failures (slumping) (Section 3.5, Water Quality). Shoreline processes leave long-term marks on the land, reworking soils and exposing underlying layers (Section3.22, Visual Resources).

END OF TEXT MOVED FROM SECTION 3.3.2.1.2, ENVIRONMENTAL CONSEQUENCES, STORAGE PROJECT METRICS

There are two existing reservoir sediment mobilization models in the WVS, at Detroit Dam (USACE 2016a) and Lookout Point/Dexter Dam (USACE 2015c). The intent of both studies was to assess the movement of accumulated sediments in and out of the reservoir during a deep drawdown reduction in the pool elevation to the lowest outlet in each dam. In addition, USACE has lowered the reservoir elevation at Fall Creek Dam during the fall in recent years with a deep drawdown.

Figure 3.3-4 illustrates results of the scour analysis during a modeled drawdown of Lookout Point Dam. The Lookout Point model was designed to investigate sediment movement in and out of the reservoir in preparation to replace the spillway gates, which required a lowering of the reservoir.

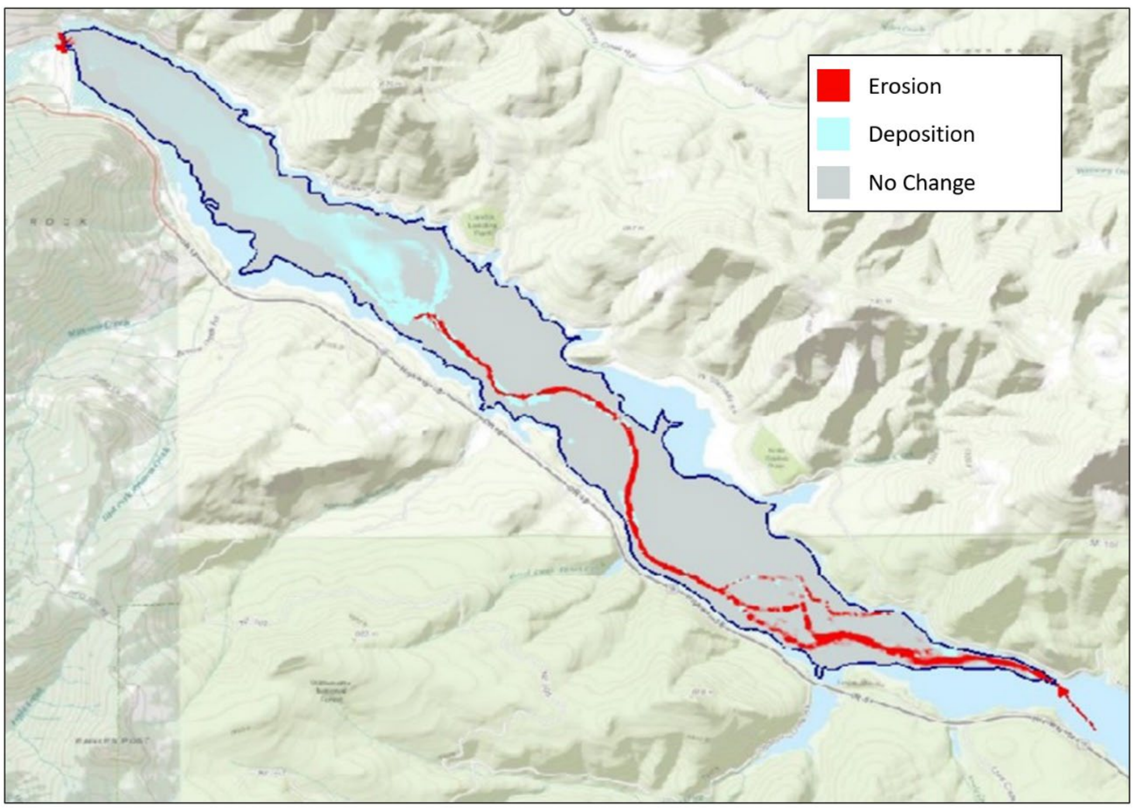

Figure 3.3-4. Modeled Sediment Mobility during Modeled Lookout Point Dam Drawdown.

Results show sediment accumulated at the upstream end of Lookout Point Dam since construction (bottom right in the figure) moving closer to the dam (top left) and a limited amount of sediment passing through to Dexter Reservoir downstream.

River Sediment Mechanics

Most coarse sediments in the WRB are from the Cascade Mountains, which primarily supplies volcanic basalts. This material degrades relatively slowly and typically disappears from river channels due to coarse sediments being broken into smaller particles as they are carried downstream (O'Connor et al. 2014) (Section 3.4, Geology).

The McKenzie and North Santiam Rivers currently contribute the highest amount of sediment to the mainstem Willamette (Wallick et al. 2013). These two rivers support large portions of drainage basins that are both relatively steep and outside the control of any WVS dam and reservoir. Figure 3.3-5 shows gravel bar formation in the North Santiam River south of Stayton, Oregon that demonstrates sediment transport in the reach. The side channels and various ages of vegetation and gravel bars are evidence that the river channel is mobile within its immediate floodplain in this area.

Although the Coast Range does contribute substantial sediments, the soft sedimentary sandstone from this mountain range rapidly degrades to silt and clay (O'Connor et al. 2014) and is transported as suspended and wash load ("wash load" is the portion of sediments that remain suspended even without water flow, thereby contributing to turbidity).

Figure 3.3-5. Gravel Bars and Side Channel Morphology in North Santiam River South of Stayton, Oregon.

Most sediment transport capacity in riverine environments occurs during near channel bankfull water conditions. Bankfull refers to the water level stage that just begins to spill water out of the channel into the floodplain. As noted in Section 3.2, Hydrologic Processes, the frequency of these events has been reduced by the upstream storage operations of the WVS.

Combined with the sediment capture in the reservoir pools, WRB modifications have had the effect of reducing sediment load in the Willamette Valley. In total, the WVS is estimated to reduce the estimated coarse sediment flux in the WRB by about two-thirds, from about 199,000 cubic meters to 72,000 cubic meters per year (Wallick et al. 2013).

As with hydrology and peak flows, sediment movement in rivers closest to dams and reservoirs is most heavily affected by their construction. Generally, the streambed in these areas coarsens (or 'armors') over time as the water from the dam outlets erode the fine material in the downstream channel. In a natural system, this material would be replaced by incoming transporting sediments, but these sediments are instead trapped in the reservoir itself.

This coarsening effect is not limited to river reaches directly downstream of reservoirs and, over time, the regulated rivers in the WRB have coarsened (Klingeman 1987; Minear 1994). Simultaneously, the regulation of the peak flow in the main reaches reduces the transport capacity for coarse sediment load. Sediment coming into the main reaches from downstream rivers still contains the coarse sediment, in contrast to water from the reservoirs. The reduced peak flows leave the incoming coarse sediment behind as fine material moves downstream. The combined effect of these two riverine processes is an overall coarsening of riverbeds in the regulated portions of the WRB.

Coarse sediment availability and mobilization and large changes in flow all contribute to river channel migration. The segments of the mainstem Willamette River that currently experience the most migration due to these factors are the areas downstream of the confluences with the McKenzie River and Santiam River. As the river flows away from these confluences, the river adjusts to its larger flow, the coarse sediment is lost to attrition and the river is more incised in the sections between Corvallis until the confluence with the Santiam River – farthest away from the McKenzie River – and downstream of Salem, Oregon – furthest away from the Santiam River (Wallick et al. 2013).

<u>Bank Stabilization by Revetments and Other Structures</u>

USACE, private landowners, and others have built revetments along the historically mobile river reaches of the WR (Figure 1.7-1, Figure 3.3-6). Individual revetments vary in geometry based on the local river and bank conditions (Section 1.7.2, Revetments and Other Structures for Bank Protection).

These structures typically consist of large stones (riprap) placed along the river to prevent the bank from eroding further and protect adjacent property. Stone revetments often have accessory structures like drift barriers, which are placed at the mouth of high-water overflow channels to collect debris and reduce the velocity of flows into the channel; and groins, which extend into the channel diagonally or perpendicularly to the riverbank to reduce near-bank velocities. Revetments are typically placed on the outside of a river bend where erosion is most likely to occur but are sometimes also used to realign or straighten the main channel.

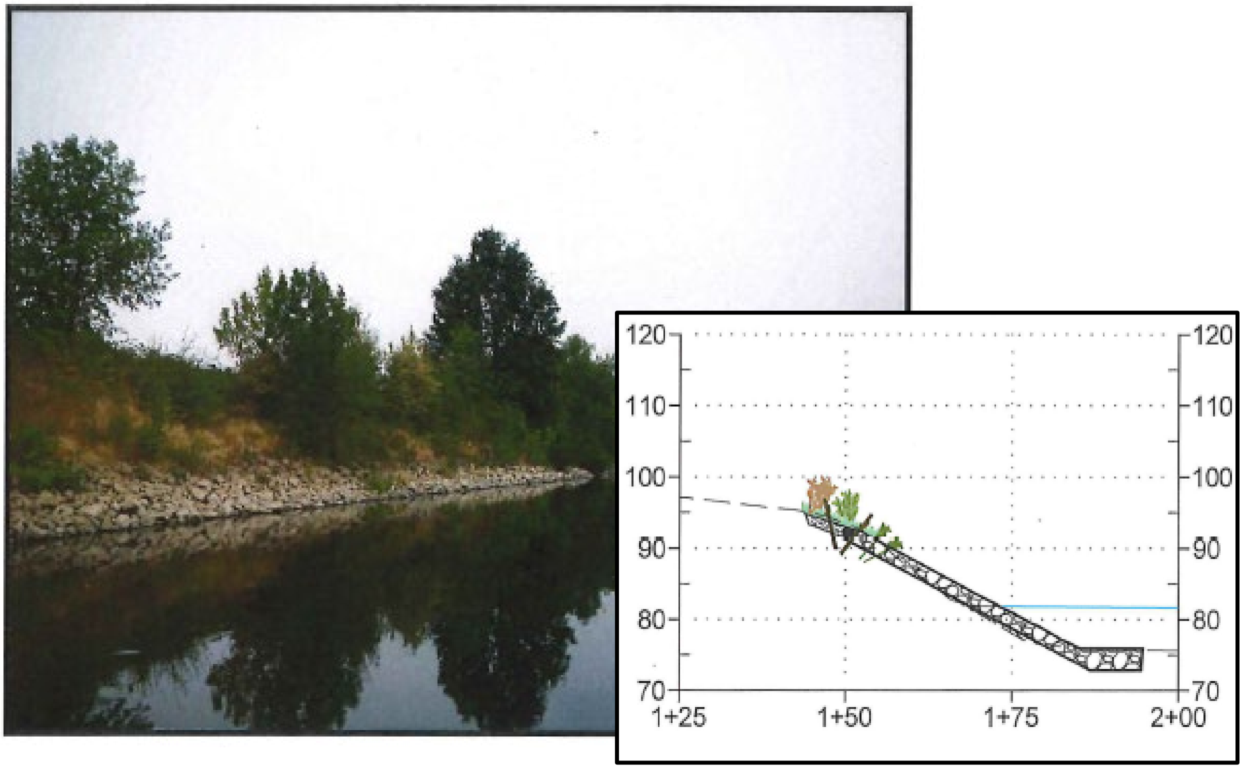

Figure 3.3-6. Example Willamette River Revetment north of Salem, Oregon, with Typical Cross Section.

USACE has frequently constructed two other types of hydraulic structures: levees and embankments. Levees are designed to protect an area from high flood waters and typically connect to high ground on either side. There would necessarily be a water surface elevation differential inside and outside of the levee during periods of high flow.

USACE has also constructed hydraulic embankments in some locations. These linear structures appear like levees but can be perforated with culverts or may not connect to high ground. Often, these structures increase channel flow capacity (as along the Long Tom River downstream of Fern Ridge Dam) but can be designed for other purposes.

Importantly, neither embankments nor revetments are designed to protect an area against flooding. In summary, levees mitigate flooding, revetments mitigate erosion, and embankments can increase channel capacity, redirect flow or serve other functions as necessary. There are projects that incorporate aspects of each into their design.

Revetments are most common in river reaches with the most historic channel migration, such as the McKenzie, upper mainstem Willamette, and South Santiam Rivers. Currently, about 26 percent of the banks of the mainstem Willamette between Eugene and Portland, Oregon have revetments. A substantial portion of the rest is geologically stable (e.g., bedrock canyon, banks made of compacted gravels resistant to erosion, etc.), so approximately 25 percent of the river is able to migrate freely through erodible soils, down from 80 percent in 1932 (Wallick et al. 2007).

Along with the lower water levels due to flood damage reduction operations, revetment projects can have the effect of partially restricting previously active floodplain interaction with the main channel. Riprap is typically placed on a slope with no associated embankment. Some revetments have placed earthen embankments or plugs where the existing bank is uneven in elevation or planform.

Typically, any embankment that is part of a revetment project only provides a consistent surface for facing with riprap and does not stop water from moving behind them like a levee. Riprap on the landward side of an embankment slope prevents erosion when floodwaters flow over the embankment into the floodplain. Where revetment projects with embankments isolate previously connected low areas, suspended sediments passing into the floodplain over the revetments would then fall out of suspension in the lower energy areas behind the structure and, over the course of years, fill in previously active areas with fine sediment.

Since revetments constrain lateral movement of the river, material in the banks is no longer available to be eroded and transported downstream as bed and suspended sediment load. The accumulated material is lost to the floodplain from the river as the revetments reduce bank erosion in the system.

3.3.1.3 Lower Willamette Basin

The Lower Willamette River below Willamette Falls at RM 26 is included in the analysis area. This section of the river is tidally influenced by the Columbia River and was analyzed in the Columbia River System Operations EIS (USACE et al. 2020).

3.3.1.4 Middle Willamette Basin

The Middle Willamette River, from Willamette Falls to the Santiam River confluence, is divided into two parts. The Willamette Falls backwater, commonly referred to as the Newberg Pool, extends up to about RM 50. The channel slope is about 1.2 feet/mile, and the water surface can be nearly flat during the summer, though high flows steepen the water surface profile somewhat. The river is confined by canyons and high terraces in some areas, and the geomorphic floodplain is narrow: generally, between 1,000 feet to 3,500 feet across.

The natural backwater associated with the Willamette Falls results in less energy available for channel movement. The Willamette River has few side channels and limited floodplain interaction downstream of RM 50.

Upstream of Newberg Pool, the river increases in slope slightly (1.8 feet/mile) but remains a very low gradient river. There are gravel bars with the material supplied by the Santiam River and occasional side channels, but the river is predominately a single-threaded channel. The river contains relatively steep banks, between 10 feet and 20 feet high. High flows are required for floodplain interaction. The river is geologically constrained in certain places – such as south of Salem, Oregon – but the geomorphic floodplain is generally wide in this stretch at 1 to 4 miles across. The furthest downstream WVS revetments are in this reach (Figure 1.7-1).

3.3.1.5 Upper Willamette Basin

Upstream of the sediment supply coming from the Santiam River, gravel bars are much less prevalent. The largely single-thread channel, up until the Corvallis, Oregon area, remains low gradient, (1.5 feet/mile), and the geomorphic floodplain is between 3,000 feet and 3.5 miles. The river channel is relatively stable due to geographic constraints. Fewer revetments were constructed in this reach than upstream, primarily due to the natural stability of the reach (Figure 1.7-1).

Upstream of Corvallis is the most active and varied portion of the mainstem Willamette River. Previous work has described this area as a “wandering gravel-bed river” (Wallick et al. 2007). The overall channel slope steepens considerably to 4 to 5 feet/mile, and the channel is unconstrained by geography like it is downstream. This is the widest geomorphic floodplain in the mainstem Willamette River (upper, middle, and lower), at up to 5 miles.

Gravel bars are prevalent, and larger flows can sometimes realign the channel in a relatively short period of time. However, these events, called river avulsions, have decreased by about 70 percent in the 20th Century (Wallick et al. 2007). Figure 3.3-7 shows one such location south of Peoria, Oregon, comparing August 2005 and August 2006, where a flood in January 2006 cut off an existing meander, straightening the channel. This area of the mainstem has the greatest number and longest total length of revetments because the historic response to the Willamette River’s ability to wander was to construct revetments.

Figure 3.3-7. Willamette River Realignment before and after January 2006 Flood, South of Peoria, Oregon.

3.3.1.6 North Santiam Basin

The North Santiam River is the steepest reach downstream of any WVS project, with an average slope of 14 feet/mile, with the highest slopes as it approaches Big Cliff Dam. There are many secondary channels and gravel bars.

The North Santiam River is the source for much of the sediment in the mainstem Willamette River downstream of the confluence. Channel movement and avulsions (where a river channel shifts location) are relatively common in the North Santiam River as compared to other rivers in the WRB. The geomorphic floodplain is a still relatively narrow with widths between 3,500 feet to 1.5 miles due to bedrock and other hardened geologic features.

3.3.1.7 South Santiam Basin

The South and mainstem Santiam Rivers have wide geomorphic floodplains, up to 3 miles across. This is due to a combination of moderate overall channel grades – ranging from 4 to 6 feet/mile – and unconstrained geology. Historically, this would have resulted in an active channel, but most of the river is single thread currently due to the construction of revetments.

Vegetation has colonized previously active gravel bars, further hardening the modified morphology. Since the area surrounding the river channel is relatively flat across the floodplain, the inundated area can expand quickly once floodwaters overtop the riverbanks.

3.3.1.8 Long Tom Basin

The Long Tom River is lined with embankments along nearly its entire length downstream of Fern Ridge Reservoir to its confluence with the Willamette River. These embankments were designed so that the highly modified channel can pass the output from Fern Ridge Dam. There is limited interaction between the channel and its historic floodplain because of the embankments, but culverts in the embankments allow for regular inundation of floodplain regions.

The river was shortened from 36.5 miles to 23.6 miles by USACE between 1944 and 1951 with the intent of increasing channel capacity and, therefore, reducing flooding downstream of Fern Ridge Dam. A series of seven drop structures were also built with the intent to reduce channel velocity and decrease erosion, while still moving water downstream efficiently.

3.3.1.9 McKenzie Basin

Near the confluence with the mainstem Willamette River (north of Eugene, Oregon and south of Coburg, Oregon), the McKenzie River floodplain is up to 2 miles wide, but the channel is single thread due to modifications such as revetments and gravel mining along the banks. The floodplain is lower with respect to the channel than most other rivers in the WRB; inundation is possible at levels as low as the 50 percent annual exceedance probability flow (commonly referred to as the 2-year flood).

The McKenzie River steepens upstream of Hayden Bridge (about RM 10, upstream of the confluence with the Mohawk River) to 10 feet/mile, with the geomorphic floodplain narrowing, intermittent multithread sections, and increasing prevalence of gravel bars. Further upstream, near Blue River and Cougar Dams, the river is increasingly single thread in a canyon, and the banks are generally forested (Figure 3.3-8).

There is about 1.6 miles of river between Blue River Dam and the confluence with the McKenzie River. The channel is modified to accommodate the outlet works of the dam, but there are no revetments on Blue River (Figure 1.7-1).

Figure 3.3-8. Winter Drawdown on Cougar Reservoir.

3.3.1.10 Middle Fork Willamette Basin

The Middle Fork between the mainstem Willamette River and Dexter Reservoir has little inflow that is not controlled by the upstream WVS (Hills Creek, Lookout Point, Dexter, and Fall Creek Dams). The geomorphic floodplain is constrained by the foothills of the Cascade Mountains and is between 3,500 feet and 1.5 miles wide.

The proximity of the WVS reducing peak flow and sediment supply, and construction of revetments in the most mobile areas, means that the Middle Fork Willamette River is largely stable through this reach. Historic gravel bars were forested, further hardening the banks against movement.

There are about 7 RM of Fall Creek below the Fall Creek Dam. The geomorphic floodplain is confined by hills on each side and ranges from 1,000 feet to 4,000 feet across. Upstream of Little Fall Creek (RM 3), the effects of the reservoir predominate. The channel is oversized for its current reduced peak flows and lack of sediments. From Little Fall Creek to the confluence with the Middle Fork, there are a few side channels and more sediment as the two floodplains interact and merge.

3.3.1.11 Coast Fork Willamette Basin

Near the confluence with the Middle Fork of Willamette River to form the mainstem Willamette River, the Coast Fork has several secondary channels and swales. This area also has substantial developed areas and historic gravel mines.

Upstream of the Highway 58 bridge (RM 6), the geomorphic floodplain progressively narrows and is more confined by the hills up to the WVS (Cottage Grove and Dorena Dams). The channel is single thread for most of its length, modified with both revetments and channel capacity straightening through urbanized areas. Trees have stabilized most historic gravel bars.

END OF NEW TEXT INSERTED INTO APPENDIX C FROM DEIS SECTION 3.3

CHAPTER 1 - METHODOLOGY

1.1 OVERVIEW

The general approach for evaluating river mechanics response in the system was to leverage the period of record (POR) flow and stage output from the quantitative hydroregulation planning models (Appendix B, Hydrologic Processes Technical Information) across the study area as inputs to a suite of qualitative hydraulic and geomorphic metrics. Discrete metrics were developed for the storage projects as well as run-of-river reservoirs and free-flowing reaches as detailed in sections 1.3, Storage Project Metrics and 1.4, Run-of-River and Free-Flowing Reaches Metrics below. Metrics were limited to evaluating annualized effects across the period of record. Results by season are not presented, but seasonal variations in flow and reservoir storage were incorporated when calculating annualized values of metrics. In addition, because the metrics directly leveraged the hydroregulation planning models, they are subject to the baseline limitations and caveats of those models, including real-time management deviations, sub-daily variability resulting from power operations, and other irregular events such as equipment servicing, and fisheries demands (Appendix B, Hydrologic Processes Technical Information). The effects of projected climate change on river mechanics and geomorphology are also discussed.

DEIS APPENDIX C HAS BEEN MODIFIED TO INCLUDE THE FOLLOWING INFORMATION IN THE FEIS

The river mechanics and geomorphology analysis is intended to provide a basis for assessment of complex sediment and morphologic phenomena within the Willamette River Basin as they relate to modified operations of the WVS. The analysis and metrics described in this appendix are necessarily described as changes relative to the No-action Alternative, which is considered quantitatively equivalent to operations and conditions that created the Affected Environment for River Mechanics and Geomorphology.

Analyses in this appendix are intended to be referenced by affected resources within the WVS EIS. Since thresholds for affected resource effects related to river mechanics and geomorphology metrics vary by resource, changes from the No-action Alternative can be used as a qualitative indicator for degrees of effect anticipated for each related affected resource as is individually appropriate.

END NEW TEXT

1.2 ANALYSIS METRICS SUMMARY

Both quantitative and qualitative assessment methods were used to assess relative potential changes to river hydraulics, sediment supply and geomorphology for each EIS alternative. Five quantitatively informed, but qualitative metrics were developed to represent various physical characteristics and processes that could affect sediment processes in storage reservoirs, run-of-river reservoirs, and free-flowing reaches as enumerated below:

- Storage Project Metrics
  - Head-of-Reservoir Sediment Mobilization
  - Sediment Trap Efficiency
  - Shoreline Exposure
- Run-of-River and Free-Flowing Reach Metrics
  - Potential for Changes in Sediment Supply
  - Potential for Geomorphic Change

The analysis method for river mechanics and geomorphology is qualitative, driven by quantitative storage and flow metrics. Visible or measurable expected change to a field observer drives the analysis. The basis for the quantitative metrics and the resulting qualitative descriptions is the hydrology and HEC-ResSim outputs for each alternative, as compared to the NAA. There are four levels of magnitude of effects, three levels of duration and three levels of extents when comparing the NAA to the others as shown in Table 1-1 below.

Table 1-1. Evaluation Criteria for Potential Effects to River Mechanics and Geomorphology

Effect Magnitude	**Criteria**
None/Negligible	The resource area would not be affected, or changes would be either nondetectable or, if detected, would have effects that would be slight and localized. The area extent of effects would be small (limited) and would not require additional consideration or mitigation.
Minor	Changes to the resource would be measurable, although the changes would be small and localized. The duration of effects may vary.
Moderate	Changes to the resource would be measurable and have either localized or regional-scale effects.
Major	Changes would be readily measurable and would have substantial consequences on a local or regional level.
Effect Duration	**Criteria**
Short-term	Changes to river mechanics and/or geomorphology would last less than two years.
Medium-term	Changes to river mechanics and/or geomorphology would last between two and five years.
Long-term	Changes to river mechanics and/or geomorphology would last throughout the duration of the project (2050).
Effect Extents	**Criteria**
Local	Changes to river mechanics and/or geomorphology would be confined to the dam/reservoir or river.
Regional	Changes to river mechanics and/or geomorphology would be perceived throughout a single county, multiple counties, or the entire WVS.
State-wide	Changes to river mechanics and/or geomorphology would be perceived throughout the entire state.

As an example, a newly implemented deep fall drawdown of a reservoir would likely result in a major effect as it alters the accumulation point of coarse sediments and exposes more shoreline and lake-bottom fine sediments to potential movement. The deep fall drawdown operation would be in effect through the project life and, therefore, long-term in duration. Effects within the reservoir would be local to the reservoir. A smaller alteration in the rule curve, such as refill at a later calendar date, would likely be negligible or minor effects, long-term in duration and local to the reservoir.

There are no new hydraulic or sediment models (e.g., HEC-RAS) run as part of the analysis. Existing hydraulic models inform the professional engineering judgment wrapped into the qualitative levels of change listed above. Furthermore, the measures under consideration are primarily about operational changes outside of the major flood season.

1.3 STORAGE PROJECT METRICS

Three storage project metrics were developed to investigate potential for changes in sediment processes at the eleven WVS storage projects in the study area (Blue River, Cottage Grove, Cougar, Detroit, Dorena, Fall Creek, Fern Ridge, Foster, Green Peter, Hills Creek, Lookout Point). Development and impact threshold determination for the storage project metrics is described in this section.

1.3.1 Shoreline Exposure

Shoreline erosion of bank sediments along reservoir margins is a complex process that is influenced by the cumulative effects of: wind and boat wave erosion, reservoir currents, precipitation runoff, freeze-thaw, soil properties, exposure, and vegetation density and type. One commonly observed process is that, during times of extended reservoir drawdown, exposed un-vegetated shoreline soils that were previously saturated are prone to erosion and localized slope failures (slumping). The shoreline exposure metric was developed as a surrogate for shoreline erosion processes. This metric compares the number of days that the reservoir water surface spends at any elevation to identify change in shoreline exposure and indicate the potential for change in shoreline erosion in the WVS storage projects. Shoreline processes leave long-term marks on the land, reworking soils and exposing underlying layers.

The simplest metric is a reservoir elevation exceedance percentage analysis. Comparison of the reservoir elevation exceedance percentage between alternatives would demonstrate the range of reservoir operations. If the range and duration of the reservoir elevations changes, there is a potential that the shoreline erosion rates, or patterns, may change. While the shoreline exposure metric does not directly consider reservoir draft rate, it does represent the duration effects that could result from draft rate operational measures.

Shoreline exposure effects may vary in magnitude, but would be long-term, as long as the alternative operation set remains in effect, and local to the reservoir where the draft is occurring.

1.3.1.1 Shoreline Exposure Metric

Elevation-duration curves used in this metric are developed from daily average data extracted from the POR hydroregulation operations model. The curves are integrated to calculate an average and are compared with the No Action Alternative using the following formula:

$$AVE_{alt} – AVE_{na}$$

Where:

AVE_{alt} is the average reservoir elevation of the alternative being analyzed
AVE_{na} is the average reservoir elevation of the No Action Alternative

1.3.1.2 Shoreline Exposure Impact Thresholds

Average differences less than ±5 feet are likely not discernable within the reservoir due to sub-daily power fluctuation and other processes such as waves, which occur within a similar range. A ±5- to ±10-foot difference is estimated to be the threshold when shoreline effects would be observable on the landscape and are considered small changes in shoreline exposure. Differences greater than ±10 feet would be observable and would result in moderate change in shoreline exposure. A difference greater than ±20 feet or a modification in the operational range of the project would produce large changes in shoreline exposure with shoreline becoming submerged or exposed more often (Table 1-2).

Table 1-2. Magnitude of Effects: Shoreline Exposure

Shoreline Exposure Change	Impact Threshold
$\lvert\Delta x\rvert < 5$ feet	Negligible Effect
5 feet < $\lvert\Delta x\rvert$ < 10 feet	Minor Effect
10 feet < $\lvert\Delta x\rvert$ < 20 feet	Moderate Effect
$\lvert\Delta x\rvert > 20$ feet or Change in Operational Range	Major Effect

1.3.2 Head-of-Reservoir Sediment Mobilization

The head-of-reservoir sediment mobilization metric is designed to indicate the potential for changes in sediment scour and deposition patterns in the most upstream portion of storage reservoirs. In dams that use large amounts of storage volume and operate over a wide range of elevations throughout the year, the transition from riverine to reservoir conditions can shift upstream and downstream considerable distances. If reservoir drawdown leaves the delta exposed during high-flow periods, the upper layers of delta would be eroded and transported further into the reservoir, potentially increasing turbidity within the reservoir and thickness of lakebed deposits. Changes in storage project elevations or changes to the flow of water and sediment into the reservoir can result in changes to the head-of-reservoir erosion and deposition patterns. This metric compares the paired relationships of flow and stage over time to indicate the potential for change in sediment mobilization at the head-of-reservoir for each alternative. Changes in delta sediment mobilization could alter the sediment load farther downstream within the reservoir and potentially the amount of sediment passing a dam, particularly during high-flow periods.

Head-of-reservoir sediment mobilization effects may vary in magnitude, but would be long-term under all of the alternatives, and local to the reservoir where the change in the metric would occur.

1.3.2.1 Sediment Transport Potential Calculation

Frequently, Lane's Balance is used to analyze the qualitative relationship between sediment transport rates (Q_s), bed material size (d_{50}), flow (Q), and water surface slope (S). It can be written as:

$$Q_s d_{50} \sim QS$$

Where the symbol ~ is generally taken to mean "is related to." A similar relationship can be derived from principles proposed in Henderson 1966 and used in Schmidt and Wilcock 2008 to analyze the effect of dams:

$$\frac{q_s}{{d_{50}}^{1.5}} \propto \left(\frac{\tau}{d_{50}}\right)^3$$

Where τ is the bed shear stress and the symbol $\propto$ means "is proportional to." Using Manning's equation, flow continuity, and assuming bed material size is fixed, the relationship can be rewritten as:

$$q_s \propto q^{1.8} S^{2.1}$$

In the riverine reaches, the river slope would be essentially unaffected by reservoir operations, but in the reservoir reaches, the slope increases when the reservoir elevation is low. The metric assumes the slope in the reservoir reach at any given day is the ratio of reservoir drawdown relative to full pool (ΔH) to the length of reservoir (L). The transport indicator variable can be written as:

$$Q_s \propto Q^{1.8} \left(\frac{\Delta H}{L}\right)^{2.1}$$

The value of ΔH is assumed to vary according to the daily average reservoir elevation, but the length (L) is assumed to be constant and equal to the length of the full pool. The analysis is limited to comparing the relative value of this indicator between alternatives, and therefore the value of L would not change the alternative comparison. The metric is not intended to provide a comparison between reservoirs. A sediment transport duration curve could be constructed from this equation. An indicator of changes to sediment transport in the upper portion of the reservoirs is, therefore, the change to Q_S. A schematic of various reservoir pool elevation and the upper portion of the reservoir is given in Figure 1-1.

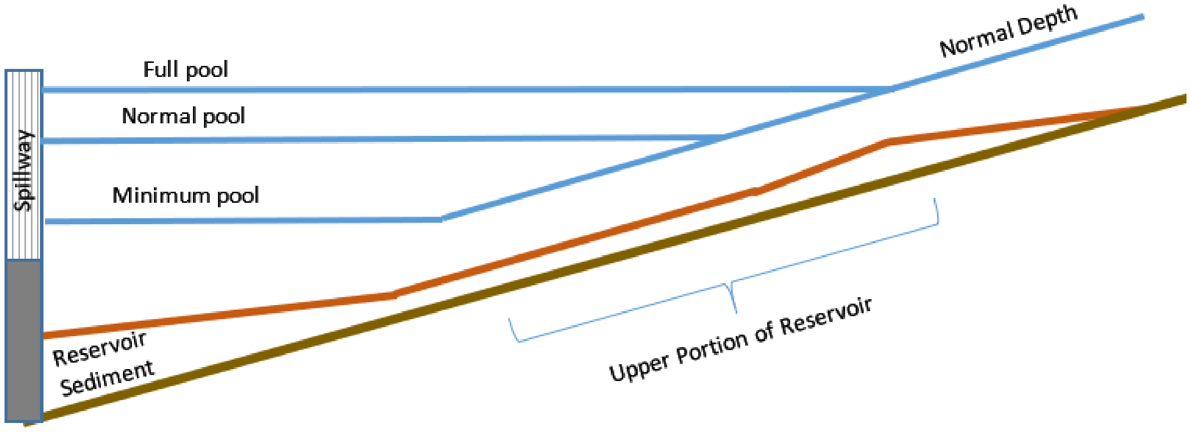

Figure 1-1. Schematic Showing Definition of Reservoir Pools and Idealized Sediment Deposit

1.3.2.2 Head-of-Reservoir Metric

Sediment transport duration curves used in this metric are developed from daily average data extracted from the 84-year period of record reservoir operation model. Curves were developed for each of the major tributaries to the WVS storage projects. The curves are integrated to calculate an average that is compared with the No Action Alternative using the following formula for each reservoir.

$$\frac{\overline{Qs}alt}{\overline{Qs}NA} - 1$$

Where:

$\overline{Qs}alt$ is the average of the sediment transport duration curve of the alternative being analyzed.

$\overline{Qs}NA$ is the average of the sediment transport duration curve of the No Action Alternative.

The metric calculates a percent change in sediment transport potential relative to the No Action Alternative due to changes in paired inflow and reservoir elevation. Without a change in reservoir operational range, the ultimate erosion and deposition patterns of head-of-reservoir bed materials is likely unchanged between alternatives and would be related to the lowest drawdown elevation at the reservoir. Change identified by this metric may only be temporary in nature as sediment deposits can be remobilized when the reservoir elevation drops in subsequent seasons or years.

1.3.2.3 Head-of-Reservoir Impact Thresholds

A less than 10 percent change in sediment transport potential at the head-of-reservoir is considered likely unmeasurable with any confidence and negligible. A 10 percent to 50 percent increase or decrease would be a measurable but small change. A 100 percent or greater change in sediment transport potential would be considered a large change at the head-of-reservoir (Table 1-3).

Table 1-3. Magnitude of Effects: Head of Reservoir Sediment Mobilization

Sediment Transport Potential Change	Impact Threshold
$\lvert\Delta x\rvert$ <10%	Negligible Effect
10% < $\lvert\Delta x\rvert$ <50%	Minor Effect
50% < $\lvert\Delta x\rvert$ <100%	Moderate Effect
$\lvert\Delta x\rvert$ >100%	Major Effect

1.3.3 Sediment Trap Efficiency

The sediment trap efficiency metric estimates the potential for changes in the amount of sediment that can deposit within or pass through the storage reservoirs. Trap efficiency is the proportion of inflowing sediment deposited in the reservoir relative to the total incoming sediment load. The trap efficiency is computed based on the ratio of reservoir storage volume to annual inflow. Because the volume of water stored at any given time in the storage projects can vary between alternatives, there is potential for the amount of material being deposited in the reservoir to change between alternatives. This metric compares the paired relationship of flow and reservoir storage to indicate the potential for changes in the amount of sediment being trapped by the storage projects for each action alternative relative to the NAA. The actual amount of sediment trapped is dependent not only on trap efficiency but also the incoming sediment load.

Sediment trap efficiency effects may vary in magnitude, but would be long-term under all of the alternatives, and local to the reservoir where the change in the metric would occur. Indirect effects of sediment being transported downstream of a dam are expressed in the run-of-river reservoir and free-flowing reach metric - potential changes in sediment supply.

1.3.3.1 Sediment Trap Efficiency Calculation

The Brune Curve (Brune 1953) is an empirical function used to determine the fraction of sediment trapped within a reservoir and is a function of the reservoir volume and incoming flow (Figure 1-2). The ratio is computed for each day of the 84- year operation model outputs (annual hydrographs). Then, a duration curve is constructed. Changes to the estimated trap efficiency would indicate changes to the amount of sediment that originates in the watershed and is transported into the reservoir by flowing rivers is stored in the reservoir. This can also be viewed as changes in the amount of sediment that moved through the reservoir. The lower the trap efficiency, the less sediment that would be stored in the reservoir and the more sediment that would pass through the reservoir.

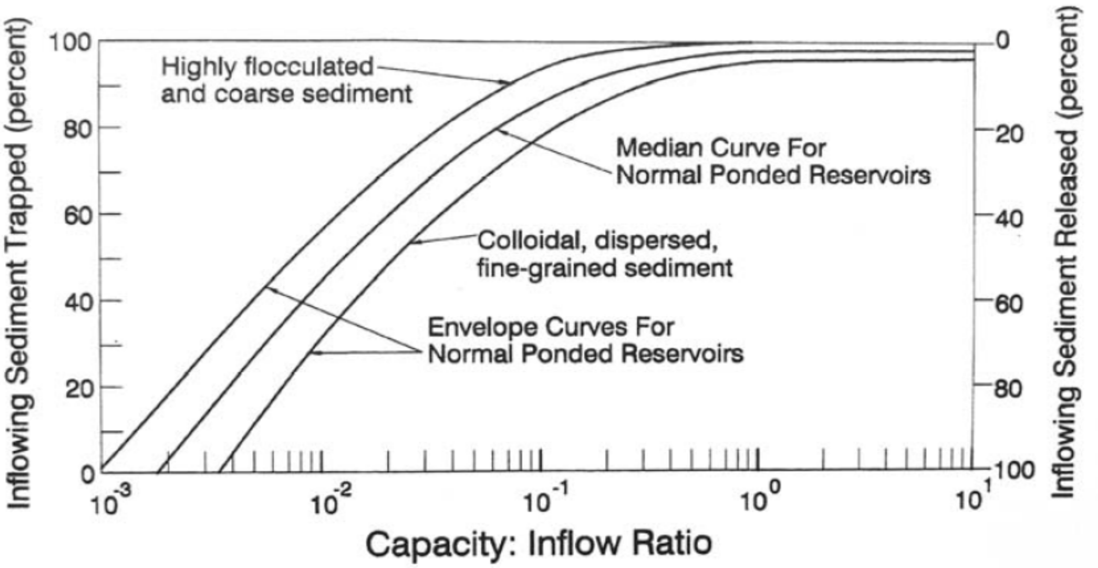

Figure 1-2. Brune Curve Used in Alternative Assessment for Trap Efficiency

Source: Adapted from Brune 1953

Reservoir sedimentation and loss of storage capacity has been historically assumed to be small such that it does not affect operations. Repeat surveys of a subset of the WVS storage projects shows that this assumption is accurate. The 2017 Lookout Point water control manual provides a good summary of the sedimentation study history and system design assumptions:

> The Portland District conducted a sediment sampling program in the Willamette River Basin from 1 December 1948 to 1 July 1951, for the purpose of obtaining factual data on sedimentation rates and bedload movement in this area. As a result of this investigation, it was found that suspended sediment rates and bed-load movement is comparatively low in Willamette River Basin streams. Consequently, loss of reservoir storage in existing reservoirs was estimated as small and would not materially affect storage capacities during the 50-year economic life of these projects (USACE 2015a).

USACE has performed a limited resurvey of WVS reservoirs since the original sedimentation transects were established. Where repeat surveys exist, data support the low overall sediment yield design assumptions. Lookout Point Reservoir was surveyed in 1956 and 2014. Updated rating curves show a 1.0 percent loss in storage capacity below maximum pool with all of the total loss occurring below minimum flood pool. Dorena Reservoir was surveyed in 1953 and 2017. Updated rating curves show a 4.8 percent loss in storage capacity below maximum pool with approximately half of this loss occurring below minimum flood pool. Fern Ridge Reservoir was surveyed in 1947 and 1993. Reporting identifies a 3.8 percent loss in storage capacity below maximum conservation pool with 80 percent of the loss in storage capacity occurring in the lower half of the pool. Loss of storage capacity is not a metric utilized for analyses of alternative conditions because loss of storage capacity is not expected to impact operations in the analysis period.

1.3.3.2 Sediment Trap Efficiency Metric (Fine-Grained Sediment Only)

Trap efficiency-duration curves used in this metric are developed from daily average data extracted from the POR reservoir operation model. The curves are integrated to calculate an average that is compared with the No Action Alternative using the following formula. The metric estimates a percent change in the amount of sediment stored in the project.

Where:

$$\frac{1-\overline{TE}alt}{1-\overline{TE}na}-1$$

$\overline{TE}alt$ is the average trap efficiency of the alternative being analyzed
$\overline{TE}na$ is the average trap efficiency of the No Action Alternative

1.3.3.3 Sediment Trap Efficiency Impact Thresholds

A less than 10 percent change in sediment passing a project is considered likely unmeasurable with any confidence and negligible. A 10 percent to 50 percent increase or decrease would be a measurable but small change. A 100 percent or greater change in sediment passing a project would be considered large change in trapping efficiency. With high trapping efficiencies in most of the WVS projects, a change in sediment passing (such as doubling) may only increase the depositional rate by a few percentage points (Table 1-2).

Table 1-4. Magnitude of Effects: Sediment Trap Efficiency

Sediment Trap Efficiency Change	Impact Threshold
$\lvert\Delta x\rvert$ <10%	Negligible Effect
10% < $\lvert\Delta x\rvert$ <50%	Minor Effect
50% < $\lvert\Delta x\rvert$ <100%	Moderate Effect
$\lvert\Delta x\rvert$ >100%	Major Effect

1.4 RUN-OF-RIVER RESERVOIRS AND FREE-FLOWING REACHES METRICS

Run-of-river reservoirs and free-flowing reaches include all the river reaches downstream of WVS storage projects. Run-of-river reservoirs are formed by dams that are operated to discharge water downstream at rates that generally match the upstream inflows. Big Cliff, and Dexter dams are run-of-river projects that operate in a small range of pool elevations for daily or weekly hydropower purposes but do not attempt to store water for release in later seasons. Foster Dam is considered both a storage and a run-of-river project in this analysis as it is partially operated to re-regulate the outflows from Green Peter. Free-flowing reaches are portions of the river downstream of WVS storage reservoirs that are not influenced by the backwater of a downstream reservoir. The run-of-river and free-flowing reach metrics are necessarily qualitative due to a lack of continuous bed material sediment data or lack of continuous and integrated hydraulic modeling.

1.4.1 Potential for Changes in Sediment Supply

This metric estimates the potential for changes in sediment passing WVS projects relative to NAA. This can occur when WVS storage projects experience large changes in sediment trapping efficiency. This can also occur where there is a change in operational range of the WVS reservoirs that can potentially re-entrain sediment currently stored in the reservoir or induce slope failures and introduce new sediment to the system. This metric also addresses the gravel augmentation below dams (#384) measure where sediment supply would be actively augmented.

The sediment supply analysis assumes that sediment supply from rivers upstream of WVS projects, or tributaries to WVS impacted reaches that are not downstream of a WVS reservoir, would be unchanged relative to the NAA.

The sediment trap efficiency metric integrates coincident daily reservoir inflow with storage to estimate trapping efficiency. This calculation focuses on sediment delivered to the reservoir from the basin with the sediment load assumed to be correlated to inflow. Decreases in sediment trapping efficiency indicate that the reservoir has the potential to deliver more sediment downstream and is considered in the potential for change in sediment supply metric assessing potential variations among alternatives. This transfer of basin supplied sediment to downstream reaches due to decreased reservoir trapping efficiency is an indirect, long term, effect.

A separate potential source of sediment to the reservoir and downstream reaches can come from bank erosion or bank failures within the reservoir itself. Drafts deeper than those historically experienced have the potential to re-suspend stored sediments or induce landslides (USACE 2003) introducing new sediment to the reservoir. The timing of these deep drawdowns is not correlated to reservoir inflow and are not fully captured in the sediment trap efficiency metric.

Deep drafts, particularly drafts deeper than historical operating conditions, are assumed to increase the potential for sediment re-entrainment (re-suspending sediment that has previously been transported and stored) supplying additional suspended sediment to the reservoir. Whether this sediment would resettle within the reservoir or pass downstream would depend on sediment particle size and hydraulics within the reservoir. Lacking detailed data for both factors, reduction in minimum pool storage relative to the NAA, which is coincident with drafts, is used to indicate if there is an expected variation in potential for sediment to pass a reservoir among alternatives. Increase in sediment supply due to deep drafts is expected to be greatest during the first draw down. The reservoir supplied sediment increase is expected to decrease toward the affected environment condition over the course of one to several years as the system equilibrates to the new operating range. Any subsequent changes in operational range, where the reservoir is drafted deeper than it has historically operated, will have the potential to increase sediment supply from the reservoir once again resetting the timeframe for return to affected environment conditions. Variation in sediment supply from the reservoir to downstream reaches due to deeper drafts are indirect, short to medium term impacts.

Sediment augmentation though spawning gravel nourishment or geomorphic process-based sediment nourishment below target WVS projects in included in the gravel augmentation below dams (#384) measure. A direct introduction of bed material to the system would change sediment supply in a known and controlled manner. Gravel augmentation is a direct, long-term impact to sediment supply.

1.4.1.1 Sediment Coming Out of Storage Reservoirs

Reservoir sediment release metrics are described in this section.

1.4.1.1.1 Watershed Supplied Sediment

Sediment Trap Efficiency Metric (1.3.2) is used directly to indicate potential for fine suspended sediment entering the reservoir during higher flows to pass the reservoir into downstream run-of-river reservoirs and free-flowing reaches. Decreases in the Trapping Efficiency Metric indicate increased potential for suspended sediment supply below the dam. The qualitative metric is directly applied in the sediment supply and expressed as: $qualitative\ TEmetric$

1.4.1.1.2 Reservoir Supplied Sediment

Changes in operational range, calculated from the Inactive Pool Elevation entered into each ResSim alternative, is used to indicate changes in sediment supply internal to the reservoir. Wind-wave erosion on stored fines and rarely exposed banks as well as mainstem and tributary erosion into stored sediments are drivers for changes in sediment supply internal to the reservoir. Deeper drawdowns relative to NAA ($MinPool\ \Delta\mathrm{x}$) indicate higher potential for increased sediment supply.

Table 1-5. Sediment Re-Entrainment or Bank Failure Potential

Minimum Pool Elevation Reduction from NAA	Sediment Re-Entrainment or Bank Failure Potential
Δx < 5 feet	Negligible
5 feet < Δx < 10 feet	Minor
10 feet < Δx < 20 feet	Moderate
Δx > 20 feet	Major

This sediment supply potential is then qualified by the percent reduction in minimum pool storage relative to NAA ($MinPool\ \Delta\mathrm{v}$). Reduction in minimum pool storage volume increases the potential for sediment to pass the reservoir and move downstream during drawdown.

Table 1-6. Reservoir Bank Sediment Passing Dam Potential

Minimum Pool Storage Volume Reduction from NAA	Bank Sediment Passing Dam Potential
Δv < 10%	Negligible
10% < Δv < 25%	Minor
25% < Δv < 75%	Moderate
Δv > 75%%	Major

The reservoir bank supplied sediment component of the Sediment Supply Metric, expressed as $BSSmetric$, is the lesser of the qualitative assessment for $(MinPool\ \Delta\mathrm{x})$ and $(MinPool\ \Delta\mathrm{v})$ for each alternative. For example, a drawdown 25 feet deeper than NAA has a major potential for increasing local sediment supply, but if the minimum storage volume only decreases by 5% relative to NAA, there would be negligible potential for that sediment to pass the reservoir.

$$qualitative\ BSSmetric = the\ qualitative\ lesser\ of\ (MinPool\ \Delta\mathrm{x})\ \text{and}\ (MinPool\ \Delta\mathrm{v})$$

1.4.1.2 Sediment Augmentation

Any direct sediment augmentation is considered a major impact as it would be readily observable and performed with the intention of creating or modifying the trajectory of geomorphic features and habitat.

1.4.1.3 Sediment Transfer Between Reaches

Sediment coming from a WVS storage project or directly from a sediment augmentation effort would originate from a point source, typically at the upstream end of an impact assessment reach. In most cases, the downstream end of an impact reach is at a confluence which is the upstream end of the next impact reach. Sediment, particularly very fine suspended sediment, may transfer downstream into the next reach. A particularly complicated version of this is the Middle Fork of the Willamette where the Hills Creek storage project flows into a free-flowing segment fork the Middle Fork, then into the Lookout Point storage project, then into the run-of-river Dexter re-regulation dam and then again into the free-flowing Middle fork where confluences with the regulated Fall Creek and Coast Fork of the Willamette may bring changed sediment loads from upstream regulation. Changes in operations may impact the transfer of sediment between all segments. Absent hydraulic models and integrated bed and bank material classification as well as details on upstream sediment loading, the analysis of sediment transfer between reaches is necessarily qualitative.

This analysis assumes that run-of-river projects can successfully trap all coarse sediments delivered and a portion of the suspended sediment entering from upstream. Sediment transfer is assumed to occur, but concentrations are assumed to be reduced. This qualitative assessment reduces the level of impact by one level when moving from upstream or a run-of-river project to a downstream reach (meaning a major sediment load input into a run-of-river reservoir would result in a moderate sediment output into the downstream reach).

For successive free-flowing river segments, such as the Middle Fork of the Willamette flowing into the Upper Willamette at the Coast Fork Confluence, it is assumed that some sediment dispersion and deposition would occur within the reach and lower sediment concentrations would transport into the downstream reach. Each downstream reach would have a successively lower sediment supply qualitative impact until negligible change is assumed in the system. For example, if the Middle Fork of the Willamette below Dexter has minor potential for change in sediment supply at its upstream end, it would be assumed that there is negligible changes in sediment supply relative to NAA at the transfer to the Upper Willamette. In this scenario, if the Coast fork had moderate potential for change in sediment supply, the downstream Upper Willamette would have a minor change caused by sediments entering from the Coast Fork.

1.4.1.4 Sediment Supply Impact Thresholds

Sediment Supply impact thresholds are a combination of reservoir passage potential for watershed supplied ($qualitative\, TEmetric$), reservoir supplied sediment ($qualitative\, BSSmetric$) and direct sediment augmentation. The total Sediment Supply Metric ($SedSupply$) for reaches below WVS storage project is the greater of the qualitative $qualitative\ TEmetric$ and $qualitative\ BSSmetric$ metrics. Any direct sediment augmentation is a Major Effect:

$$SedSupply = the\, qualitative\ greater\ of\ \ (qualitative\, TEmetric) \text{ and } (qualitative\ BSSmetric)$$

Table 1-7. Magnitude of Effects: Sediment Supply

Sediment Supply	Impact Threshold
($SedSupply$) = Negligible	Negligible Effect
($SedSupply$) = Minor	Minor Effect
($SedSupply$) = Moderate	Moderate Effect
($SedSupply$) = Major or Sediment Augmentation	Major Effect

For successive Run-of-River reservoir and Free-Flowing reaches, the level of impact is assumed to be reduce by one level for each reach segment due to fine suspended sediment dispersion and deposition. The exception to this is major changes due to sediment augmentation programs. It is assumed that placed sediment would be screened of fines and would only transport as bed load. This placed sediment is assumed to be deposited and stored within the reach where it is placed unless noted otherwise.

1.4.2 Potential for Geomorphic Change

This metric estimates the potential for changes in river character due to operations proposed by the action alternatives. System-wide morphological change as compared to the NAA would be dependent on changes to flood flow frequency, changes to bank stabilization, or changes in sediment supply. There are no measures or suites of measures that would change flood flow frequency proposed under any action alternative. Therefore, morphologic changes or processes that are driven by high flows would be unchanged from the NAA.

Under Measure 9, revetments considering nature-based engineering would be retained or revetments would be modified for aquatic ecosystem restoration. Alternatives incorporating Measure 9 would result in local habitat changes as compared to the NAA; however, the river stabilization purposes, and geomorphic trajectory of these revetments would be unchanged.

Alternatives that incorporate Measure 9 would include opportunities for USACE partnerships with non-federal sponsors to study and work through processes for substantial modifications. These projects would be brought under the Continuing Authority Program Section 1135 and would require analysis and compliance actions consistent with the authority.

While there is opportunity for localized or potentially larger geomorphologic effects due to revetment modifications, locations and scales are unknown at this time and would be analyzed for effects in future site-specific analyses. Other actions that could impact geomorphic trends are those that change sediment supply to the system. Potential for geomorphic change effects may vary in magnitude but would be long-term as geomorphic effects manifest over long periods of time and persist beyond immediate action. Potential for geomorphic change as compared to the NAA would be local to regional with change in sediment supply effecting both the immediate reach below a WVS dam and downstream reaches. Potential for geomorphic change due to changes in system operations would be indirect effects, while gravel augmentation below dams) would be direct (Measure 384).

1.4.2.1 Potential for Geomorphic Change Metric

The Sediment Supply Metric ($SedSupply$) would be utilized to indicate if there is potential for geomorphic change in run-of-river reservoirs or free flowing reaches. Minor and Moderate Sediment Supply changes may impact water quality, however potential changes of that order are not expected to change the morphological character of the river. Only Major changes to Sediment Supply are assumed to be capable of inducing Geomorphic Change.

1.4.2.2 Geomorphic Change Impact Thresholds

Table 1-8. Magnitude of Effects: Geomorphic Change

Sediment Supply	Impact Threshold
($SedSupply$) = Negligible, Minor, Moderate	Negligible Effect
($SedSupply$) = Major	Major Effect

1.5 CLIMATE CHANGE

Appendix F1, Willamette Basin Climate Change Qualitative Assessment, and Appendix F2, Supplemental Climate Change Information describe projected climate change trends likely to be experienced in the WVS under the alternatives. The supplemental appendix also identifies relevant climate factors or hydrology and climate variables that may change and have a consequential impact to the PEIS resource areas. The climate change factors of most importance to the hydraulics resource area are projected future changes in precipitation (rainfall and snow), rates of peak and average streamflow, snowpack and flow volumes, and wildfire intensity/frequency.

There is a causal relationship between wildfires and increased sediment supply observed in the Pacific Northwest and elsewhere. The dominant processes for increased supply in the Pacific Northwest are dry ravel in the short-term following fire and hillslope failure with associated debris flows in the longer-term (Alden Research Laboratory Inc. 2021). Ravel occurs when wildfires disturb or eliminate vegetation and other organic structures that hold loose material on steep slopes. This material can lead to debris flows during the wet season in the Pacific Northwest as material collected in valley and channel bottoms is moved downstream during high peak flow events. Hillslope failure is exacerbated in the years post wildfire by the loss of shear strength in the soils as tree roots decay, typically 5-10 years post-fire (Wondzell and King 2003). Surface erosion and shallow channels cut into the soil by the erosive action of flowing water (rilling) during direct runoff in a minor factor in sediment supply changes in the Pacific Northwest due to low rainfall intensity and high infiltration rates (Alden Research Laboratory Inc. 2021). Increases in annual very high fire danger days are assumed to be directly related to an increase in acres burned by severe forest fires, and therefore, an increase in basin sediment supply, particularly in portions of the basin with steeper topography because steep slopes foster sediment transport into water systems.

Sediment transport and many geomorphic processes associated with river and streams are dominated by high flows and associated high energies in the river. Changes in peak flows or changes in the duration of high flow can both increase the sediment transport capability of a river and increase the potential for larger scale geomorphic change (such as bar growth, bank erosion or avulsions). It is assumed that higher peak flows or longer durations of high flow are correlated to increases in sediment transport and geomorphic change. However, flood storage projects that can trap sediment and regulate peak flood flows in the WRB are expected to mitigate for potential sediment loading. Unregulated rivers would more directly support increases in potential sediment supply, transport and geomorphic changes associated with climate change.

These climate change factors as well as the climate change analysis performed in the section 3.2, Hydrologic Processes, were used to qualitatively assess the expected effects to the system under NAA and all action alternatives.

CHAPTER 2 - ALTERNATIVE COMPARISON SUMMARIES

2.1 STORAGE PROJECT METRICS

This section includes tables and figures that enumerate the storage project comparison summaries for three metrics (Table 2-1 – Table 2-6; Figure 2-1 – Figure 2-33):

- Head-of-Reservoir Sediment Mobilization
- Sediment Trap Efficiency
- Shoreline Exposure

Table 2-1. Storage Metrics – Head-of-Reservoir Quantitative Analysis

Project	Alt 1 vs. NAA	Alt 2A vs. NAA	Alt 2B vs. NAA	Alt 3A vs. NAA	Alt 3B vs. NAA	Alt 4 vs. NAA	Alt 5 vs. NAA	NTOM vs. NAA
Blue River	-0.4%	0.7%	1.5%	23.1%	23.1%	0.8%	1.8%	-0.1%
Cottage Grove	0.4%	0.9%	0.1%	0.9%	2.2%	2.2%	0.3%	2.3%
Cougar	1.6%	-0.7%	496.6%	163.4%	499.3%	-0.8%	617.3%	30.7%
Detroit	-3.0%	-2.2%	-1.8%	391.2%	113.5%	-2.3%	-1.7%	-1.7%
Dorena	-0.5%	0.4%	0.4%	-0.7%	1.4%	2.3%	0.4%	0.7%
Fall Creek	-2.2%	-1.1%	-1.4%	-2.4%	0.6%	-0.9%	-0.9%	125.3%
Fern Ridge	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Foster	2.4%	-20.5%	-20.5%	-20.8%	-11.2%	-2.6%	-20.7%	2.7%
Green Peter	-2.0%	337.3%	337.3%	336.4%	621.8%	1.6%	339.8%	338.2%
Hills Creek	-0.6%	5.0%	5.0%	28.5%	145.8%	4.7%	9.0%	20.2%
Lookout Point	2.3%	2.1%	2.3%	312.3%	122.3%	1.9%	2.3%	159.2%

Table 2-2. Storage Metrics – Head-of-Reservoir Qualitative Analysis

Project	Alt 1 vs. NAA	Alt 2A vs. NAA	Alt 2B vs. NAA	Alt 3A vs. NAA	Alt 3B vs. NAA	Alt 4 vs. NAA	Alt 5 vs. NAA	NTOM vs. NAA
Blue River	Negligible	Negligible	Negligible	**Minor**	**Minor**	Negligible	Negligible	Negligible
Cottage Grove	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible
Cougar	Negligible	Negligible	**Major**	**Major**	**Major**	Negligible	**Major**	**Minor**
Detroit	Negligible	Negligible	Negligible	**Major**	**Major**	Negligible	Negligible	Negligible
Dorena	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible
Fall Creek	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	**Major**
Fern Ridge	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible
Foster	Negligible	**Minor**	**Minor**	**Minor**	**Minor**	Negligible	**Minor**	Negligible
Green Peter	Negligible	**Major**	**Major**	**Major**	**Major**	Negligible	**Major**	**Major**
Hills Creek	Negligible	Negligible	Negligible	**Minor**	**Major**	Negligible	Negligible	**Minor**
Lookout Point	Negligible	Negligible	Negligible	**Major**	**Major**	Negligible	Negligible	**Major**

Table 2-3. Storage Metrics – Trap Efficiency Quantitative Analysis

Project	NAA Trap Eff	Alt 1 Trap Eff	Alt 1 vs. NAA	Alt 2A Trap Eff	Alt 2A vs. NAA	Alt 2B Trap Eff	Alt 2B vs. NAA	Alt 3A Trap Eff	Alt 3A vs. NAA	Alt 3B Trap Eff	Alt 3B vs. NAA
Blue River	81.4	81.5	-0.5%	81.0	2.1%	80.9	2.4%	79.2	11.7%	79.2	11.7%
Cottage Grove	81.0	80.9	0.4%	81.0	-0.2%	81.1	-0.3%	80.3	3.7%	79.9	5.7%
Cougar	90.6	90.7	-1.6%	90.7	-1.2%	47.9	453.6%	84.8	61.5%	47.8	454.0%
Detroit	91.1	91.2	-1.5%	91.2	-1.0%	91.2	-0.9%	79.2	133.6%	88.8	25.8%
Dorena	80.7	80.9	-0.5%	80.8	-0.5%	80.8	-0.4%	80.4	1.9%	80.0	4.1%
Fall Creek	81.8	82.0	-1.1%	81.8	0.0%	81.9	-0.4%	81.8	-0.2%	81.7	0.3%
Fern Ridge	80.2	80.2	0.0%	80.2	0.0%	80.2	0.0%	80.2	0.0%	80.2	0.0%
Foster	67.3	67.7	-1.2%	66.5	2.4%	66.5	2.4%	66.5	2.4%	68.2	-2.8%
Green Peter	92.6	92.7	-0.8%	86.0	88.6%	86.0	88.7%	86.0	88.6%	69.2	315.3%
Hills Creek	93.8	93.9	-1.1%	93.8	-0.1%	93.8	0.1%	93.6	2.4%	92.1	26.7%
Lookout Point	87.9	87.8	1.0%	87.8	0.9%	87.8	1.0%	71.4	136.8%	83.2	38.8%

Project	NAA Trap Eff	Alt 4 Trap Eff	Alt 4 vs. NAA	Alt 5 Trap Eff	Alt 5 vs. NAA	NTOM Trap Eff	NTOM vs. NAA
Blue River	81.4	81.0	2.1%	80.8	3.4%	81.1%	1.3%
Cottage Grove	81.0	79.6	7.3%	81.0	-0.1%	81.0%	0.2%
Cougar	90.6	90.7	-1.2%	39.1	546.5%	89.3%	14.1%
Detroit	91.1	91.2	-1.0%	91.2	-0.9%	91.2%	-0.9%
Dorena	80.7	79.7	5.5%	80.8	-0.2%	80.8%	-0.3%
Fall Creek	81.8	81.8	-0.1%	81.8	-0.1%	60.3%	117.7%
Fern Ridge	80.2	80.2	0.0%	80.2	0.0%	80.2%	0.0%
Foster	67.3	67.1	0.6%	66.4	2.6%	63.6%	11.2%
Green Peter	92.6	92.5	0.6%	86.0	89.4%	85.9%	90.9%
Hills Creek	93.8	93.8	-0.3%	93.7	1.4%	93.7%	2.2%
Lookout Point	87.9	87.8	0.8%	87.8	1.1%	81.7%	51.5%

Table 2-4. Storage Metrics – Trap Efficiency Qualitative Analysis

Project	NAA	Alt 1 vs. NAA	Alt 2A vs. NAA	Alt 2B vs. NAA	Alt 3A vs. NAA	Alt 3B vs. NAA
Blue River	N/A	Negligible	Negligible	Negligible	**Minor**	**Minor**
Cottage Grove	N/A	Negligible	Negligible	Negligible	Negligible	Negligible
Cougar	N/A	Negligible	Negligible	**Major**	**Moderate**	**Major**
Detroit	N/A	Negligible	Negligible	Negligible	**Major**	**Minor**
Dorena	N/A	Negligible	Negligible	Negligible	Negligible	Negligible
Fall Creek	N/A	Negligible	Negligible	Negligible	Negligible	Negligible
Fern Ridge	N/A	Negligible	Negligible	Negligible	Negligible	Negligible
Foster	N/A	Negligible	Negligible	Negligible	Negligible	Negligible
Green Peter	N/A	Negligible	**Moderate**	**Moderate**	**Moderate**	**Major**
Hills Creek	N/A	Negligible	Negligible	Negligible	Negligible	**Minor**
Lookout Point	N/A	Negligible	Negligible	Negligible	**Major**	**Minor**

Project	NAA	Alt 4 vs. NAA	Alt 5 vs. NAA	NTOM vs. NAA
Blue River	N/A	Negligible	Negligible	Negligible
Cottage Grove	N/A	Negligible	Negligible	Negligible
Cougar	N/A	Negligible	**Major**	**Minor**
Detroit	N/A	Negligible	Negligible	Negligible
Dorena	N/A	Negligible	Negligible	Negligible
Fall Creek	N/A	Negligible	Negligible	**Major**
Fern Ridge	N/A	Negligible	Negligible	Negligible
Foster	N/A	Negligible	Negligible	**Minor**
Green Peter	N/A	Negligible	**Moderate**	**Moderate**
Hills Creek	N/A	Negligible	Negligible	Negligible
Lookout Point	N/A	Negligible	Negligible	**Moderate**

Table 2-5. Storage Metrics – Shoreline Exposure Quantitative Analysis

Project	Alt 1 vs. NAA Metric (*Range Change)	Alt 2A vs. NAA Metric (*Range Change)	Alt 2B vs. NAA Metric (*Range Change)	Alt 3A vs. NAA Metric (*Range Change)
Blue River	4.2 (Yes)	2.9 (Yes)	2.4 (Yes)	-8.0 (Yes)
Cottage Grove	0.6 (Yes)	0.7 (No)	0.7 (No)	-0.2 (Yes)
Cougar	6.7 (Yes)	6.1 (Yes)	-188.2 (Yes)	-86.1 (Yes)
Detroit	4.4 (Yes)	1.6 (Yes)	1.5 (Yes)	-116.2 (Yes)
Dorena	2.1 (Yes)	1.5 (No)	1.4 (No)	0.7 (Yes)
Fall Creek	1.1 (No)	0.8 (No)	0.9 (No)	0.7 (No)
Fern Ridge	0.0 (No)	0.0 (No)	0.0 (No)	0.0 (No)
Foster	0.1 (No)	0.2 (No)	0.2 (No)	0.2 (No)
Green Peter	5.7 (Yes)	-31.8 (Yes)	-31.8 (Yes)	-31.8 (Yes)
Hills Creek	4.9 (Yes)	3.6 (Yes)	2.0 (Yes)	-6.4 (Yes)
Lookout Point	-0.6 (Yes)	0.5 (Yes)	-0.3 (Yes)	-72.9 (Yes)

Project	Alt 3B vs. NAA Metric (*Range Change)	Alt 4 vs. NAA Metric (*Range Change)	Alt 5 vs. NAA Metric (*Range Change)	NTOM vs. NAA Metric (*Range Change)
Blue River	-7.6 (Yes)	2.9 (Yes)	0.4 (Yes)	3.8 (Yes)
Cottage Grove	-0.1 (Yes)	0.0 (Yes)	0.4 (No)	0.6 (No)
Cougar	-188.4 (Yes)	6.3 (Yes)	-206.1 (Yes)	-21.7 (Yes)
Detroit	-19.6 (Yes)	1.6 (Yes)	1.5 (Yes)	1.5 (Yes)
Dorena	0.8 (Yes)	0.7 (Yes)	0.8 (No)	1.6 (No)
Fall Creek	0.6 (No)	0.9 (No)	0.5 (No)	-57.8 (No)
Fern Ridge	0.0 (No)	0.0 (No)	0.0 (No)	0.0 (No)
Foster	-3.0 (No)	0.1 (No)	0.2 (No)	-4.7 (No)
Green Peter	-133.5 (Yes)	-4.4 (Yes)	-32.0 (Yes)	-36.3 (Yes)
Hills Creek	-40.0 (Yes)	3.9 (Yes)	-2.0 (Yes)	3.0 (Yes)
Lookout Point	-18.5 (Yes)	0.6 (Yes)	-0.4 (Yes)	-29.8 (Yes)

Changes in range are deeper drafts relative to NAA. There is no change to full pool elevation.

Table 2-6. Storage Metrics – Shoreline Exposure Qualitative Analysis

Project	Alt 1 vs. NAA	Alt 2A vs. NAA	Alt 2B vs. NAA	Alt 3A vs. NAA
Blue River	Major	Major	Major	Major
Cottage Grove	Major	Negligible	Negligible	Major
Cougar	Major	Major	Major	Major
Detroit	Major	Major	Major	Major
Dorena	Major	Negligible	Negligible	Major
Fall Creek	Negligible	Negligible	Negligible	Negligible
Fern Ridge	Negligible	Negligible	Negligible	Negligible
Foster	Negligible	Negligible	Negligible	Negligible
Green Peter	Major	Major	Major	Major
Hills Creek	Major	Major	Major	Minor
Lookout Point	Major	Major	Major	Major

Project	Alt 3B vs. NAA	Alt 4 vs. NAA	Alt 5 vs. NAA	NTOM vs. NAA
Blue River	Major	Major	Major	Major
Cottage Grove	Major	Major	Negligible	Negligible
Cougar	Major	Major	Major	Major
Detroit	Major	Major	Major	Major
Dorena	Major	Major	Negligible	Negligible
Fall Creek	Negligible	Negligible	Negligible	Major
Fern Ridge	Negligible	Negligible	Negligible	Negligible
Foster	Negligible	Negligible	Negligible	Negligible
Green Peter	Major	Major	Major	Major
Hills Creek	Major	Major	Major	Major
Lookout Point	Major	Major	Major	Major

2.1.1 Blue River

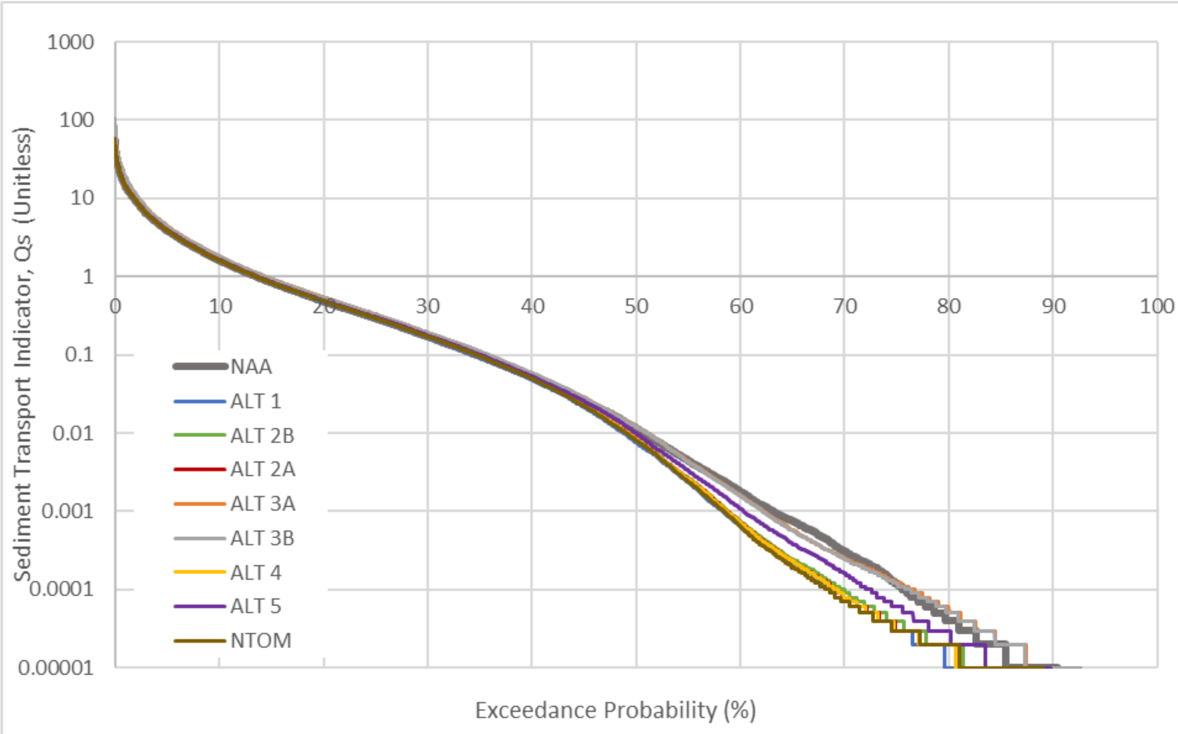

Figure 2-1. Blue River Sediment Transport Indicator

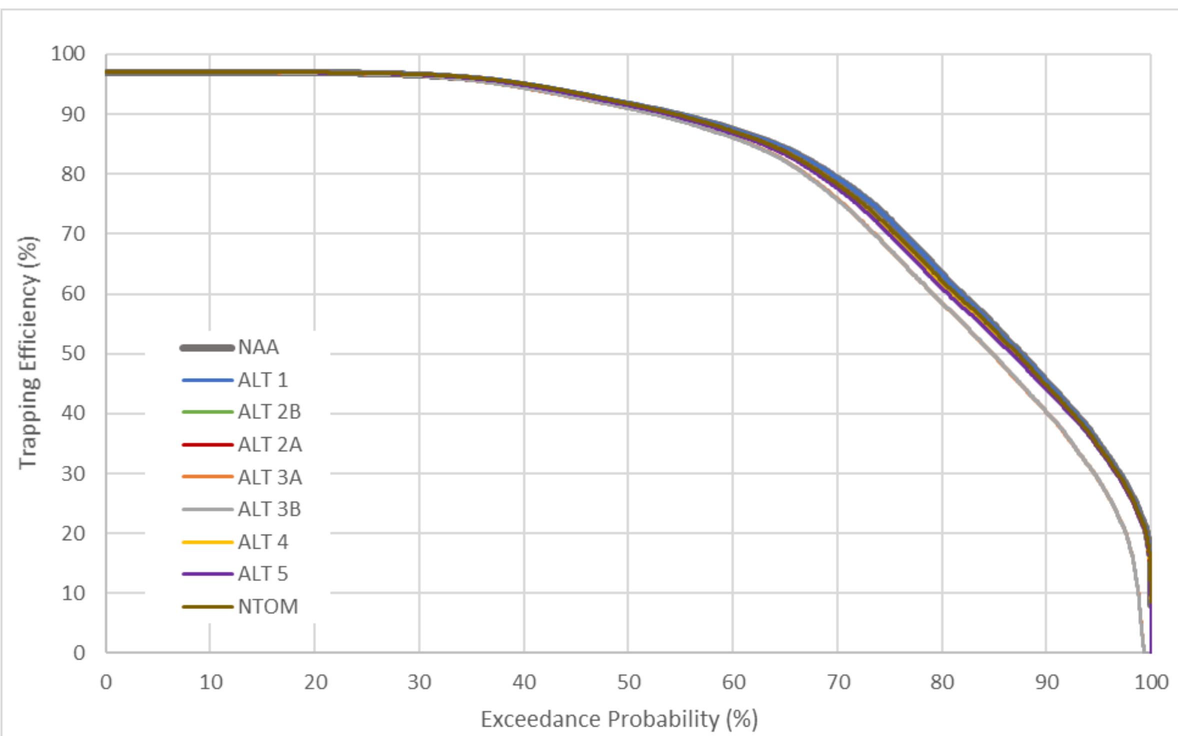

Figure 2-2. Blue River Trapping Efficiency Daily Exceedance

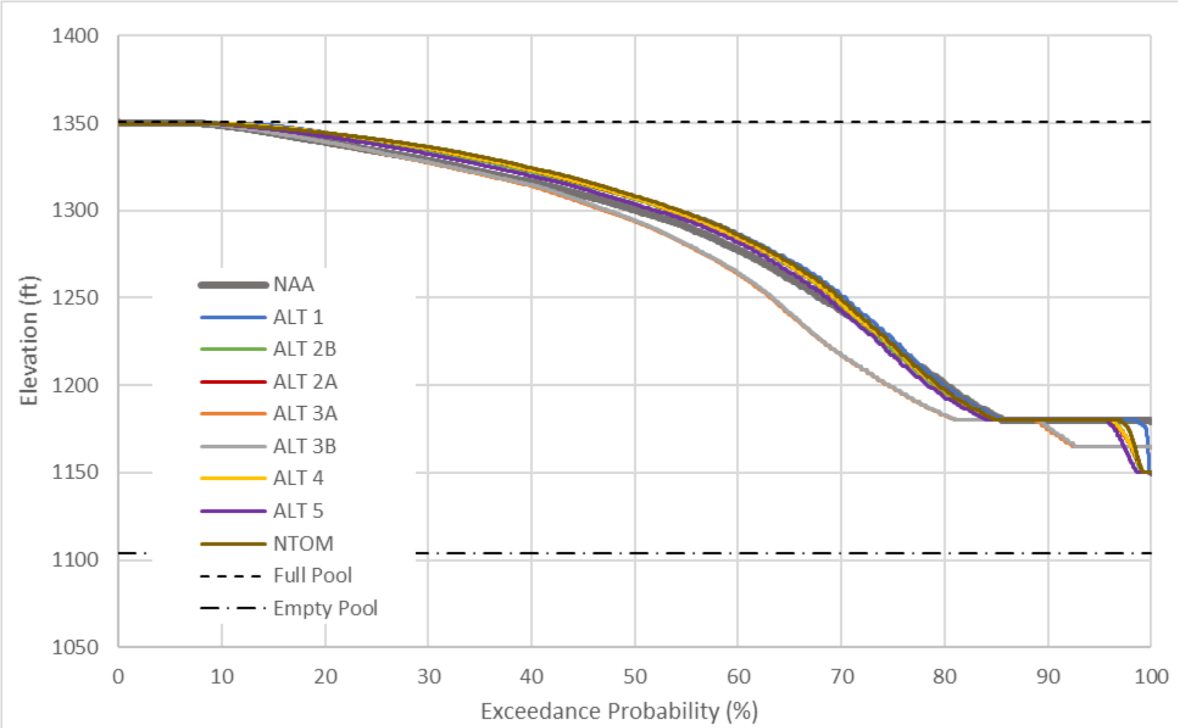

Figure 2-3. Blue River Elevation Daily Exceedance

2.1.2 Cottage Grove

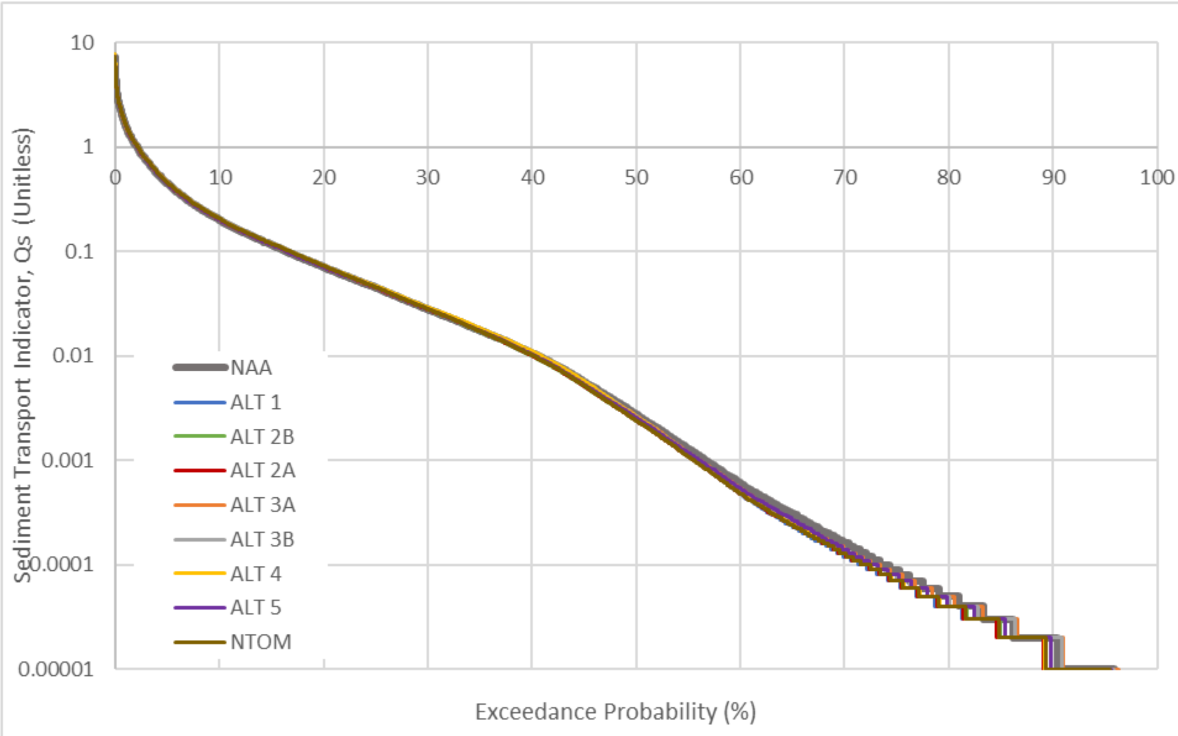

Figure 2-4. Cottage Grove Sediment Transport Indicator

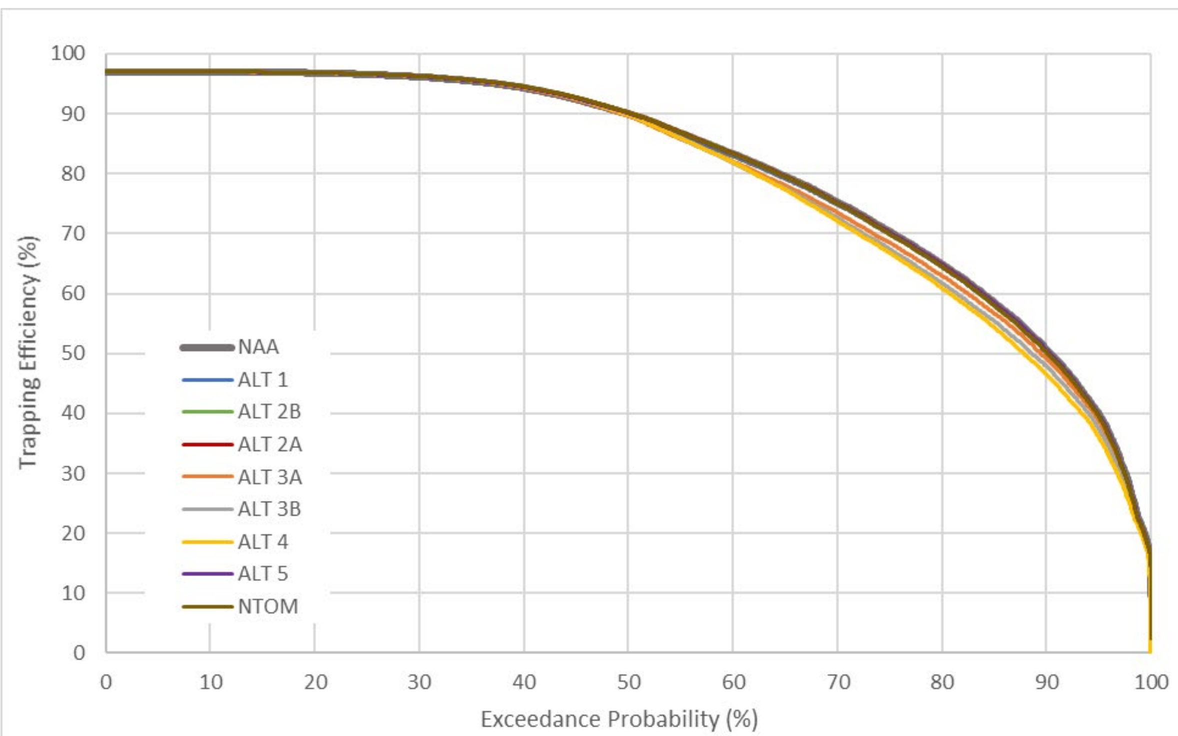

Figure 2-5. Cottage Grove Trapping Efficiency Daily Exceedance

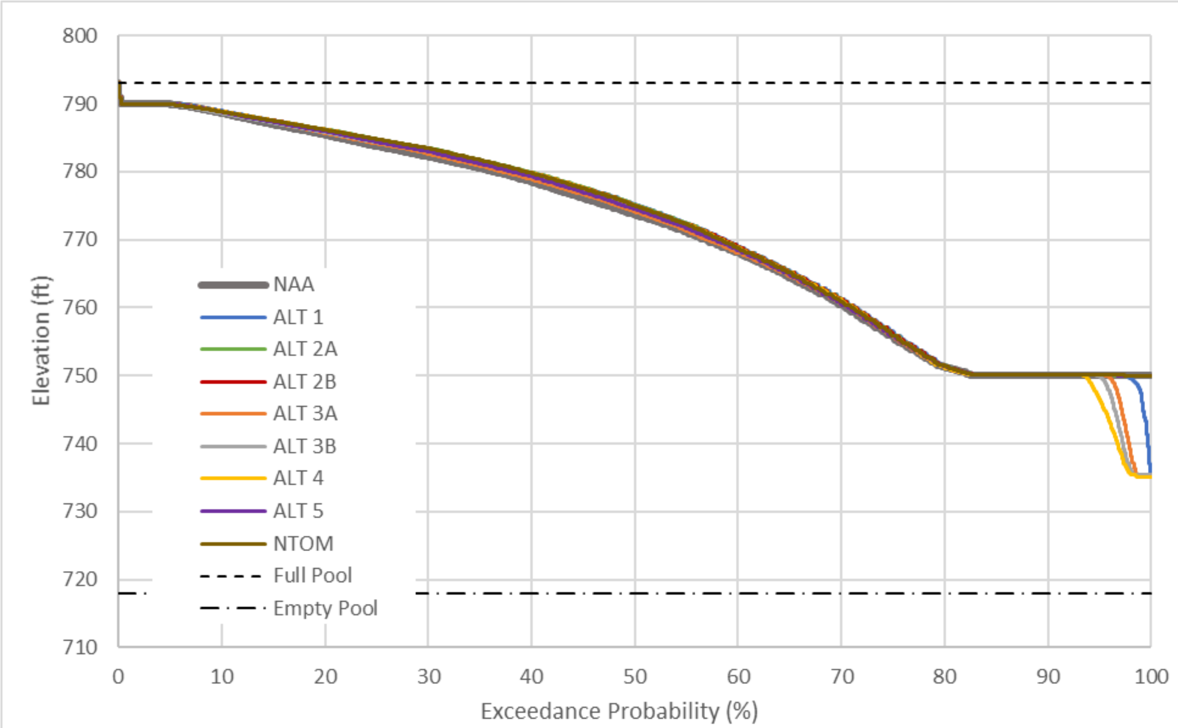

Figure 2-6. Cottage Grove Elevation Daily Exceedance

2.1.3 Cougar

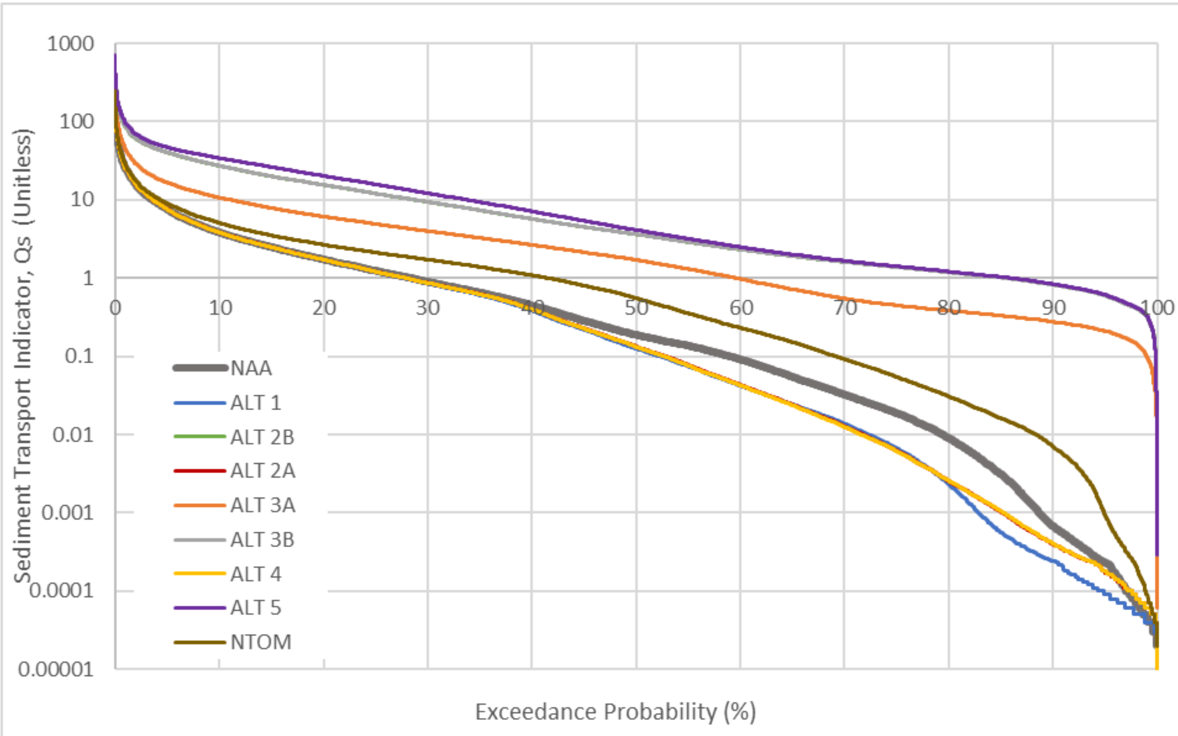

Figure 2-7. Cougar Sediment Transport Indicator

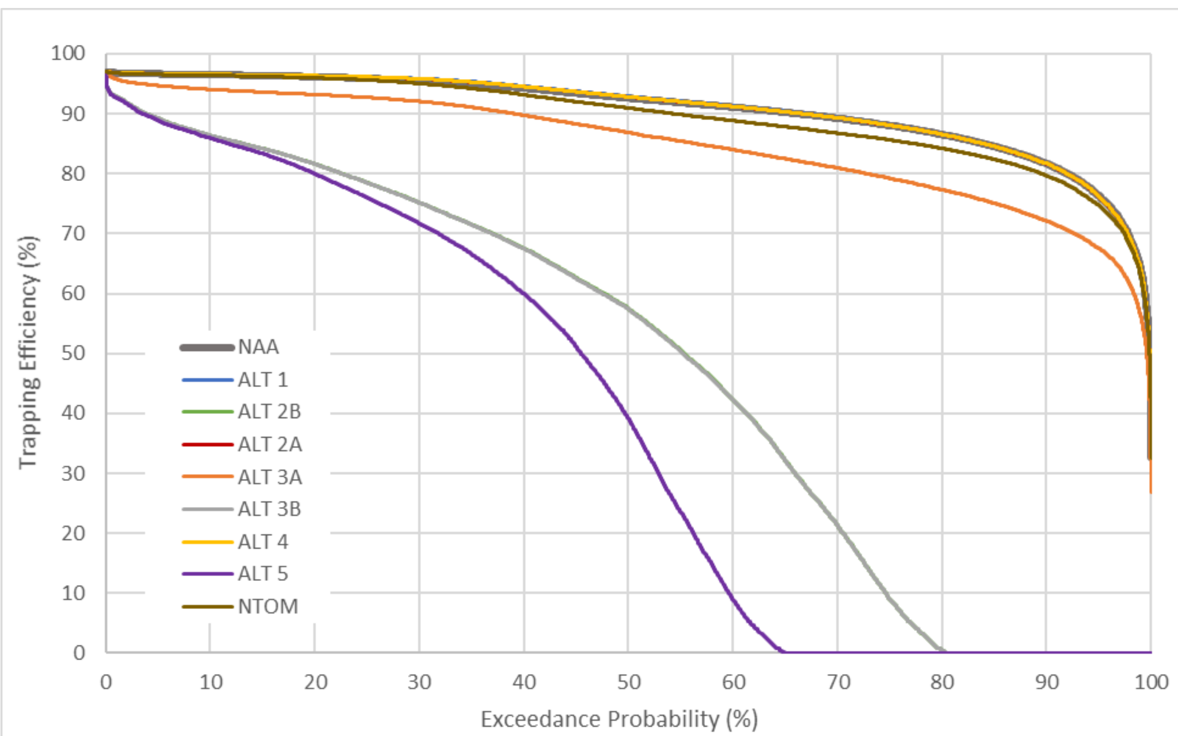

Figure 2-8. Cougar Trapping Efficiency Daily Exceedance

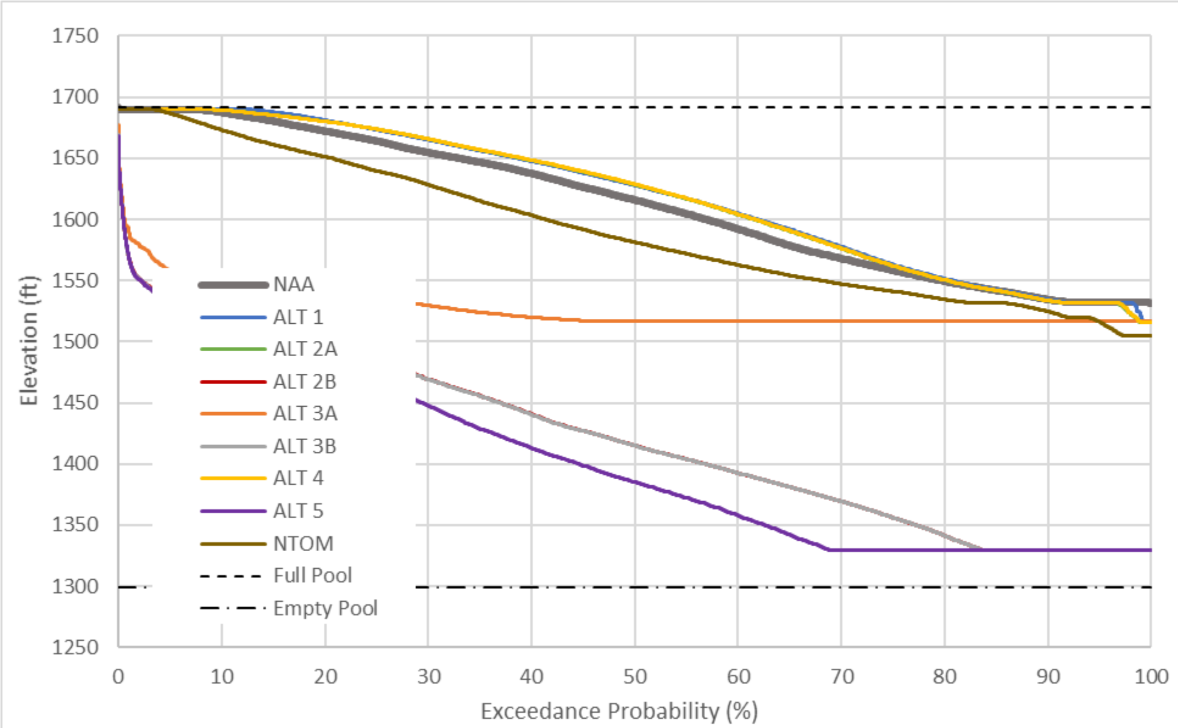

Figure 2-9. Cougar Elevation Daily Exceedance

2.1.4 Detroit

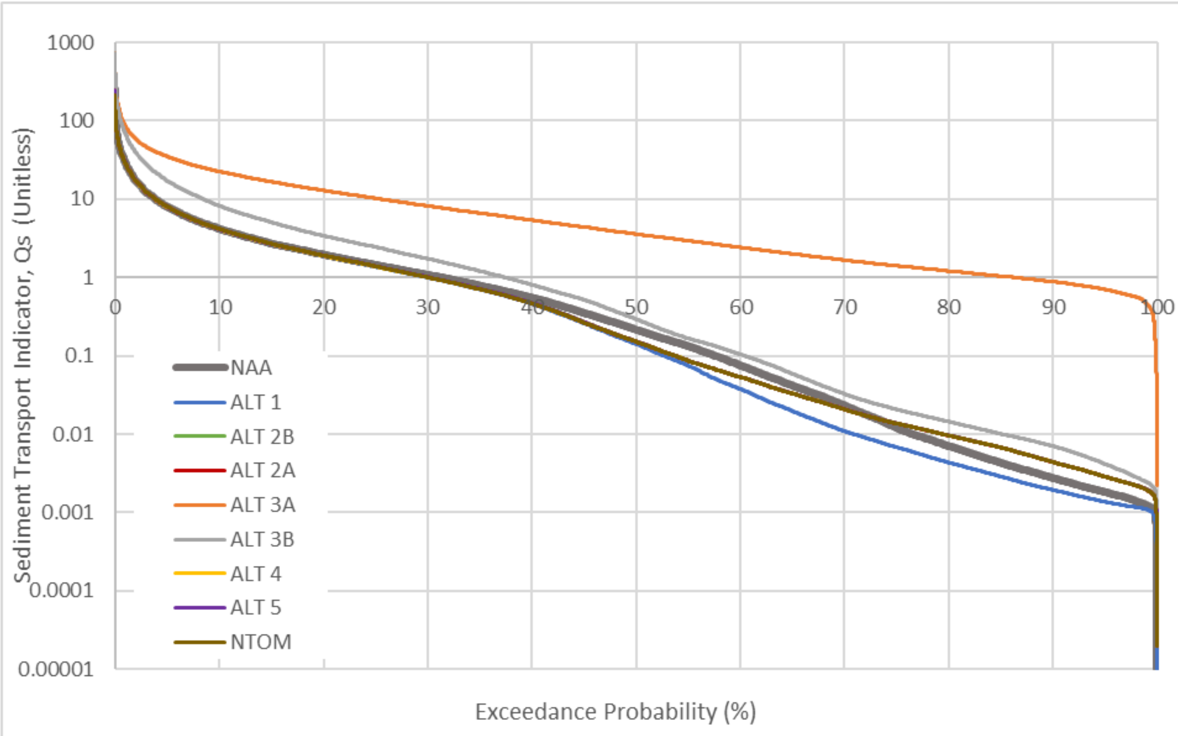

Figure 2-10. Detroit Sediment Transport Indicator

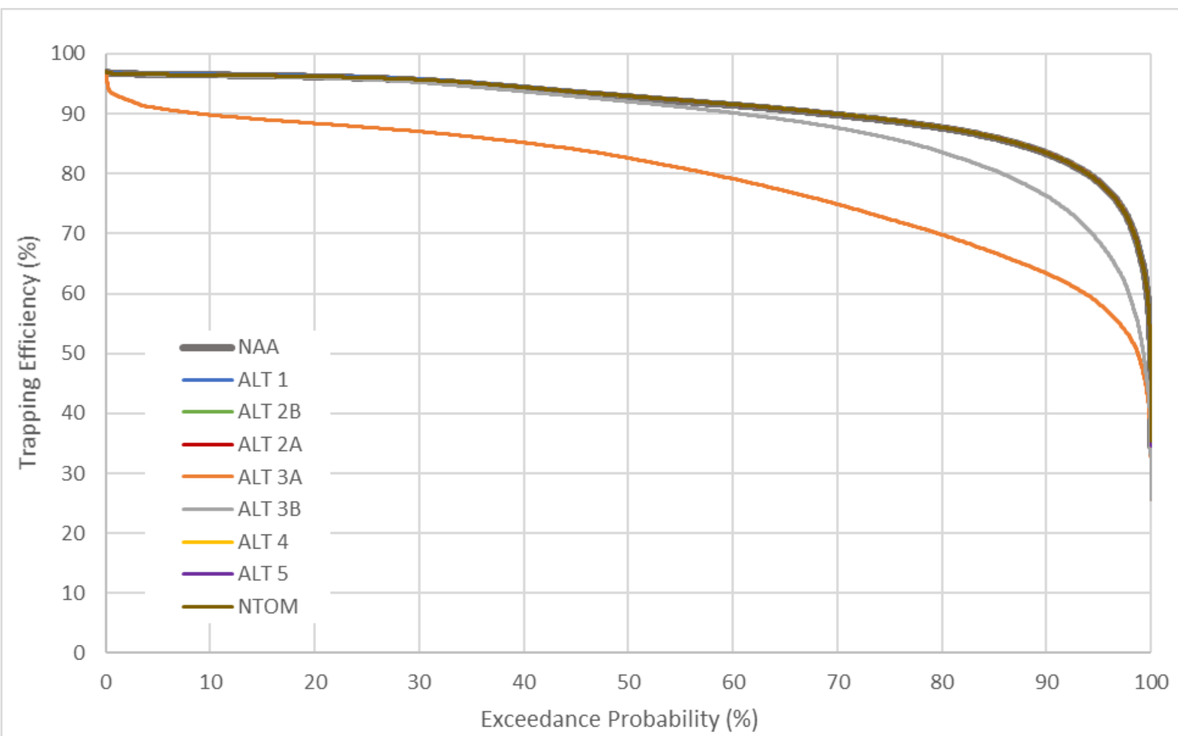

Figure 2-11. Detroit Trapping Efficiency Daily Exceedance

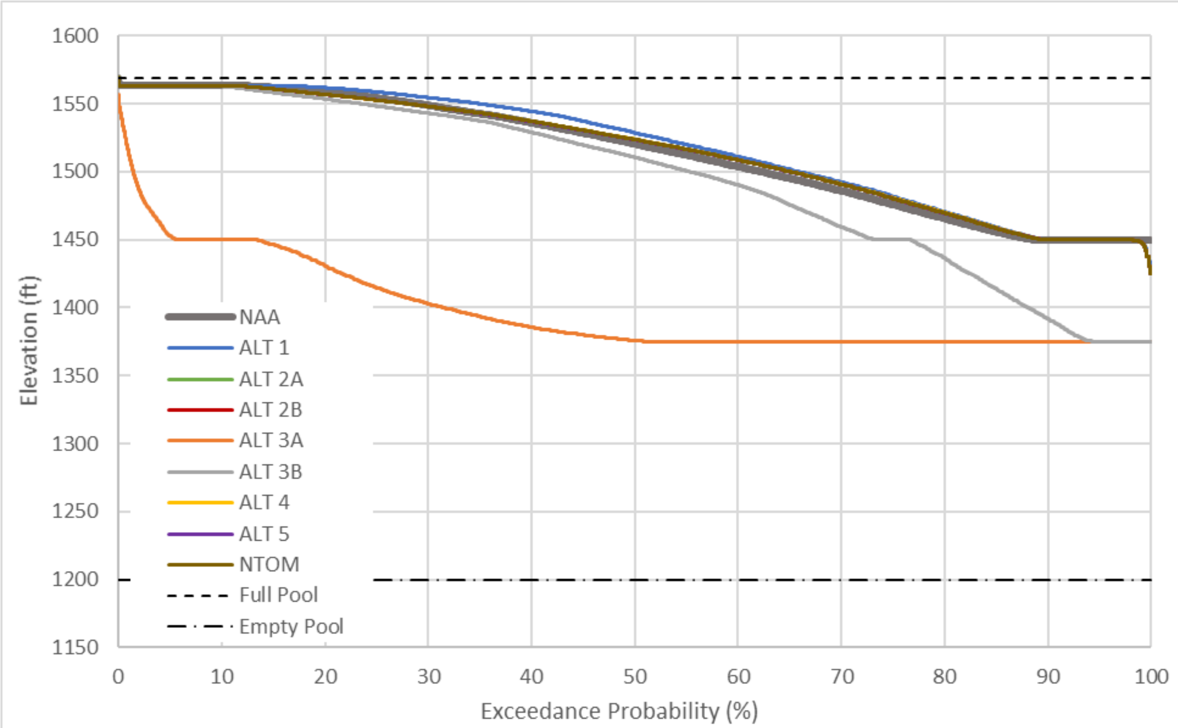

Figure 2-12. Detroit Elevation Daily Exceedance

2.1.5 Dorena

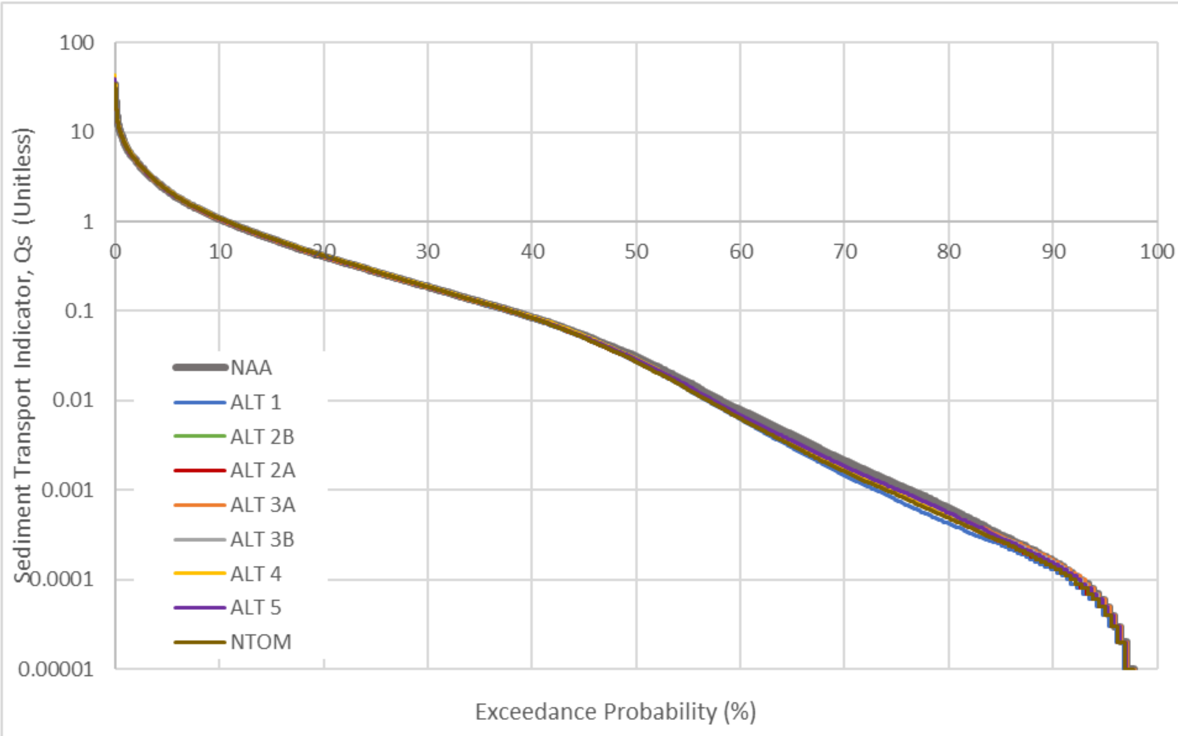

Figure 2-13. Dorena Sediment Transport Indicator

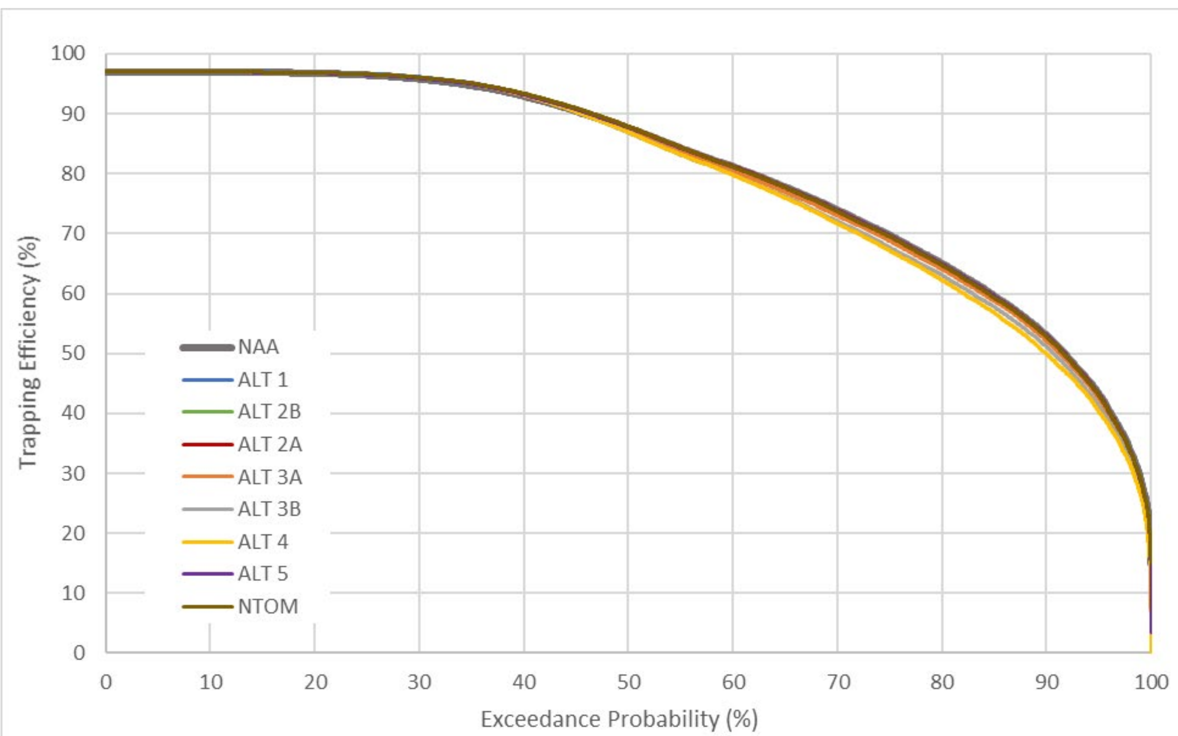

Figure 2-14. Dorena Trapping Efficiency Daily Exceedance

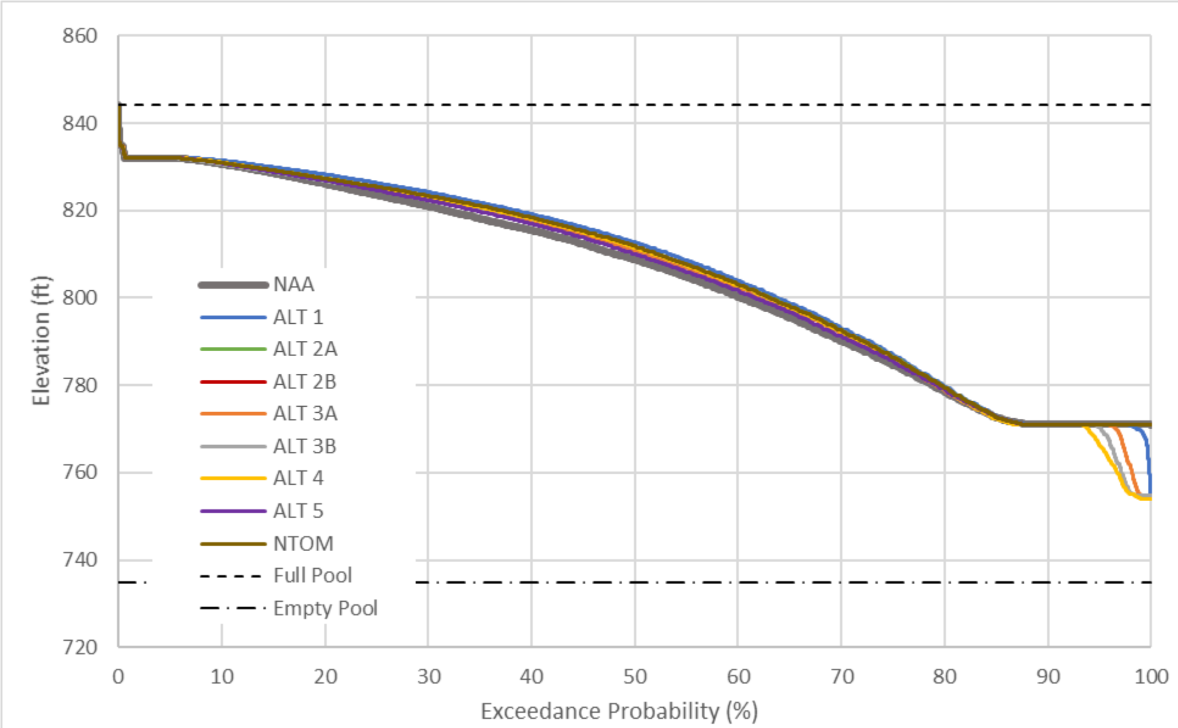

Figure 2-15. Dorena Elevation Daily Exceedance

2.1.6 Fall Creek

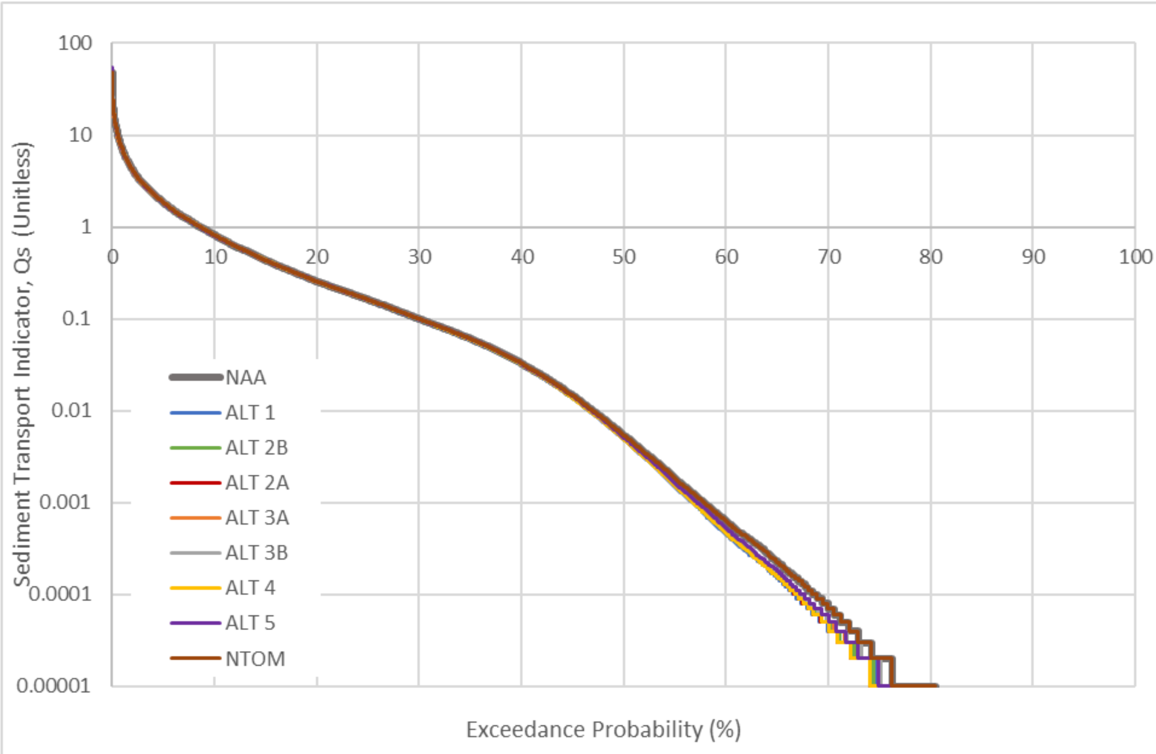

Figure 2-16. Fall Creek Sediment Transport Indicator

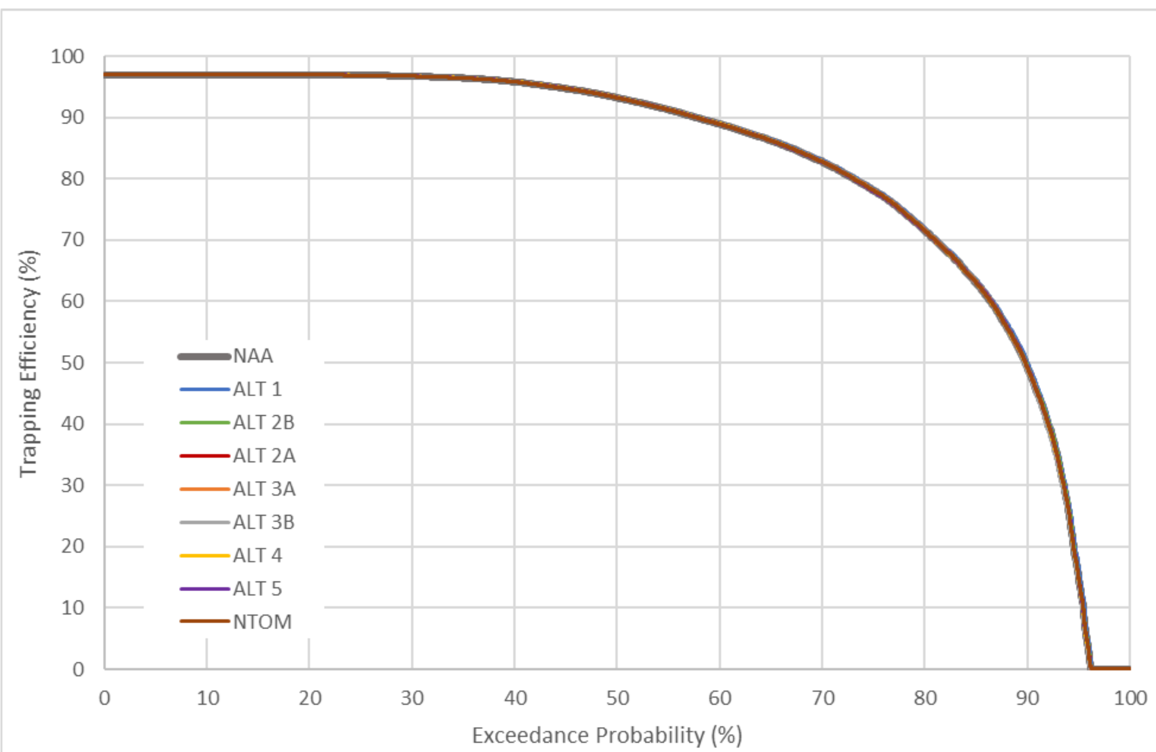

Figure 2-17. Fall Creek Trapping Efficiency Daily Exceedance

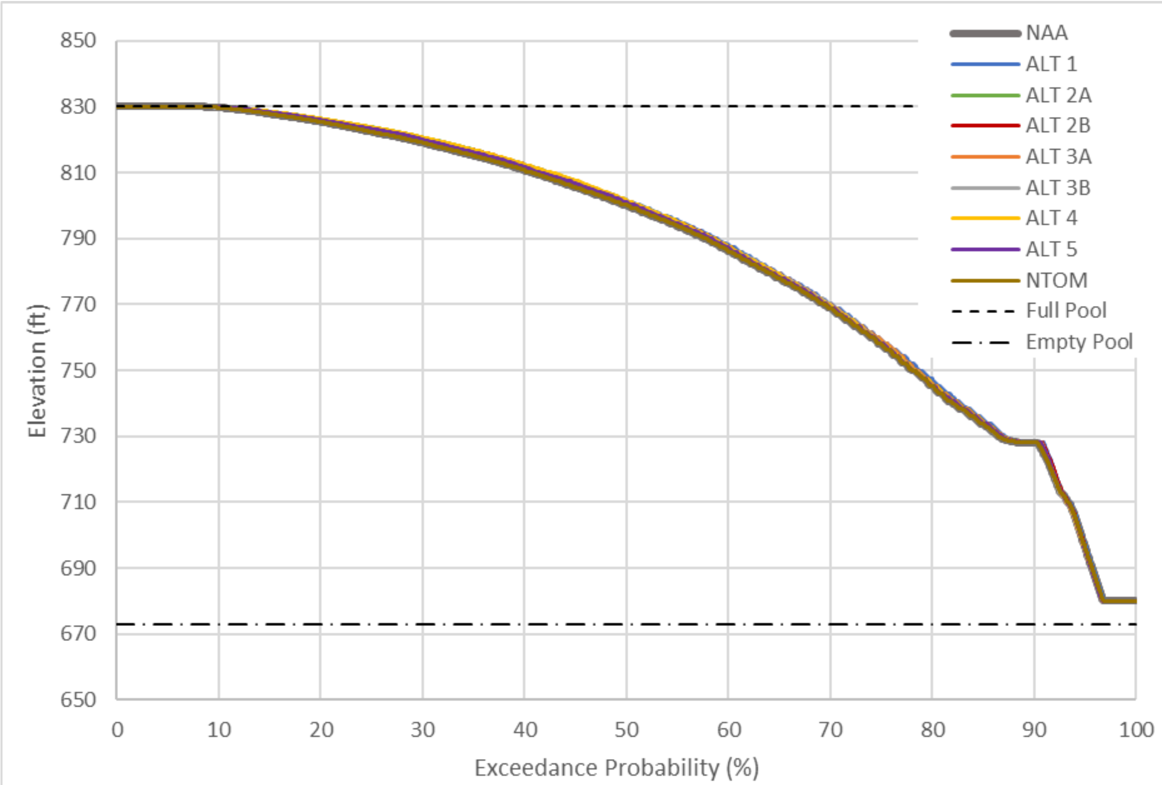

Figure 2-18. Fall Creek Elevation Daily Exceedance

2.1.7 Fern Ridge

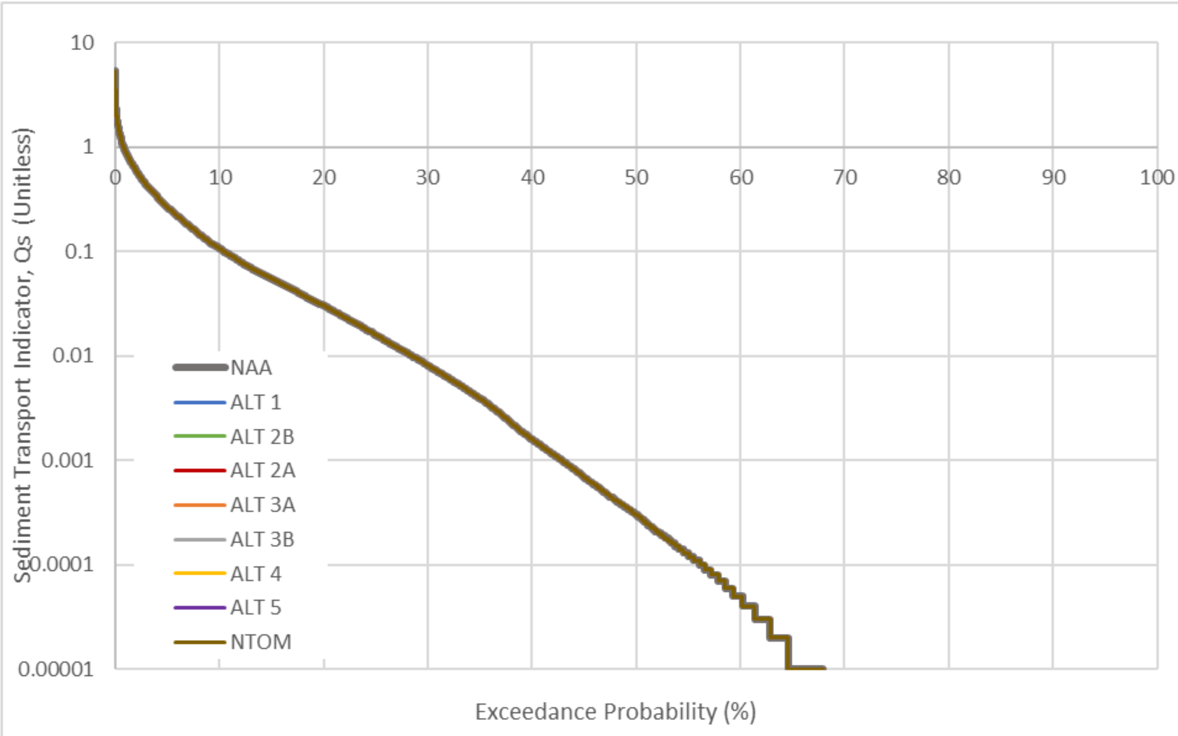

Figure 2-19. Fern Ridge Sediment Transport Indicator

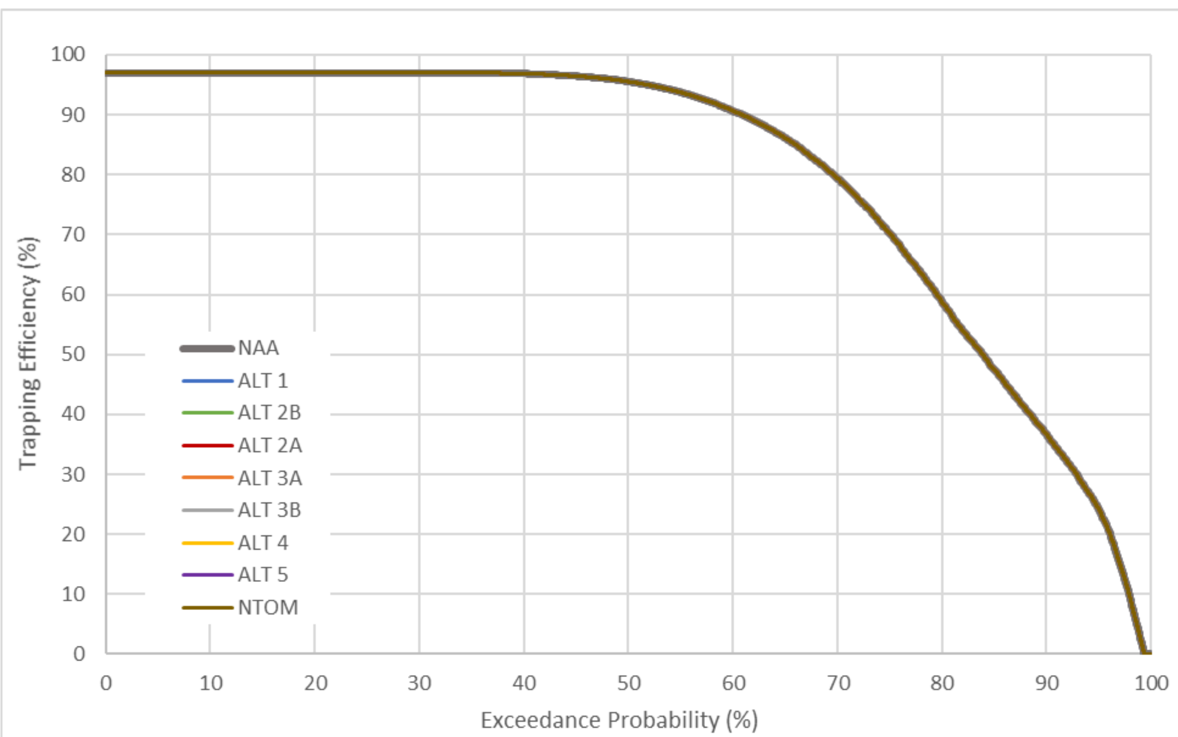

Figure 2-20. Fern Ridge Trapping Efficiency Daily Exceedance

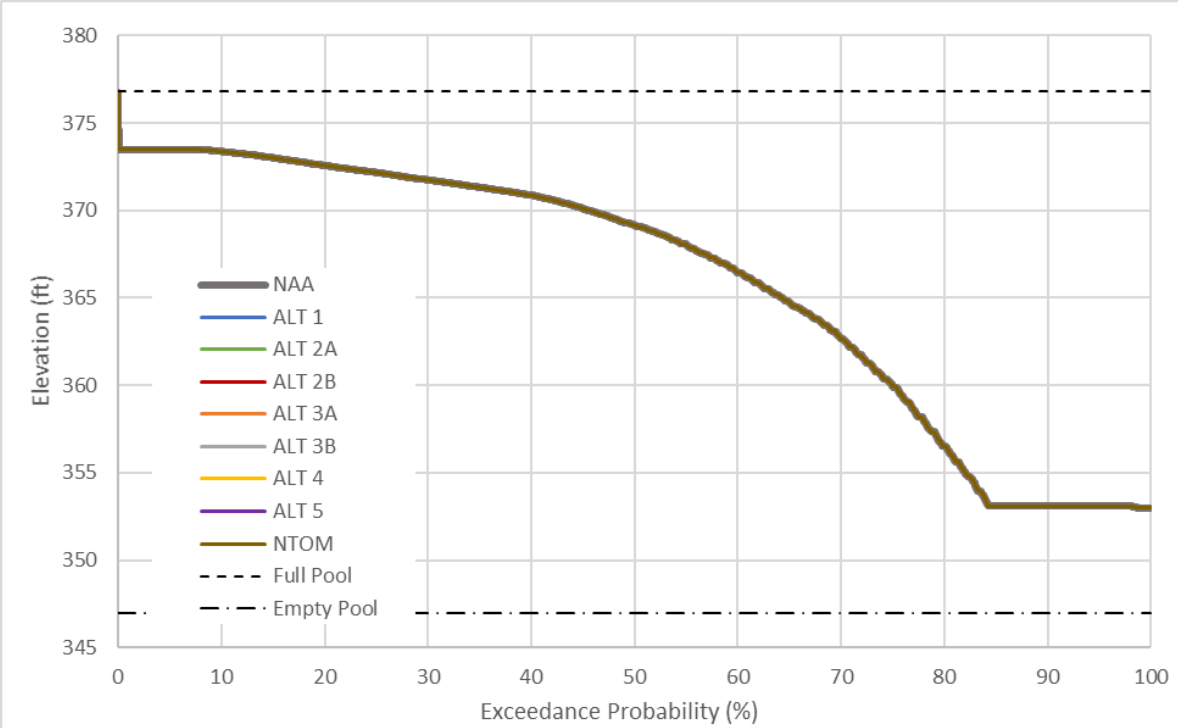

Figure 2-21. Fern Ridge Elevation Daily Exceedance

2.1.8 Foster

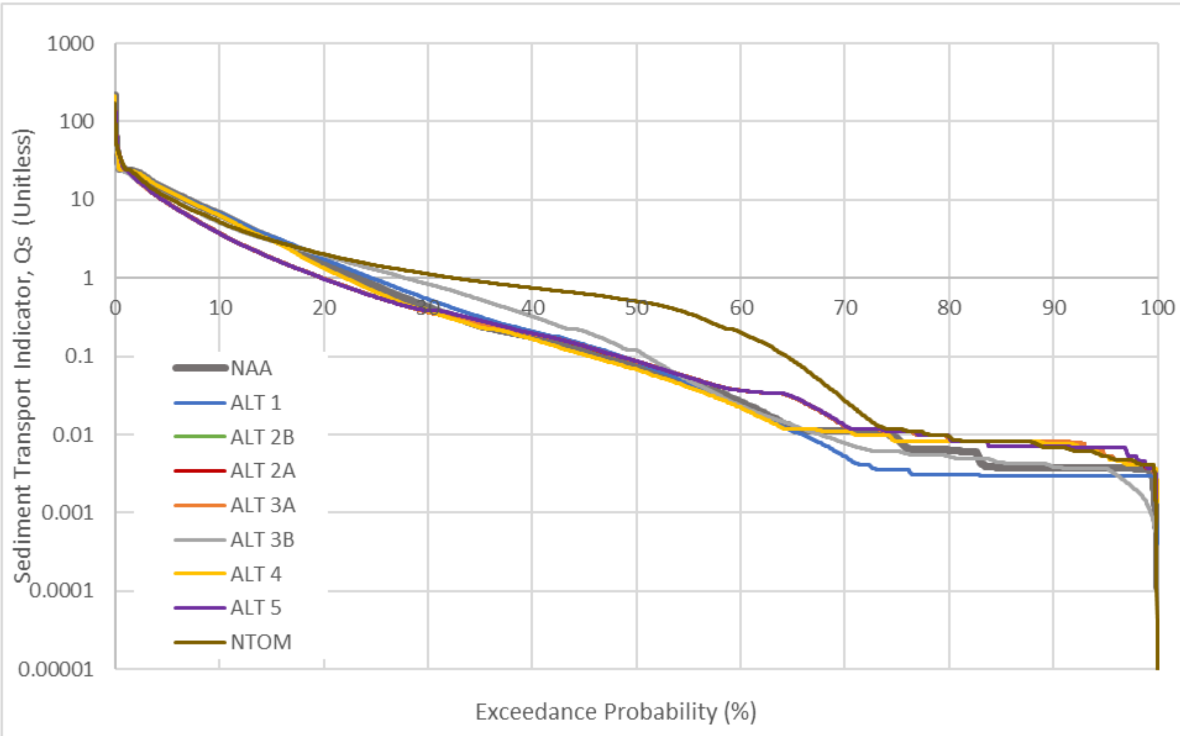

Figure 2-22. Foster Sediment Transport Indicator

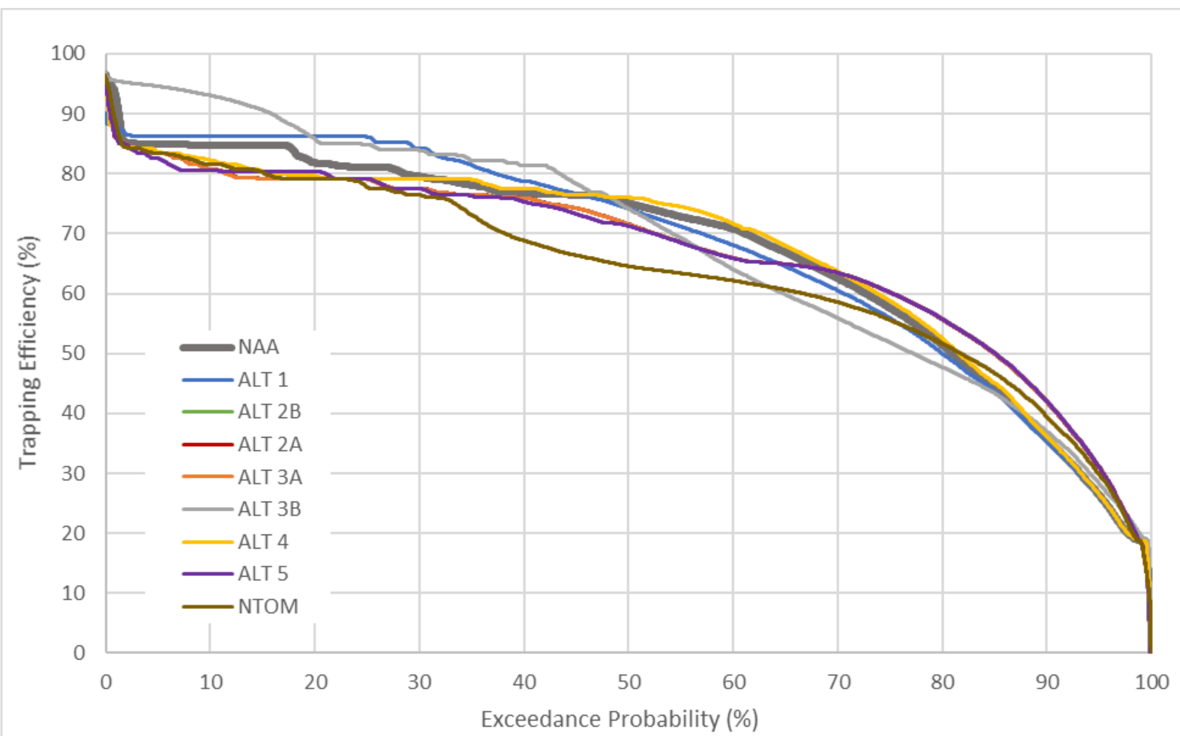

Figure 2-23. Foster Trapping Efficiency Daily Exceedance

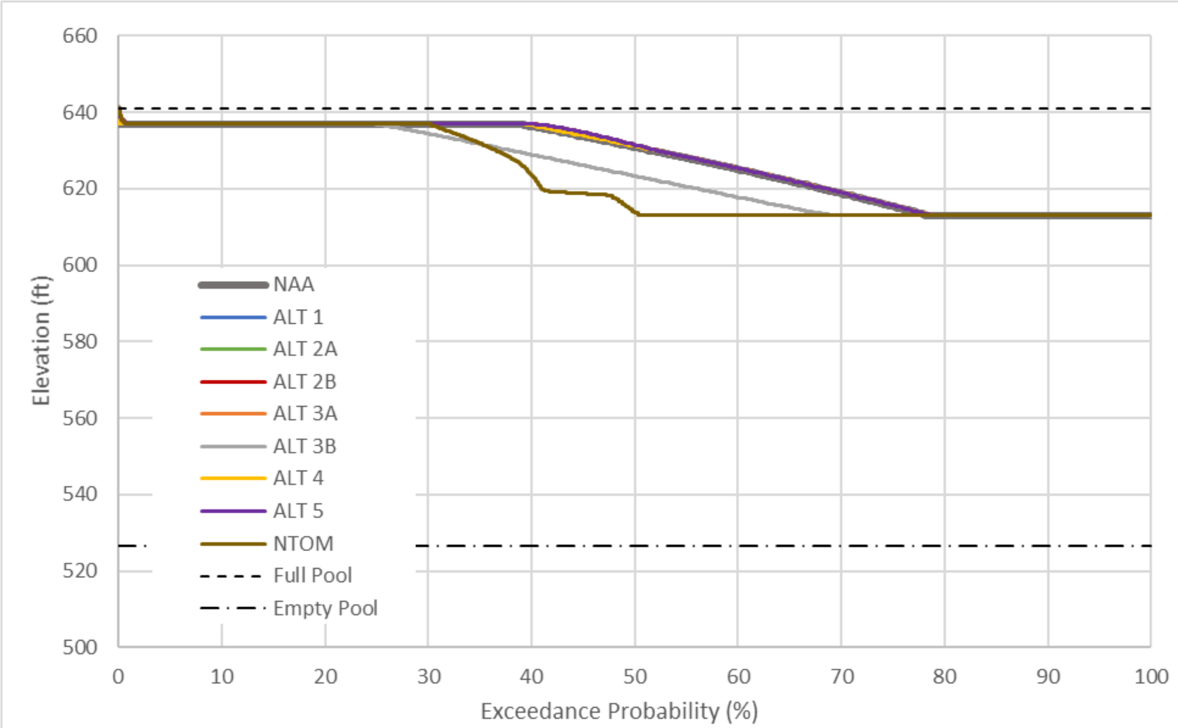

Figure 2-24. Foster Elevation Daily Exceedance

2.1.9 Green Peter

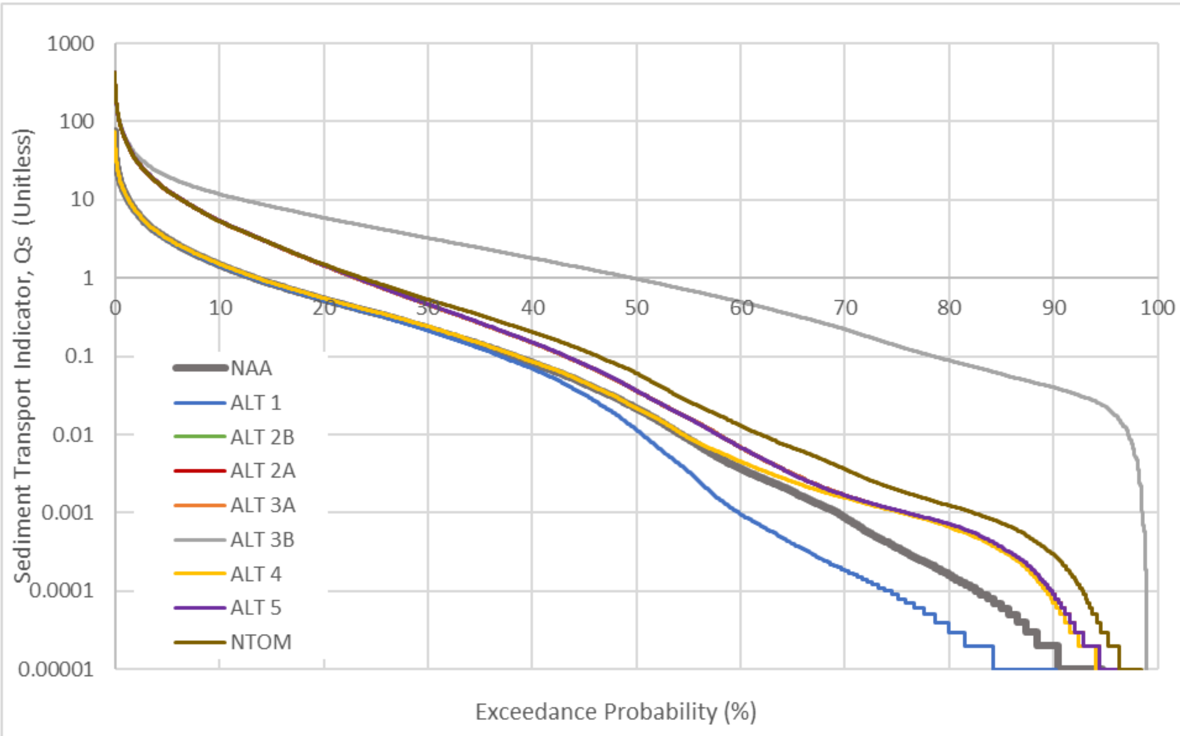

Figure 2-25. Green Peter Sediment Transport Indicator

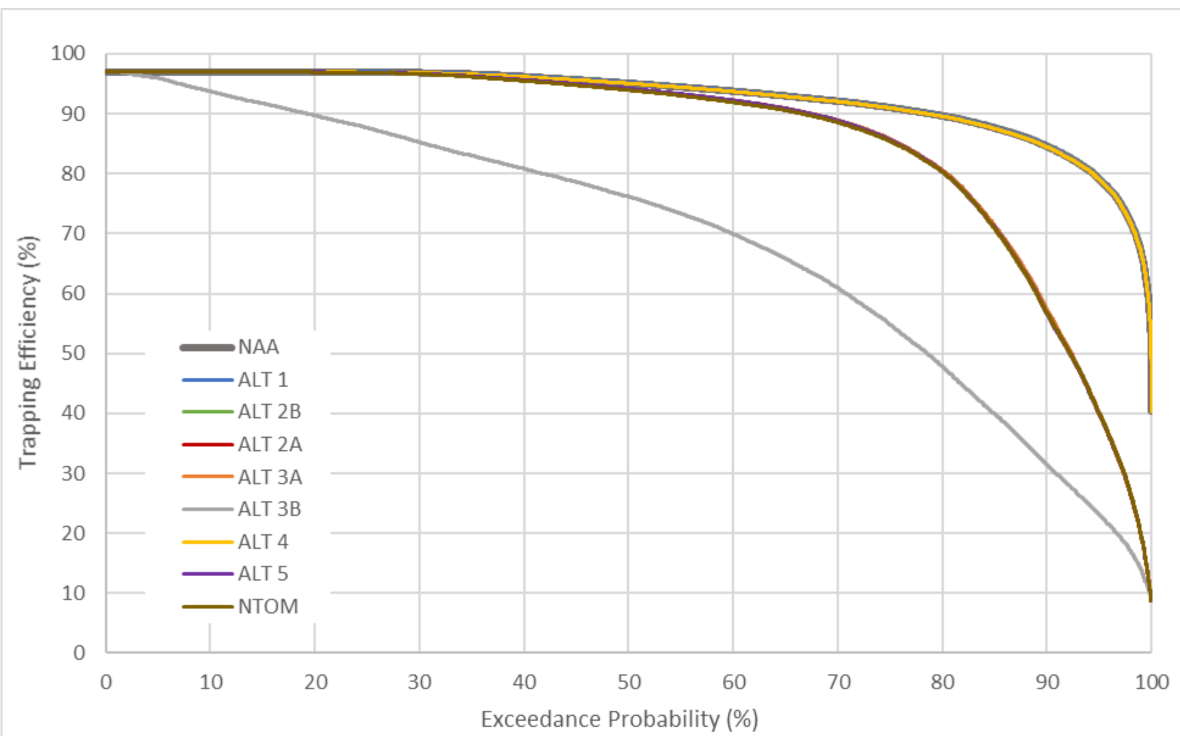

Figure 2-26. Green Peter Trapping Efficiency Daily Exceedance

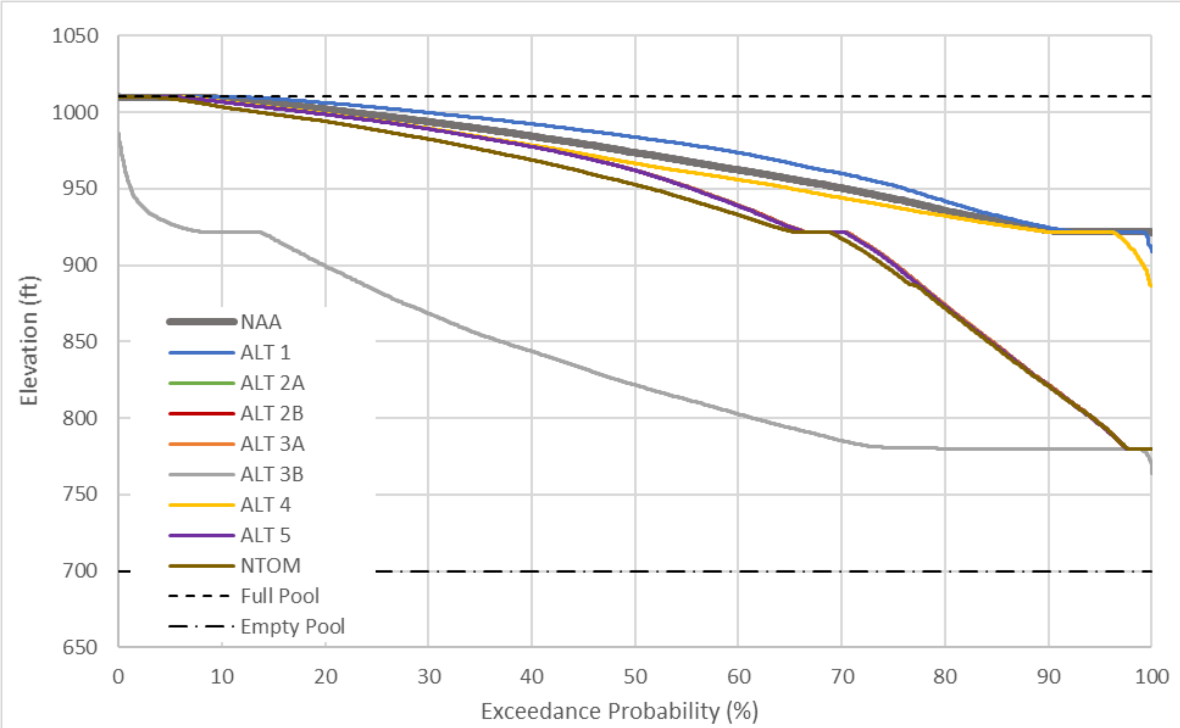

Figure 2-27. Green Peter Elevation Daily Exceedance

2.1.10 Hills Creek

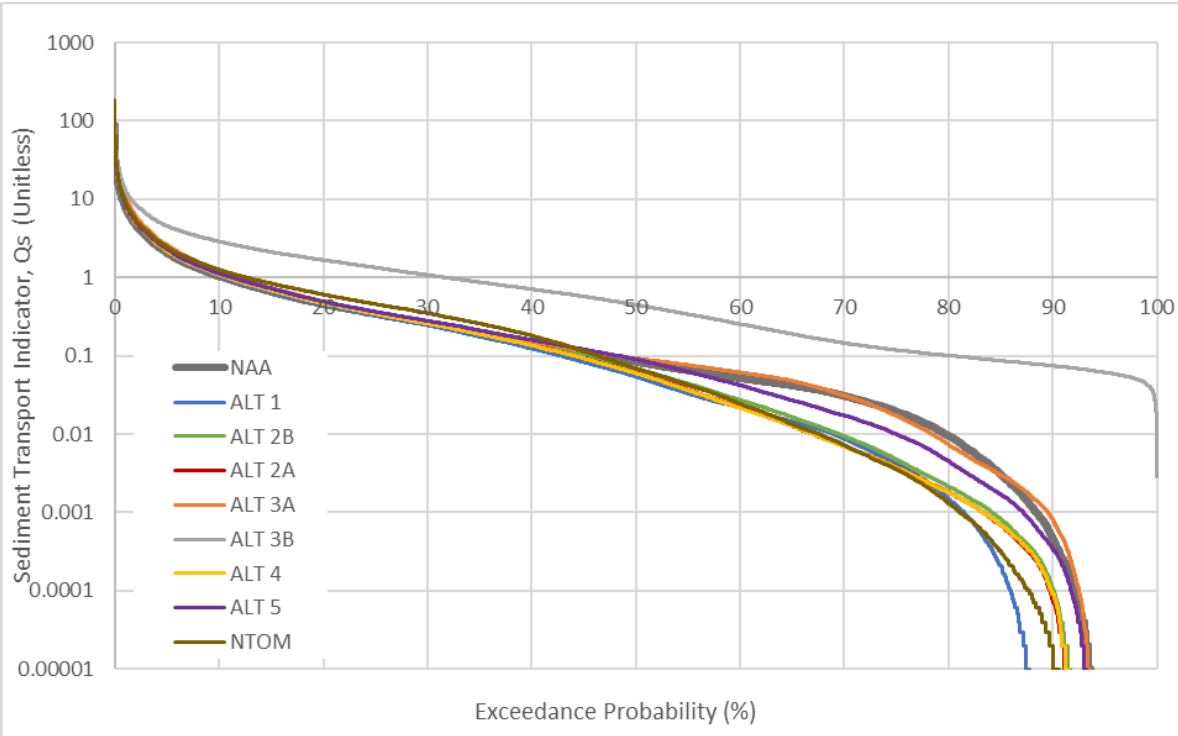

Figure 2-28. Hills Creek Sediment Transport Indicator

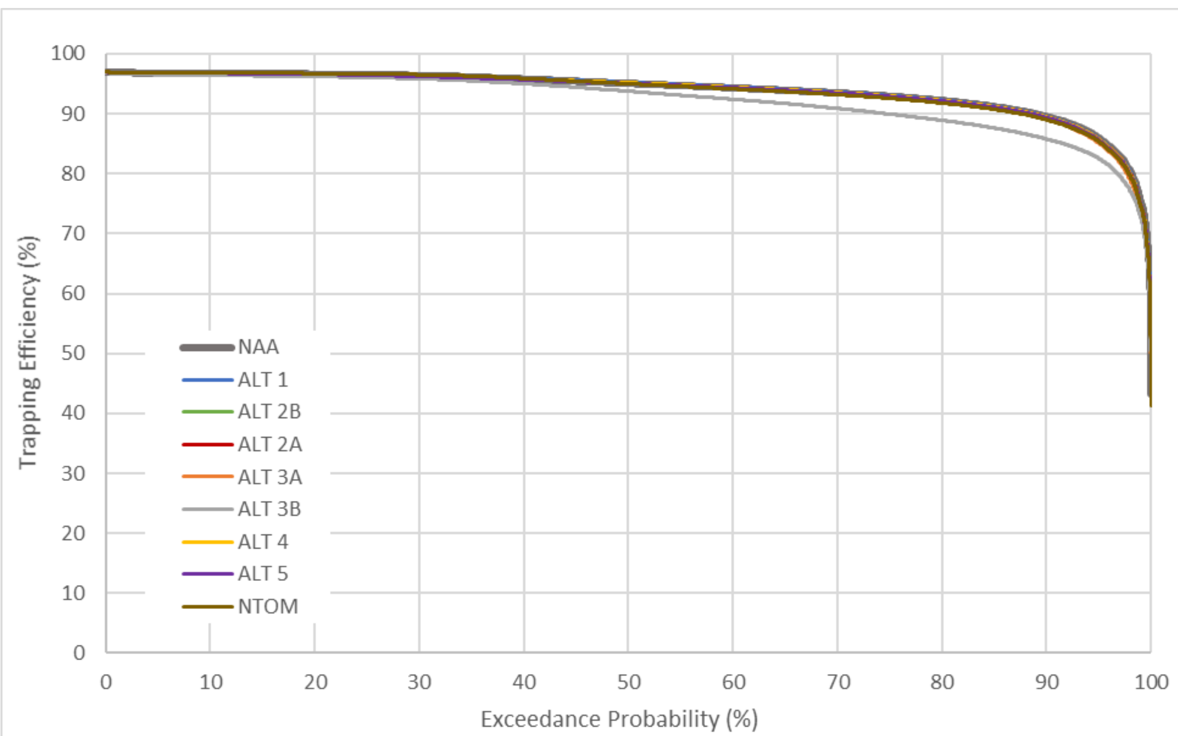

Figure 2-29. Hills Creek Trapping Efficiency Daily Exceedance

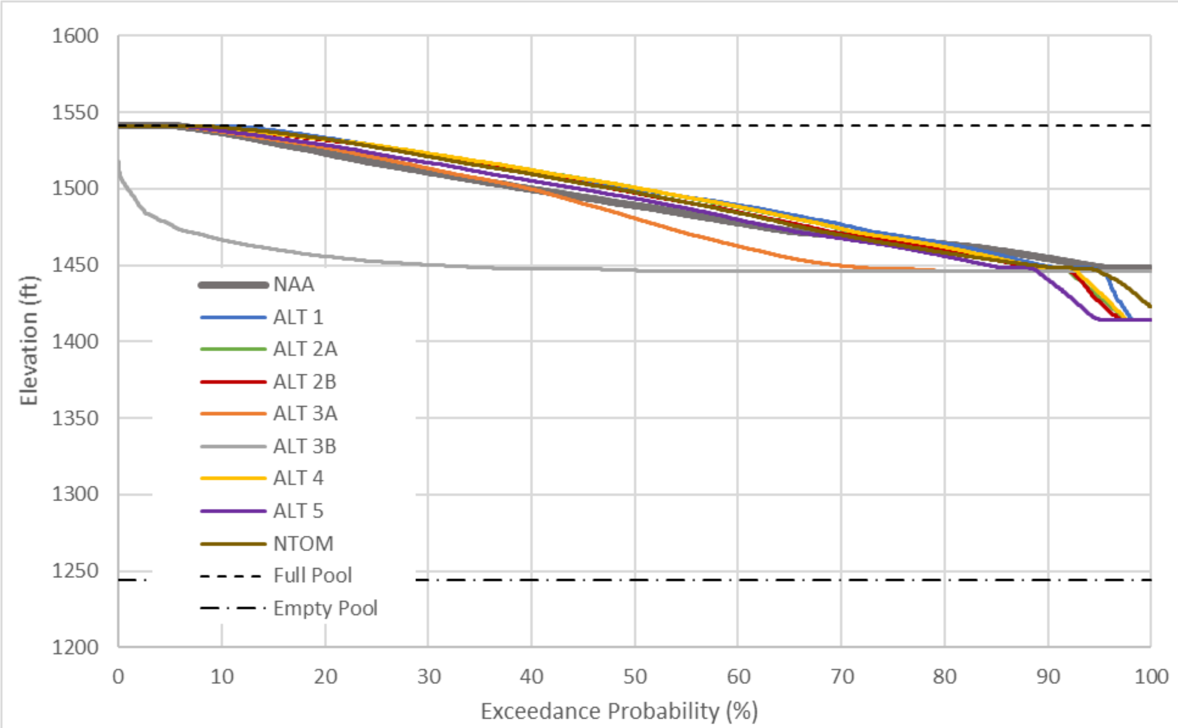

Figure 2-30. Hills Creek Elevation Daily Exceedance

2.1.11 Lookout Point

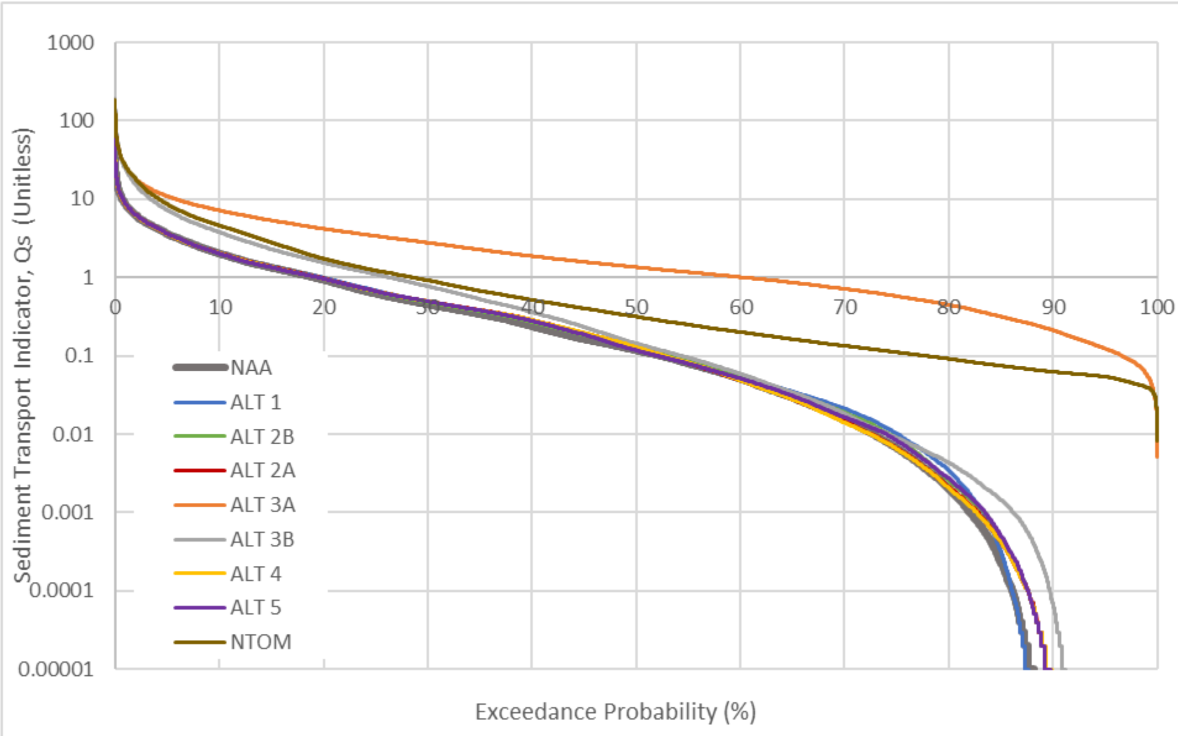

Figure 2-31. Lookout Point Sediment Transport Indicator

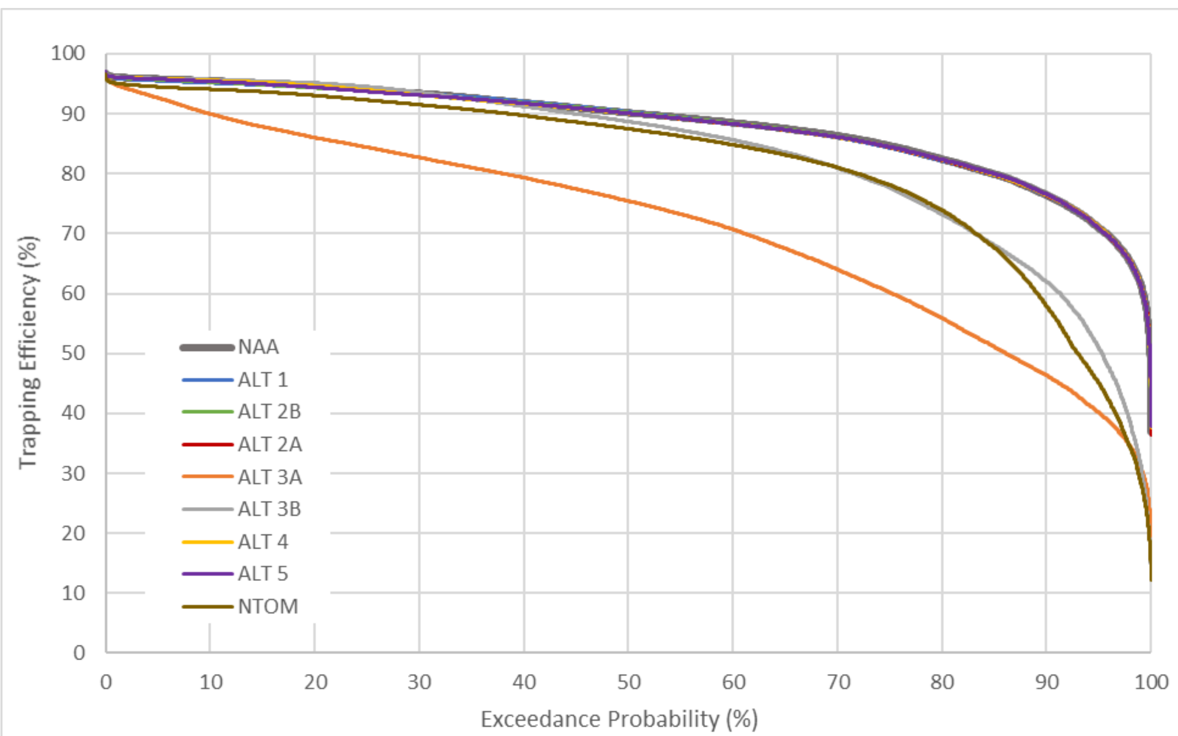

Figure 2-32. Lookout Point Trapping Efficiency Daily Exceedance

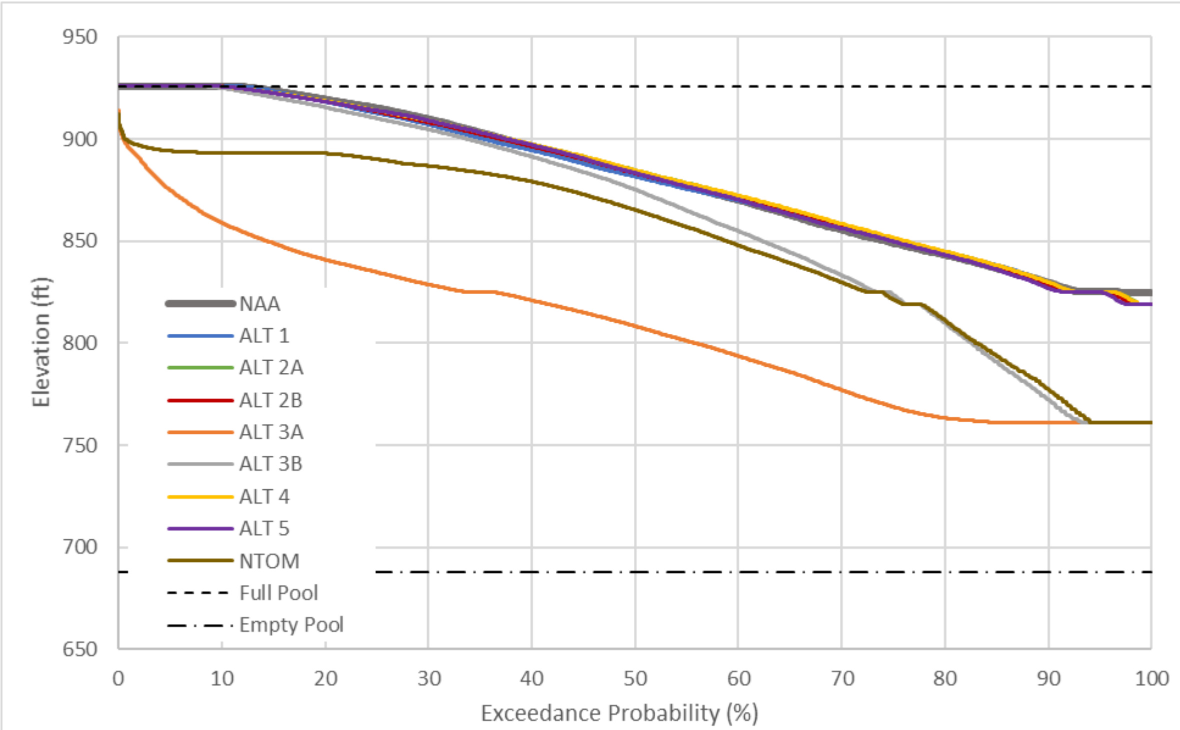

Figure 2-33. Lookout Point Elevation Daily Exceedance

2.2 RUN-OF-RIVER AND FREE FLOWING REACH METRICS

This section includes tables and figures that enumerate the run-of-river reservoir and free-flowing reach comparison summaries for two metrics (Table 2-7 – Table 2-19):

- Sediment Supply
- Geomorphic Change

2.2.1 Sediment Supply

Table 2-7. Quantitative Sediment Re-Entrainment or Bank Failure Potential ($MinPool\ \Delta x$)

Project	NAA Min (ft)	Alt 1 Min (ft)	Alt 1 - NAA	Alt 2A Min (ft)	Alt 2A - NAA	Alt 2B Min (ft)	Alt 2B - NAA	Alt 3A Min (ft)	Alt 3A - NAA
Blue River	1180.0	1149.9	-30.1	1150.0	-30.0	1150.0	-30.0	1165.0	-15.0
Cottage Grove	750.0	735.4	-14.6	750.0	0.0	750.0	0.0	735.4	-14.6
Cougar	1531.0	1515.9	-15.1	1516.0	-15.0	1330.0	-201.0	1517.0	-14.0
Detroit	1450.0	1425.0	-25.0	1425.0	-25.0	1425.0	-25.0	1375.0	-75.0
Dorena	771.0	754.9	-16.1	771.0	0.0	771.0	0.0	754.9	-16.1
Fall Creek	680.0	680.0	0.0	680.0	0.0	680.0	0.0	680.0	0.0
Fern Ridge	353.0	353.0	0.0	353.0	0.0	353.0	0.0	353.0	0.0
Foster	613.0	613.0	0.0	613.0	0.0	613.0	0.0	613.0	0.0
Green Peter	922.0	886.9	-35.1	780.0	-142.0	780.0	-142.0	780.0	-142.0
Hills Creek	1447.0	1413.9	-33.1	1414.0	-33.0	1414.0	-33.0	1446.0	-1.0
Lookout Point	825.0	818.9	-6.1	819.0	-6.0	819.0	-6.0	761.0	-64.0

Project	NAA Min (ft)	Alt 3B Min (ft)	Alt 3B - NAA	Alt 4 Min (ft)	Alt 4 - NAA	Alt 5 Min (ft)	Alt 5 - NAA	NTOM Min (ft)	NTOM - NAA
Blue River	1180.0	1165.0	-15.0	1150.0	-30.0	1150.0	-30.0	1150.0	-30.0
Cottage Grove	750.0	735.4	-14.6	735.0	-15.0	750.0	0.0	750.0	0.0
Cougar	1531.0	1330.0	-201.0	1516.0	-15.0	1330.0	-201.0	1505.0	-26.0
Detroit	1450.0	1375.0	-75.0	1425.0	-25.0	1425.0	-25.0	1425.0	-25.0
Dorena	771.0	754.9	-16.1	754.0	-17.0	771.0	0.0	771.0	0.0
Fall Creek	680.0	680.0	0.0	680.0	0.0	680.0	0.0	680.0	0.0
Fern Ridge	353.0	353.0	0.0	353.0	0.0	353.0	0.0	353.0	0.0
Foster	613.0	613.0	0.0	613.0	0.0	613.0	0.0	613.0	0.0
Green Peter	922.0	780.0	-142.0	886.9	-35.1	780.0	-142.0	780.0	-142.0
Hills Creek	1447.0	1446.0	-1.0	1414.0	-33.0	1414.0	-33.0	1414.0	-33.0
Lookout Point	825.0	761.0	-64.0	819.0	-6.0	819.0	-6.0	761.0	-64.0

Table 2-8. Qualitative Sediment Re-Entrainment or Bank Failure Potential ($MinPool\,\Delta x$)

Project	Alt 1 vs. NAA	Alt 2A vs. NAA	Alt 2B vs. NAA	Alt 3A vs. NAA	Alt 3B vs. NAA	Alt 4 vs. NAA	Alt 5 vs. NAA	NTOM vs. NAA
Blue River	Major	Major	Major	Moderate	Moderate	Major	Major	Major
Cottage Grove	Moderate	Negligible	Negligible	Moderate	Moderate	Moderate	Negligible	Negligible
Cougar	Moderate	Moderate	Major	Moderate	Major	Moderate	Major	Major
Detroit	Major	Major	Major	Major	Major	Major	Major	Major
Dorena	Moderate	Negligible	Negligible	Moderate	Moderate	Moderate	Negligible	Negligible
Fall Creek	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible
Fern Ridge	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible
Foster	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible
Green Peter	Major	Major	Major	Major	Major	Major	Major	Major
Hills Creek	Major	Major	Major	Negligible	Negligible	Major	Major	Major
Lookout Point	Minor	Minor	Minor	Major	Major	Minor	Minor	Major

Table 2-9. Quantitative Bank Sediment Passing Dam Potential ($MinPool\,\Delta v$)

Project	NAA Acre-ft	Alt 1 Acre-ft	Alt 1 % Diff from NAA	Alt 2A Acre-ft	Alt 2A % Diff from NAA	Alt 2B Acre-ft	Alt 2B % Diff from NAA	Alt 3A Acre-ft	Alt 3A % Diff from NAA
Blue River	3971	1155	-71%	1208	-70%	1208	-70%	2299	-42%
Cottage Grove	3139	399	-87%	3139	0%	3139	0%	399	-87%
Cougar	51700	43000	-17%	43500	-16%	234	-100%	44100	-15%
Detroit	154400	115000	-26%	115000	-26%	115000	-26%	56700	-63%
Dorena	7355	1348	-82%	7355	0%	7355	0%	1348	-82%
Fall Creek	93	93	0%	93	0%	93	0%	93	0%
Fern Ridge	2802	2802	0%	2802	0%	2802	0%	2802	0%
Foster	31100	31100	0%	31100	0%	31100	0%	31100	0%
Green Peter	159900	95700	-40%	4500	-97%	4500	-97%	4500	-97%
Hills Creek	153800	105400	-31%	106700	-31%	106700	-31%	152200	-1%
Lookout Point	118800	104600	-12%	104600	-12%	104600	-12%	24600	-79%

Project	NAA Acre-ft	Alt 3B Acre-ft	Alt 3B % Diff from NAA	Alt 4 Acre-ft	Alt 4 % Diff from NAA	Alt 5 Acre-ft	Alt 5 % Diff from NAA	NTOM Acre-ft	NTOM % Diff from NAA
Blue River	3971	2299	-42%	1208	-70%	1208	-70%	1208	-70%
Cottage Grove	3139	399	-87%	399	-87%	3139	0%	3139	0%
Cougar	51700	234	-100%	43500	-16%	234	-100%	38100	-26%
Detroit	154400	56700	-63%	115000	-26%	115000	-26%	115000	-26%
Dorena	7355	1348	-82%	1348	-82%	7355	0%	7355	0%
Fall Creek	93	93	0%	93	0%	93	0%	93	0%
Fern Ridge	2802	2802	0%	2802	0%	2802	0%	2802	0%
Foster	31100	31100	0%	31100	0%	31100	0%	31100	0%
Green Peter	159900	4500	-97%	95700	-40%	4500	-97%	4500	-97%
Hills Creek	153800	152200	-1%	106700	-31%	106700	-31%	106700	-31%
Lookout Point	118800	24600	-79%	104600	-12%	104600	-12%	24600	-79%

Table 2-10. Qualitative Bank Sediment Passing Dam Potential ($MinPool\,\Delta v$)

Project	Alt 1 vs. NAA	Alt 2A vs. NAA	Alt 2B vs. NAA	Alt 3A vs. NAA	Alt 3B vs. NAA	Alt 4 vs. NAA	Alt 5 vs. NAA	NTOM vs. NAA
Blue River	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate
Cottage Grove	Major	Negligible	Negligible	Major	Major	Major	Negligible	Negligible
Cougar	Minor	Minor	Major	Minor	Major	Minor	Major	Moderate
Detroit	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate
Dorena	Major	Negligible	Negligible	Major	Major	Major	Negligible	Negligible
Fall Creek	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible
Fern Ridge	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible
Foster	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible
Green Peter	Moderate	Major	Major	Major	Major	Moderate	Major	Major
Hills Creek	Moderate	Moderate	Moderate	Negligible	Negligible	Moderate	Moderate	Moderate
Lookout Point	Minor	Minor	Minor	Major	Major	Minor	Minor	Major

Table 2-11. Qualitative Reservoir Bank Supplied Sediment ($qualitative\ BSSmetric$)

Project	Alt 1 vs. NAA	Alt 2A vs. NAA	Alt 2B vs. NAA	Alt 3A vs. NAA	Alt 3B vs. NAA	Alt 4 vs. NAA	Alt 5 vs. NAA	NTOM vs. NAA
Blue River	**Moderate**	**Moderate**	**Moderate**	**Moderate**	**Moderate**	**Moderate**	**Moderate**	**Moderate**
Cottage Grove	**Moderate**	Negligible	Negligible	**Moderate**	**Moderate**	**Moderate**	Negligible	Negligible
Cougar	**Minor**	**Minor**	**Major**	**Minor**	**Major**	**Minor**	**Major**	**Moderate**
Detroit	**Moderate**	**Moderate**	**Moderate**	**Moderate**	**Moderate**	**Moderate**	**Moderate**	**Moderate**
Dorena	**Moderate**	Negligible	Negligible	**Moderate**	**Moderate**	**Moderate**	Negligible	Negligible
Fall Creek	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible
Fern Ridge	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible
Foster	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible
Green Peter	**Moderate**	**Major**	**Major**	**Major**	**Major**	**Moderate**	**Major**	**Major**
Hills Creek	**Moderate**	**Moderate**	**Moderate**	Negligible	Negligible	**Moderate**	**Moderate**	**Moderate**
Lookout Point	**Minor**	**Minor**	**Minor**	**Major**	**Major**	**Minor**	**Minor**	**Major**

Table 2-12. Alternative 1 - Qualitative Sediment Supply Metric

Impact Reach	Upstream Project or WVS Impacted Reach	Watershed Supplied (*qualitative* TE_{metric})	Reservoir Supplied (*qualitative* BSS_{metric})	Sediment Augmentation	Upstream Reach Sediment Transfer	Sediment Supply to Reach
Big Cliff Reservoir	Detroit Dam	Negligible	**Moderate**	No	NA	**Moderate**
Dexter Reservoir	Lookout Point Dam	Negligible	**Minor**	No	NA	**Minor**
Foster Reservoir	Green Peter Dam	Negligible	**Moderate**	No	NA	**Moderate**
Lower Willamette	Middle Willamette River	NA	NA	No	Negligible	Negligible
Middle Willamette	Upper Willamette and Santiam Rivers	NA	NA	No	Negligible	Negligible
Upper Willamette	Coast And Middle Fork Willamette and McKenzie River	NA	NA	No	**Minor**	**Minor**
Middle Fork of The Willamette Below Dexter	DEXTER Dam and Fall Creek	NA	NA	No	Negligible	Negligible
Middle Fork of The Willamette Above Lookout Point	Hills Creek Dam	Negligible	**Moderate**	No	NA	**Moderate**
Fall Creek	Fall Creek Dam	Negligible	Negligible	No	NA	Negligible
Coast Fork of The Willamette	Cottage Grove Dam	Negligible	**Moderate**	No	NA	**Moderate**
Row	Dorena Dam	Negligible	**Moderate**	No	NA	**Moderate**
Mainstem Santiam	North Santiam and South Santiam Rivers	NA	NA	No	Negligible	Negligible
North Santiam	Big Cliff Dam	NA	NA	**Yes**	**Minor**	**Major**
South Santiam	Foster Dam	NA	NA	**Yes**	**Minor**	**Major**
Long Tom	Fern Ridge Dam	Negligible	Negligible	No	NA	Negligible
McKenzie	Cougar Dam and Blue River	Negligible	**Minor**	**Yes**	NA	**Major**
Blue	Blue River Dam	Negligible	**Moderate**	**Yes**	NA	**Major**

Table 2-13. Alternative 2A - Qualitative Sediment Supply

Impact Reach	Upstream Project or WVS Impacted Reach	Watershed Supplied (*qualitative* TE_{metric})	Reservoir Supplied (*qualitative* BSS_{metric})	Sediment Augmentation	Upstream Reach Sediment Transfer	Sediment Supply to Reach
Big Cliff Reservoir	Detroit Dam	Negligible	**Moderate**	No	NA	**Moderate**
Dexter Reservoir	Lookout Point Dam	Negligible	**Minor**	No	NA	**Minor**
Foster Reservoir	Green Peter Dam	**Moderate**	**Major**	No	NA	**Major**
Lower Willamette	Middle Willamette River	NA	NA	No	Negligible	Negligible
Middle Willamette	Upper Willamette and Santiam Rivers	NA	NA	No	Negligible	Negligible
Upper Willamette	Coast and Middle Fork Willamette and McKenzie River	NA	NA	No	Negligible	Negligible
Middle Fork of The Willamette Below Dexter	Dexter Dam and Fall Creek	NA	NA	No	Negligible	Negligible
Middle Fork of The Willamette Above Lookout Point	Hills Creek Dam	Negligible	**Moderate**	No	NA	**Moderate**
Fall Creek	Fall Creek Dam	Negligible	Negligible	No	NA	Negligible
Coast Fork of The Willamette	Cottage Grove Dam	Negligible	Negligible	No	NA	Negligible
Row	Dorena Dam	Negligible	Negligible	No	NA	Negligible
Mainstem Santiam	North Santiam and South Santiam Rivers	NA	NA	No	**Minor**	**Minor**
North Santiam	Big Cliff Dam	NA	NA	**Yes**	**Minor**	**Major**
South Santiam	Foster Dam	NA	NA	**Yes**	**Moderate**	**Major**
Long Tom	Fern Ridge Dam	Negligible	Negligible	No	NA	Negligible
McKenzie	Cougar Dam and Blue River	Negligible	**Minor**	**Yes**	NA	**Major**
Blue	Blue River Dam	Negligible	**Moderate**	**Yes**	NA	**Major**

Table 2-14. Alternative 2B - Qualitative Sediment Supply

Impact Reach	Upstream Project or WVS Impacted Reach	Watershed Supplied (*qualitative* TE_{metric})	Reservoir Supplied (*qualitative* BSS_{metric})	Sediment Augmentation	Upstream Reach Sediment Transfer	Sediment Supply to Reach
Big Cliff Reservoir	Detroit Dam	Negligible	**Moderate**	No	NA	**Moderate**
Dexter Reservoir	Lookout Point Dam	Negligible	**Minor**	No	NA	**Minor**
Foster Reservoir	Green Peter Dam	**Moderate**	**Major**	No	NA	**Major**
Lower Willamette	Middle Willamette River	NA	NA	No	Negligible	Negligible
Middle Willamette	Upper Willamette and Santiam Rivers	NA	NA	No	**Minor**	**Minor**
Upper Willamette	Coast And Middle Fork Willamette and McKenzie River	NA	NA	No	**Moderate**	**Moderate**
Middle Fork of The Willamette Below Dexter	Dexter Dam and Fall Creek	NA	NA	No	Negligible	Negligible
Middle Fork of The Willamette Above Lookout Point	Hills Creek Dam	Negligible	**Moderate**	No	NA	**Moderate**
Fall Creek	Fall Creek Dam	Negligible	Negligible	No	NA	Negligible
Coast Fork of The Willamette	Cottage Grove Dam	Negligible	Negligible	No	NA	Negligible
Row	Dorena Dam	Negligible	Negligible	No	NA	Negligible
Mainstem Santiam	North Santiam and South Santiam Rivers	NA	NA	No	**Minor**	**Minor**
North Santiam	Big Cliff Dam	NA	NA	**Yes**	**Minor**	**Major**
South Santiam	Foster Dam	NA	NA	**Yes**	**Moderate**	**Major**
Long Tom	Fern Ridge Dam	Negligible	Negligible	No	NA	Negligible
McKenzie	Cougar Dam and Blue River	**Major**	**Major**	**Yes**	NA	**Major**
Blue	Blue River Dam	Negligible	**Moderate**	**Yes**	NA	**Major**

Table 2-15. Alternative 3A - Qualitative Sediment Supply

Impact Reach	Upstream Project or WVS Impacted Reach	Watershed Supplied (*qualitative TE_{metric}*)	Reservoir Supplied (*qualitative BSS_{metric}*)	Sediment Augmentation	Upstream Reach Sediment Transfer	Sediment Supply to Reach
Big Cliff Reservoir	Detroit Dam	Major	Moderate	No	NA	Major
Dexter Reservoir	Lookout Point Dam	Major	Major	No	NA	Major
Foster Reservoir	Green Peter Dam	Moderate	Major	No	NA	Major
Lower Willamette	Middle Willamette River	NA	NA	No	Negligible	Negligible
Middle Willamette	Upper Willamette and Santiam Rivers	NA	NA	No	Negligible	Negligible
Upper Willamette	Coast And Middle Fork Willamette and McKenzie River	NA	NA	No	Minor	Minor
Middle Fork of The Willamette Below Dexter	Dexter Dam and Fall Creek	NA	NA	No	Moderate	Moderate
Middle Fork of The Willamette Above Lookout Point	Hills Creek Dam	Negligible	Negligible	No	NA	Negligible
Fall Creek	Fall Creek Dam	Negligible	Negligible	No	NA	Negligible
Coast Fork of The Willamette	Cottage Grove Dam	Negligible	Moderate	No	NA	Moderate
Row	Dorena Dam	Negligible	Moderate	No	NA	Moderate
Mainstem Santiam	North Santiam and South Santiam Rivers	NA	NA	No	Minor	Minor
North Santiam	Big Cliff Dam	NA	NA	Yes	Moderate	Major
South Santiam	Foster Dam	NA	NA	Yes	Moderate	Major
Long Tom	Fern Ridge Dam	Negligible	Negligible	No	NA	Negligible
McKenzie	Cougar Dam and Blue River	Moderate	Minor	Yes	NA	Major
Blue	Blue River Dam	Minor	Moderate	Yes	NA	Major

Table 2-16. Alternative 3B - Qualitative Sediment Supply

Impact Reach	Upstream Project or WVS Impacted Reach	Watershed Supplied (*qualitative* TE_{metric})	Reservoir Supplied (*qualitative* BSS_{metric})	Sediment Augmentation	Upstream Reach Sediment Transfer	Sediment Supply to Reach
Big Cliff Reservoir	Detroit Dam	Minor	Moderate	No	NA	Moderate
Dexter Reservoir	Lookout Point Dam	Minor	Major	No	NA	Major
Foster Reservoir	Green Peter Dam	Major	Major	No	NA	Major
Lower Willamette	Middle Willamette River	NA	NA	No	Negligible	Negligible
Middle Willamette	Upper Willamette and Santiam Rivers	NA	NA	No	Minor	Minor
Upper Willamette	Coast And Middle Fork Willamette and McKenzie River	NA	NA	No	Moderate	Moderate
Middle Fork of The Willamette Below Dexter	Dexter Dam and Fall Creek	NA	NA	No	Moderate	Moderate
Middle Fork of The Willamette Above Lookout Point	Hills Creek Dam	Minor	Negligible	No	NA	Minor
Fall Creek	Fall Creek Dam	Negligible	Negligible	No	NA	Negligible
Coast Fork of The Willamette	Cottage Grove Dam	Negligible	Moderate	No	NA	Moderate
Row	Dorena Dam	Negligible	Moderate	No	NA	Moderate
Mainstem Santiam	North Santiam and South Santiam Rivers	NA	NA	No	Minor	Minor
North Santiam	Big Cliff Dam	NA	NA	Yes	Minor	Major
South Santiam	Foster Dam	NA	NA	Yes	Moderate	Major
Long Tom	Fern Ridge Dam	Negligible	Negligible	No	NA	Negligible
McKenzie	Cougar Dam and Blue River	Major	Major	Yes	NA	Major
Blue	Blue River Dam	Minor	Moderate	Yes	NA	Major

Table 2-17. Alternative 4 - Qualitative Sediment Supply.

Impact Reach	Upstream Project or WVS Impacted Reach	Watershed Supplied (*qualitative* TE_{metric})	Reservoir Supplied (*qualitative* BSS_{metric})	Sediment Augmentation	Upstream Reach Sediment Transfer	Sediment Supply to Reach
Big Cliff Reservoir	Detroit Dam	Negligible	**Moderate**	No	NA	**Moderate**
Dexter Reservoir	Lookout Point Dam	Negligible	**Minor**	No	NA	**Minor**
Foster Reservoir	Green Peter Dam	Negligible	**Moderate**	No	NA	**Moderate**
Lower Willamette	Middle Willamette River	NA	NA	No	Negligible	Negligible
Middle Willamette	Upper Willamette and Santiam Rivers	NA	NA	No	Negligible	Negligible
Upper Willamette	Coast And Middle Fork Willamette and McKenzie River	NA	NA	No	**Minor**	**Minor**
Middle Fork of The Willamette Below Dexter	Dexter Dam and Fall Creek	NA	NA	No	Negligible	Negligible
Middle Fork of The Willamette Above Lookout Point	Hills Creek Dam	Negligible	**Moderate**	No	NA	**Moderate**
Fall Creek	Fall Creek Dam	Negligible	Negligible	No	NA	Negligible
Coast Fork of The Willamette	Cottage Grove Dam	Negligible	**Moderate**	No	NA	**Moderate**
Row	Dorena Dam	Negligible	**Moderate**	No	NA	**Moderate**
Mainstem Santiam	North Santiam and South Santiam Rivers	NA	NA	No	Negligible	Negligible
North Santiam	Big Cliff Dam	NA	NA	**Yes**	**Minor**	**Major**
South Santiam	Foster Dam	NA	NA	**Yes**	**Minor**	**Major**
Long Tom	Fern Ridge Dam	Negligible	Negligible	No	NA	Negligible
McKenzie	Cougar Dam and Blue River	Negligible	**Minor**	**Yes**	NA	**Major**
Blue	Blue River Dam	Negligible	**Moderate**	**Yes**	NA	**Major**

Table 2-18. Alternative 5 - Qualitative Sediment Supply

Impact Reach	Upstream Project or WVS Impacted Reach	Watershed Supplied (*qualitative* TE_{metric})	Reservoir Supplied (*qualitative* BSS_{metric})	Sediment Augmentation	Upstream Reach Sediment Transfer	Sediment Supply to Reach
Big Cliff Reservoir	Detroit Dam	Negligible	**Moderate**	No	NA	**Moderate**
Dexter Reservoir	Lookout Point Dam	Negligible	**Minor**	No	NA	**Minor**
Foster Reservoir	Green Peter Dam	**Moderate**	**Major**	No	NA	**Major**
Lower Willamette	Middle Willamette River	NA	NA	No	Negligible	Negligible
Middle Willamette	Upper Willamette and Santiam Rivers	NA	NA	No	**Minor**	**Minor**
Upper Willamette	Coast And Middle Fork Willamette and McKenzie River	NA	NA	No	**Moderate**	**Moderate**
Middle Fork of The Willamette Below Dexter	Dexter Dam and Fall Creek	NA	NA	No	Negligible	Negligible
Middle Fork of The Willamette Above Lookout Point	Hills Creek Dam	Negligible	**Moderate**	No	NA	**Moderate**
Fall Creek	Fall Creek Dam	Negligible	Negligible	No	NA	Negligible
Coast Fork of The Willamette	Cottage Grove Dam	Negligible	Negligible	No	NA	Negligible
Row	Dorena Dam	Negligible	Negligible	No	NA	Negligible
Mainstem Santiam	North Santiam and South Santiam Rivers	NA	NA	No	**Minor**	**Minor**
North Santiam	Big Cliff Dam	NA	NA	**Yes**	**Minor**	**Major**
South Santiam	Foster Dam	NA	NA	**Yes**	**Moderate**	**Major**
Long Tom	Fern Ridge Dam	Negligible	Negligible	No	NA	Negligible
McKenzie	Cougar Dam and Blue River	**Major**	**Major**	**Yes**	NA	**Major**
Blue	Blue River Dam	Negligible	**Moderate**	**Yes**	NA	**Major**

Table 2-19. NTOM - Qualitative Sediment Supply

Impact Reach	Upstream Project or WVS Impacted Reach	Watershed Supplied (*qualitative* TE_{metric})	Reservoir Supplied (*qualitative* BSS_{metric})	Sediment Augmentation	Upstream Reach Sediment Transfer	Sediment Supply to Reach
Big Cliff Reservoir	Detroit Dam	Negligible	**Moderate**	No	NA	**Moderate**
Dexter Reservoir	Lookout Point Dam	**Moderate**	**Major**	No	NA	**Major**
Foster Reservoir	Green Peter Dam	**Moderate**	**Major**	No	NA	**Major**
Lower Willamette	Middle Willamette River	NA	NA	No	Negligible	Negligible
Middle Willamette	Upper Willamette and Santiam Rivers	NA	NA	No	Negligible	Negligible
Upper Willamette	Coast And Middle Fork Willamette and McKenzie River	NA	NA	No	**Minor**	**Minor**
Middle Fork of The Willamette Below Dexter	DEXTER Dam And Fall Creek	NA	NA	No	**Moderate**	**Moderate**
Middle Fork of The Willamette Above Lookout Point	Hills Creek Dam	Negligible	**Moderate**	No	NA	**Moderate**
Fall Creek	Fall Creek Dam	Negligible	Negligible	No	NA	Negligible
Coast Fork of The Willamette	Cottage Grove Dam	Negligible	Negligible	No	NA	Negligible
Row	Dorena Dam	Negligible	Negligible	No	NA	Negligible
Mainstem Santiam	North Santiam and South Santiam Rivers	NA	NA	No	**Minor**	**Minor**
North Santiam	Big Cliff Dam	NA	NA	No	**Minor**	**Minor**
South Santiam	Foster Dam	NA	NA	No	**Moderate**	**Moderate**
Long Tom	Fern Ridge Dam	Negligible	Negligible	No	NA	Negligible
McKenzie	COUGAR Dam And Blue River	**Minor**	**Moderate**	No	NA	**Moderate**

Impact Reach	Upstream Project or WVS Impacted Reach	Watershed Supplied (*qualitative TE_{metric}*)	Reservoir Supplied (*qualitative BSS_{metric}*)	Sediment Augmentation	Upstream Reach Sediment Transfer	Sediment Supply to Reach
Blue	Blue River Dam	Negligible	**Moderate**	No	NA	**Moderate**

2.2.2 Geomorphic Change

Table 2-20. Qualitative Potential for Geomorphic Change

Reaches	Alt 1 vs. NAA	Alt 2A vs. NAA	Alt 2B vs. NAA	Alt 3A vs. NAA	Alt 3B vs. NAA	Alt 4 vs. NAA	Alt 5 vs. NAA	NTOM vs. NAA
Big Cliff Reservoir	Negligible	Negligible	Negligible	**Major**	Negligible	Negligible	Negligible	Negligible
Dexter Reservoir	Negligible	Negligible	Negligible	**Major**	**Major**	Negligible	Negligible	**Major**
Foster Reservoir	Negligible	**Major**	**Major**	**Major**	**Major**	Negligible	**Major**	**Major**
Lower Willamette	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible
Middle Willamette	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible
Upper Willamette	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible
Middle Fork of The Willamette Below Dexter	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible
Middle Fork of The Willamette Above Lookout Point	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible
Fall Creek	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible
Coast Fork of The Willamette	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible
Row	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible
Mainstem Santiam	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible
North Santiam	**Major**	**Major**	**Major**	**Major**	**Major**	**Major**	**Major**	Negligible
South Santiam	**Major**	**Major**	**Major**	**Major**	**Major**	**Major**	**Major**	Negligible
Long Tom	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible
McKenzie	**Major**	**Major**	**Major**	**Major**	**Major**	**Major**	**Major**	Negligible
Blue	**Major**	**Major**	**Major**	**Major**	**Major**	**Major**	**Major**	Negligible

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