Appendix F

An Analysis of Potential Bedload Sediment Effects on Anadromous Fish in the Klamath Basin

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F.1 Introduction

This appendix describes current habitat conditions and assesses the changes to bedload sediment within analysis areas described in Section 3.3 (Aquatic Resources) and under each Klamath Facilities Removal Environmental Impact Statement/Environmental Impact Report alternative described in Chapter 2 (Project Description).

F.2 Methods

The effects analysis relied upon output from the Sediment and River Hydraulics-1 Dimension (SRH-1D) model, Version 2.6 (Huang and Greimann 2010) to estimate the spatial and temporal patterns of dam released sediment and sediment resupply from upstream on bed elevation and bed substrate (percent composition of fines [less than 0.063 mm] sand [0.063 to 2 mm], gravel [2 to 64 mm], and cobble [64 to 256 mm; median substrate size [D50]). The model examined short-term (2-year) changes by month under scenarios of two consecutive wet, median, and dry years (i.e., wet-wet [wet simulation], median-median [median simulation], and dry-dry [dry simulation] years), and longer term changes (5, 10, 25, and 50 years) using a range of flows taken from historical hydrology. A long-term simulation was not conducted for the Klamath River upstream of Iron Gate Dam under the assumption that the gradations at the end of two years are representative and will persist through time, allowing for mild fluctuations as a function of hydrology (Bureau of Reclamation [Reclamation] 2011, David Varyu, personal communication January 4, 2011). The effects determination used conclusions from the analysis and knowledge of habitat requirements of affected fish species to determine how changes in bed elevation and substrate would potentially impact aquatic resources (e.g., pool habitat, spawning gravel, benthic habitat).

Dam released sediment and sediment resupply would affect riverine spawning habitat in both the short and long term. In the short term, increased levels of fine sediment can reduce median substrate size below that usable for salmonids. Excessive amounts of fine sediment occupying interstitial spaces within spawning gravel can impede intragravel flow, preventing exchange of nutrients and dissolved oxygen between the water column and salmonid embryos, and fill interstitial spaces that impede the emergence of alevins thereby reducing survival (Chapman 1988, Bjornn and Reiser 1991). Studies vary on the size of sediment impeding intragravel flow and blocking emergence, but typically, the sizes vary between 1 and 10 mm (Kondolf 2000). A review by Kondolf (2000) found that 10 to 40 percent fine sediment (ranging in size from 2 to 10 mm) within spawning gravels corresponded to 50 percent survival to emergence of various salmonid species. For example, Bjornn and Reiser (1991) summarized the effects of increasing levels of sediment less than 6.35 mm in the bed on salmonid incubation and found embryo survival and survival to emergence largely unaffected at levels less than 20 percent (98 percent and 70 to 95 percent, respectively). Levels more than 30 percent showed minor effect on embryo survival (90 percent), but greater effects on survival to emergence (10 to 60 percent). The proportion (percent) of sand within the bed and median substrate size, as estimated by SRH-1D, was used to estimate the potential effect of the Proposed Action on salmonid spawning success in specific reaches under short-term and long-term simulations. Beds comprised of less than 20 percent sand and D50 within observed suitable ranges of spawning gravel sizes (e.g., 16 to 70 mm for Chinook salmon [Kondolf and Wolman 1993]), were assumed to provide suitable habitat for salmonid spawning, while more than 20 percent sand along with D50 outside observed ranges of spawning gravel sizes were assumed to provide unsuitable conditions. Changes in substrate composition occurring as a result of dam removal that changed habitat from suitable to unsuitable were assumed to have an adverse impact on salmonids.

In the long term, bedload sediment movement and transport are vital to create and maintain functional aquatic habitat. As described in detail below in Section F.4.2, these processes have been disrupted in the Klamath River by the construction of dams.

F.3 Affected Environment

F.3.1 Upper Klamath River: upstream of the influence of J.C. Boyle Reservoir

Bedload conditions in this region of the area of analysis are not expected to be affected by the Klamath Hydroelectric Settlement Agreement. The existing dams (Link and Keno dams) would remain in place and continue to affect hydrology and sediment transport in much the way they do currently.

For practical purposes, no sediment is supplied to the Klamath River from the basin upstream of Keno Dam (Reclamation 2012). Upper Klamath Lake, with its large surface area, traps nearly all sediment delivered from upstream tributaries. All fluvial sediment supplied to reaches upstream of Iron Gate Dam is delivered to the Klamath River between Keno Dam and Iron Gate Dam. Sources within this reach supply 24,160 tons/yr of coarse sediment (1.3 percent of the cumulative average annual basin-wide coarse sediment delivery) (Stillwater Sciences 2010a).

F.3.2 Hydroelectric Reach from upstream end of J.C. Boyle Reservoir to Iron Gate Dam

The Klamath Hydroelectric Project (Project) reservoirs are the dominant feature in this 38 mile (River Mile [RM] 228.3 to RM 190.1) reach, with a 22-mile riverine section between J.C. Boyle Dam (RM 224.1 and the upstream end of Copco 1 Reservoir (203.1) and a 1.4-mile riverine reach between Copco 2 Dam (RM 198.3) and the upstream end of Iron Gate Reservoir (RM 196.9). The four Project reservoirs currently store 13,150,000 cubic yards of sediment (3,605,000 tons) (Reclamation 2012), with Copco 1 Reservoir storing the largest amount and J.C. Boyle Reservoir storing the least (Table F-1). The sediment stored within reservoirs has a high water content and 85 percent of the particles are silts and clays (less than 0.063 mm) while 15 percent are sand or coarser (>0.063 mm) (Gathard Engineering Consulting [GEC] 2006, Stillwater Sciences 2008, Reclamation 2012).

Table F-1. Estimated Volume (yd^3) and Mass (Tons) of Sediment Currently Stored within Hydroelectric Reach Reservoirs

Reservoir	Current Sediment Volume (yd^3)	Current Sediment Mass (tons)
J.C. Boyle	1,000,000	287,000
Copco 1	7,440,000	1,884,000
Copco 2	0	0
Iron Gate	4,710,000	1,434,000
Total	13,150,000	3,600,000

Source: Reclamation 2012

F.3.3 Lower Klamath River: Downstream from Iron Gate Dam

Downstream from Iron Gate Dam, channel conditions reflect the interruption of sediment flux from upstream by Project dams and the eventual resupply of sediment from tributaries entering the mainstem Klamath River (PacifiCorp 2004, Reclamation 2012). The reach from Iron Gate Dam to Cottonwood Creek (RM 190.1 to RM 182.1) is characterized by coarse cobble-boulder bars immediately downstream from the dam transitioning to a cobble bed with pool-riffle morphology farther downstream near Cottonwood Creek (Montgomery and Buffington 1996, PacifiCorp 2004, Stillwater Sciences 2010a). Fine sediment input from tributaries locally decreases sediment size distribution in the mainstem Klamath River, but the effect is temporary, as the bed coarsens before the next tributary junction (PacifiCorp 2004). For example, median grain size at the confluence of Bogus Creek and the Klamath River is 47 mm, but downstream the bed coarsens to a median grain size of 96 mm (PacifiCorp 2004). Cottonwood Creek to the Scott River (RM 182.1 to RM 143.0) is a confined channel with a cobble-gravel bed and pool-riffle morphology (PacifiCorp 2004). The median bed material ranges from 45 to 50 mm, but bar substrates become finer in the downstream direction, with median sizes of 49 mm and 25 mm at the upstream and downstream ends, respectively. Downstream from the Scott River, including through the Seiad Valley, the Klamath River is cobble-gravel bedded with pool-riffle morphology (PacifiCorp 2004). PacifiCorp (2004) also noted increasing quantities of sand and fine gravel on the bed surface with distance downstream, likely reflecting the resupply of finer material from tributaries to the Klamath River.

The Project dams trap all coarse sediment produced in the low sediment yield, young volcanic terrain, upstream of the dams. This results in coarsening of the channel bed downstream from the dams until tributaries re-supply the channel with finer sediment. However, most of the supply from the portion of the watershed upstream of J.C. Boyle Reservoir is trapped in Upper Klamath Lake, which is a natural lake. Most of the sediment supplied to the mainstem Klamath River (~98 percent; Stillwater Sciences 2010a) is delivered from tributaries downstream from Cottonwood Creek, limiting the effects of interrupting upstream sediment supply. Analysis of the area and number of gravel bars and terraces downstream from Iron Gate Dam suggests that the influence of the Project dams on these alluvial features, which are sources of salmonid spawning gravel, is limited to the reach from Iron Gate Dam to Cottonwood Creek (PacifiCorp 2004). This effect is almost entirely absent downstream from the Shasta River, and is undetectable as the Klamath River flows through the Seiad Valley (PacifiCorp 2004).

F.4 No Action/No Project Alternative

F.4.1 Hydroelectric Reach: from upstream end of J.C. Boyle Reservoir to Iron Gate Dam

Under the No Action/No Project Alternative, Project dams would continue to trap fine and coarse sediment. Stillwater Sciences (2010a) estimates that 100,600 yd^3/yr (151,000 tons/yr assuming 1.5 tons/yd) of sediment is delivered to the Klamath River between Keno and Iron Gate Dams. A portion of the fine (less than 0.063 mm; 84,560 yd^3/yr) and all of the coarse (>0.063 mm; sediment load (16,107 yd^3/yr) loads would deposit within the Project reservoirs. Reclamation (2011) estimates Project reservoirs would store 23,500,000 yd^3 of fine and coarse sediment by 2061.

Under the No Action/No Project Alternative, anadromous fish would not have access to this reach, as is currently the case. Effects would be confined to riverine (redband trout, shortnose and Lost River suckers), and nonnative reservoir fish.

F.4.1.1 Redband Trout

Redband trout are found within the Hydroelectric Reach, migrating between tributaries and reservoirs to complete their lifecycle (Hamilton et al. 2011). No substantial effects of changes in bedload sediment dynamics as a result of the No Action/No Project Alternative are anticipated.

F.4.1.2 Lost River and Shortnose Suckers

Federally endangered Lost River and shortnose suckers are found within the Hydroelectric Reach. However, there is little or no successful reproduction of either sucker species downstream from Keno Dam and both contribute minimally to conservation goals or significantly to recovery (Hamilton et al. 2011). No substantial effects of changes in bedload sediment dynamics as a result of the No Action/No Project Alternative are anticipated.

F.4.1.3 Nonnative Reservoir Fish

No substantial effects of changes in bedload sediment dynamics as a result of the No Action/No Project Alternative are anticipated.

F.4.2 Lower Klamath River: Downstream from Iron Gate Dam

Under the No Action/No Project Alternative, the Project dams would continue to interrupt the transport of bedload. These periodic inputs of bedload sediments are necessary for the long-term maintenance of aquatic habitats. As a result of the interception of sand, gravel and coarser sediment supply from sources upstream of Iron Gate Dam the channel downstream from Iron Gate Dam would continue to coarsen and decrease in mobility (Reclamation 2012), providing fewer components of habitat, in particular spawning habitat, and decreased quality habitat over time. This effect would gradually decrease in the downstream direction as coarse sediment is resupplied by tributary inputs (Hetrick et al. 2009), and would be substantially reduced at the Cottonwood Creek confluence (PacifiCorp 2004). As occurs under existing conditions, the coarser bed material is mobilized at higher flows that occur less frequently, resulting in channel features that are unnaturally static and provide lower value aquatic habitat (Buer 1981).

F.4.2.1 Fall-Run Chinook Salmon

The distribution of fall-run Chinook salmon would continue to be limited by Iron Gate Dam. Under the No Action/No Project Alternative, the substrateimmediately downstream from Iron Gate Dam would continue to coarsen, which would result in worsening conditions for spawning in this reach. There would be no change in stream bed elevation or in habitat composition.

F.4.2.2 Spring-Run Chinook Salmon

Habitat relating to bedload movement within the current distribution of spring-run Chinook salmon would not change under the No Action/No Project Alternative, and thus would not affect this species.

F.4.2.3 Coho Salmon

Coho salmon use the Klamath River upstream as far as Iron Gate Dam, but the vast majority of spawning occurs on the tributaries. For those coho that do use the mainstem for spawning habitat, coarsening of the substrate under the No Action/No Project Alternative would further decrease the suitability of the mainstem for spawning, as described for fall-run Chinook salmon above.

F.4.2.4 Summer Steelhead

The habitat changes relating to bedload movement under the No Action/No Project Alternative would not overlap with the distribution of summer steelhead (NRC 2004). Therefore, this alternative would not affect this species.

F.4.2.5 Winter Steelhead

Winter steelhead are currently distributed throughout the Klamath River upstream to Iron Gate dam, but spawn and rear in the tributaries (Federal Energy Regulatory Commission [FERC] 2007). There is no record of winter steelhead spawning in the mainstem Klamath River, which is used mainly as a migration corridor for adults and juveniles (NRC 2004). Therefore, they would not be affected by the bed coarsening that would occur under the No Action/No Project Alternative.

F.4.2.6 Green Sturgeon

The habitat changes relating to bedload movement under the No Action/No Project Alternative would not overlap with the habitat of green sturgeon. Therefore, this alternative would not affect this species.

F.4.3 Klamath River Estuary

As discussed above, the downstream extent of the effect of dams in the Hydroelectric Reach on sediment supply (and channel condition) would be substantially reduced downstream from the Cottonwood Creek confluence, and largely absent downstream from the Shasta River (RM 176.7) (PacifiCorp 2004). There would be no bedload related effects to aquatic species in the Klamath River Estuary Reach under the No Action/No Project Alternative.

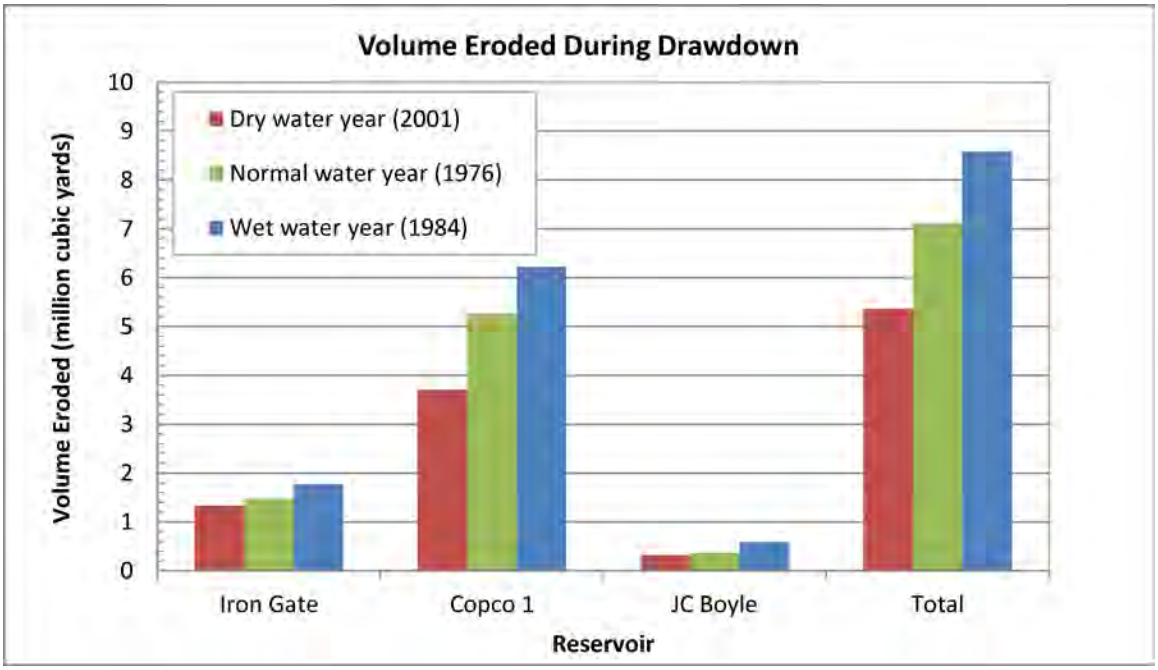
F.4.4 Pacific Ocean Near Shore Environment

As discussed above, the downstream extent of the effect of dams in the Hydroelectric Reach on sediment supply (and channel condition) would be substantially reduced at the Cottonwood Creek confluence, and largely absent downstream from the Shasta River (PacifiCorp 2004). There would be no bedload related effects to aquatic species in the Pacific Ocean near the shore environment under the No Action/No Project Alternative.

F.5 Proposed Action - Full Facilities Removal of Four Dams

F.5.1 Hydroelectric (Hydro) Reach: from upstream end of J.C. Boyle Reservoir to Iron Gate Dam

Dams in the Hydroelectric Reach currently store 13,150,000 y^3 (3,605,000 tons) of sediment (Table F-1) (Reclamation 2012). No sediment is stored within the Copco 2 Reservoir, Copco 1 Reservoir stores the greatest amount, and J.C. Boyle Reservoir stores the least. The SRH-1D model estimated 36 to 57 percent (5.3 to 8.6 million yd^3) of dam-stored sediment would be eroded the first year after dam removal depending on simulation type (wet, median, or dry) (Figure F-1). Sediment not eroded from the reservoirs during the first year would be stored in gravel bars and terraces, and released more slowly through surficial and fluvial processes (Stillwater Sciences 2008).



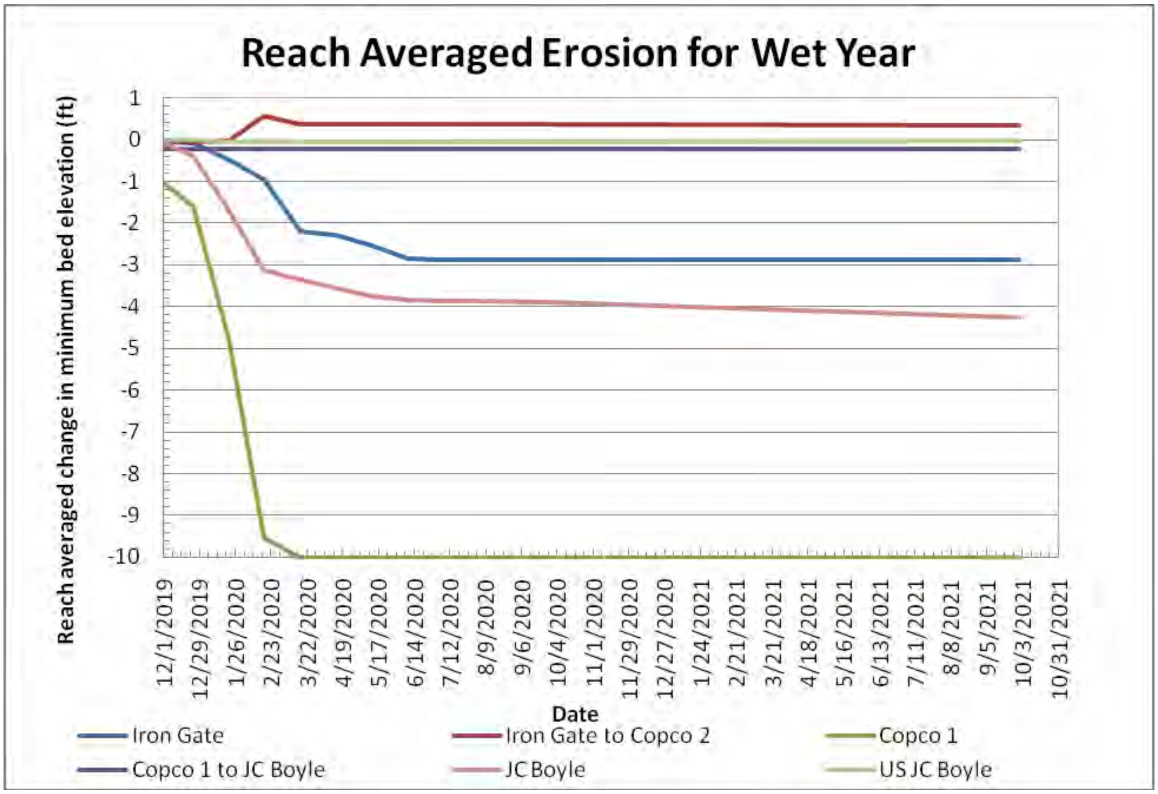
Source: Reclamation 2012.

Figure F-1. Cumulative Sediment Erosion from Dams in the Hydroelectric Reach during Drawdown Beginning January 2020.

F.5.1.1 Changes in Bed Elevation

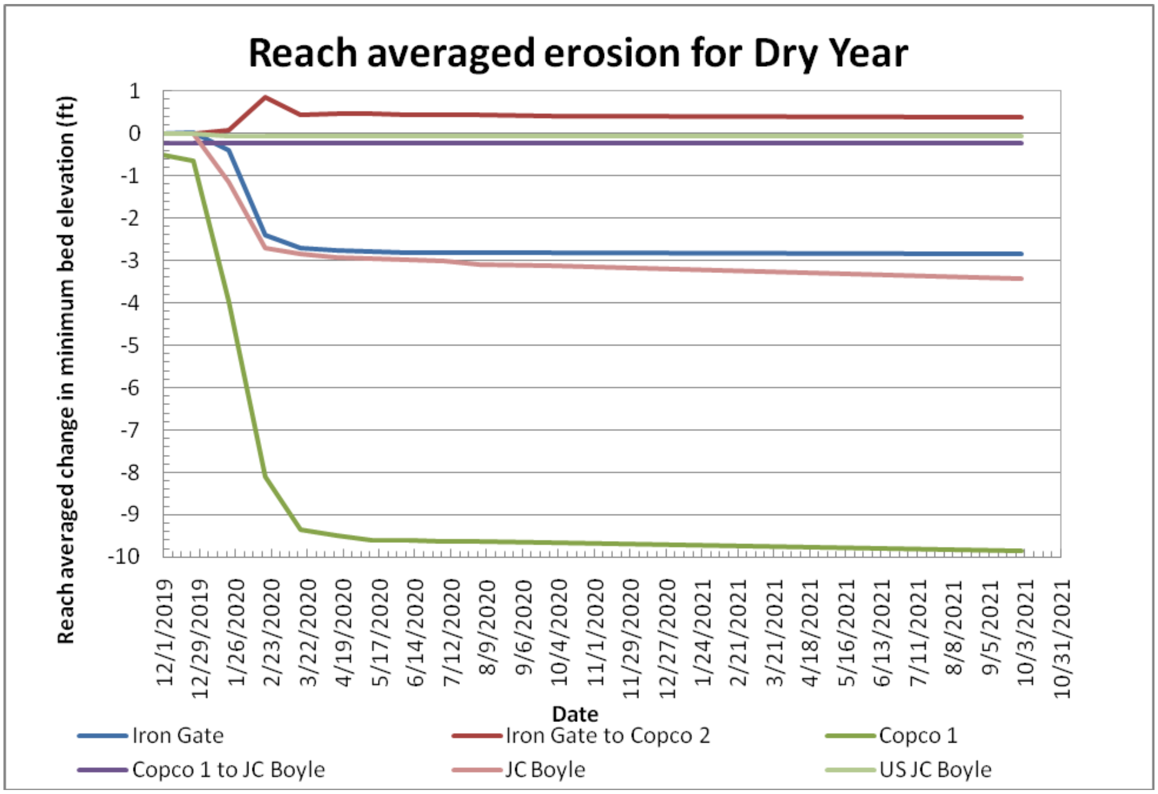
SRH-1D data show substantial decreases in bed elevation within the reservoirs during drawdown (January 2020 to April 2020), which stabilizes as the bed within the historic river channel reaches pre-dam elevations (Reclamation 2012; Blair Greimann, personal communication 23 December 2010). In all simulations, the greatest decrease in bed elevation occurs through the Copco 1 Reservoir (10 ft of erosion), followed by J.C. Boyle Reservoir (3-4 ft), and Iron Gate Reservoir (3 ft) (Figure F-2 and Figure F-3). Draining J.C. Boyle, Copco 1, Copco 2, and Iron Gate Reservoirs and erosion of the accumulated sediment is expected to result in the river channels within reservoirs reaching their pre-dam elevations within six months. These sections of the river would revert to and maintain a pool-riffle morphology, similar to that existing in reach downstream from Iron Gate Dam, due to restoration of fluvial geomorphic processes (PacifiCorp 2004).

The river reaches between the reservoirs from Copco 1 Reservoir to J.C. Boyle Dam and from Iron Gate Reservoir to Copco 2 Dam show little change during the wet and dry simulations (Figure F-2 and Figure F-3). Both simulations indicate some minimal deposition between Iron Gate Reservoir and Copco 2 Dam, but little change in the other two riverine reaches (Figure F-2 and Figure F-3). Upstream of J.C. Boyle Reservoir (US J.C. Boyle) is also shown in Figure F-2 and Figure F-3, but is part of the Upper Klamath Basin above J.C. Boyle Reservoir reach. Nonetheless, model simulations indicate little, if any change in this portion of the Klamath River.



Source: Reclamation 2012.

Figure F-2. Reach Averaged Erosion in the Hydroelectric Reach during Wet Year.

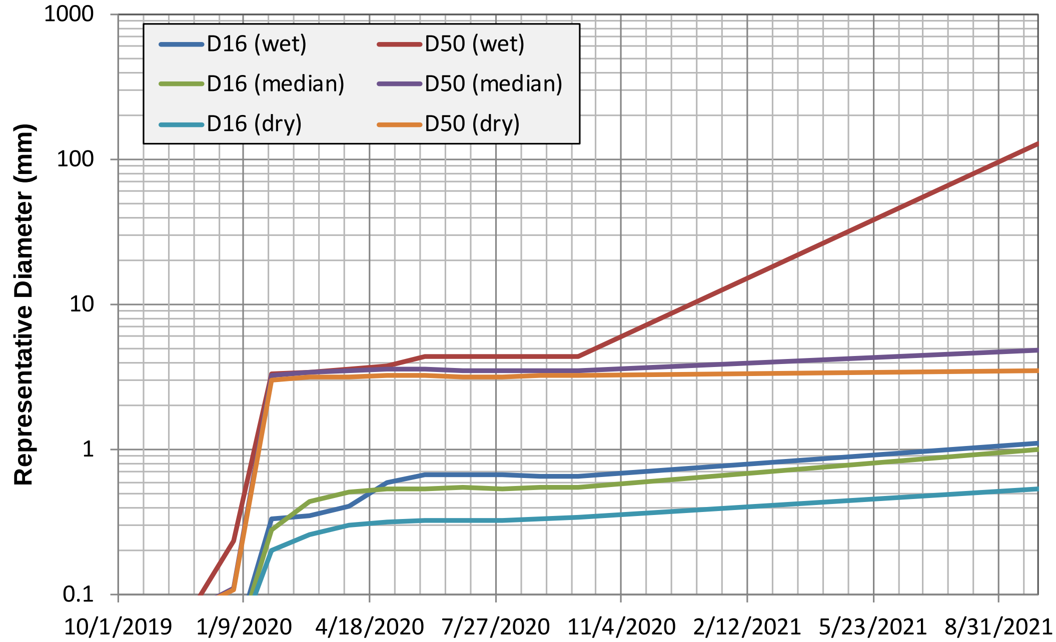


Source: Reclamation 2012.

Figure F-3. Reach Averaged Erosion in the Hydroelectric Reach during Dry Year.

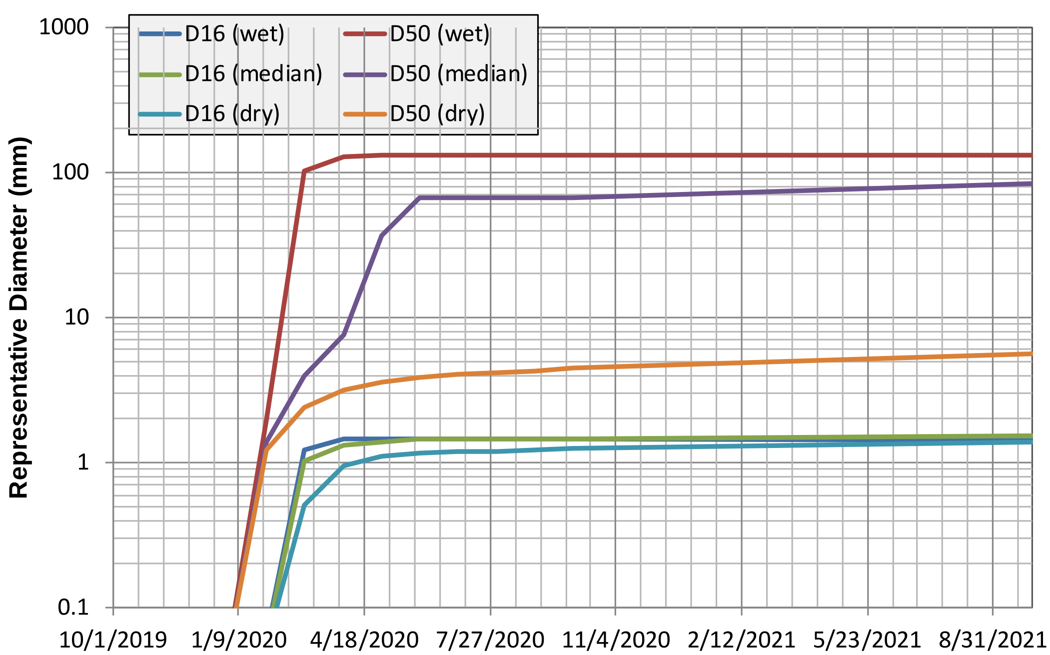
F.5.1.2 Changes in Bed Substrate

Within the reservoirs, SRH-1D modeling data for the first two years after dam removal show decreases in fine sediment and increases in median substrate size after completion of drawdown that stabilize as the bed returns to pre-dam elevation. The proportion of fine sediment decreases from 50 to 80 percent to near zero within 2 months after drawdown; the proportion of sand initially increases to 30 to 50 percent then decreases to 10 to 25 percent; the proportion of gravel changes (mostly increases) to 20 to 35 percent; and the proportion of cobble increases to 50 to 70 percent, depending on the reservoir and simulation water year type (i.e., wet, median, or dry) (Attachment F-1, Figures F1-1 to F1-9). D50s increase from less than 1 mm to small cobble (64 to 128 mm) (Figure F-4, Figure F-5, and Figure F-6) (Reclamation 2012). D50s may be slightly finer under the dry scenario, but are expected to approach wet and median scenario D50s over time (Reclamation 2012). The D16 (the size at which 16 percent of all particles are finer) shows similar patterns of increase and stabilization during drawdown, but remains sand or finer (less than 2 mm) under the dry and median simulations in the J.C. Boyle and Iron Gate Reservoir reaches (Figure F-4 and Figure F-6) (Reclamation 2012).



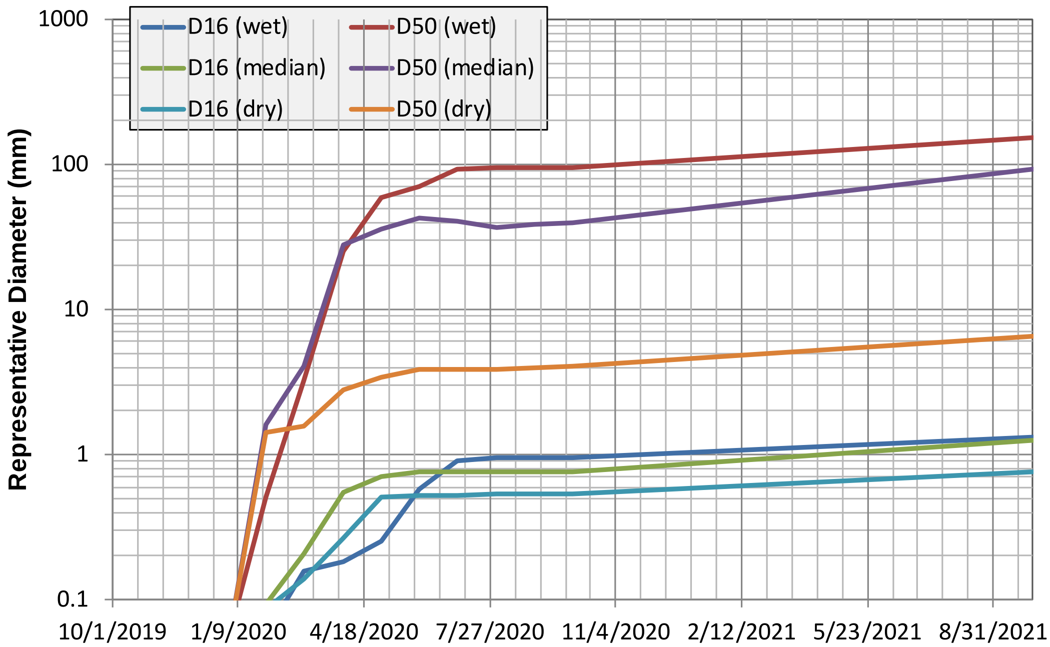
Based on simulation results provided by Reclamation, March 2012.

Figure F-4. Reach Averaged D16 and D50 in J.C. Boyle Reservoir Reach Following Dam Removal.



Based on simulation results provided by Reclamation, March 2012.

Figure F-5. Reach Averaged D16 and D50 in Copco 1 Reservoir Reach Following Dam Removal.

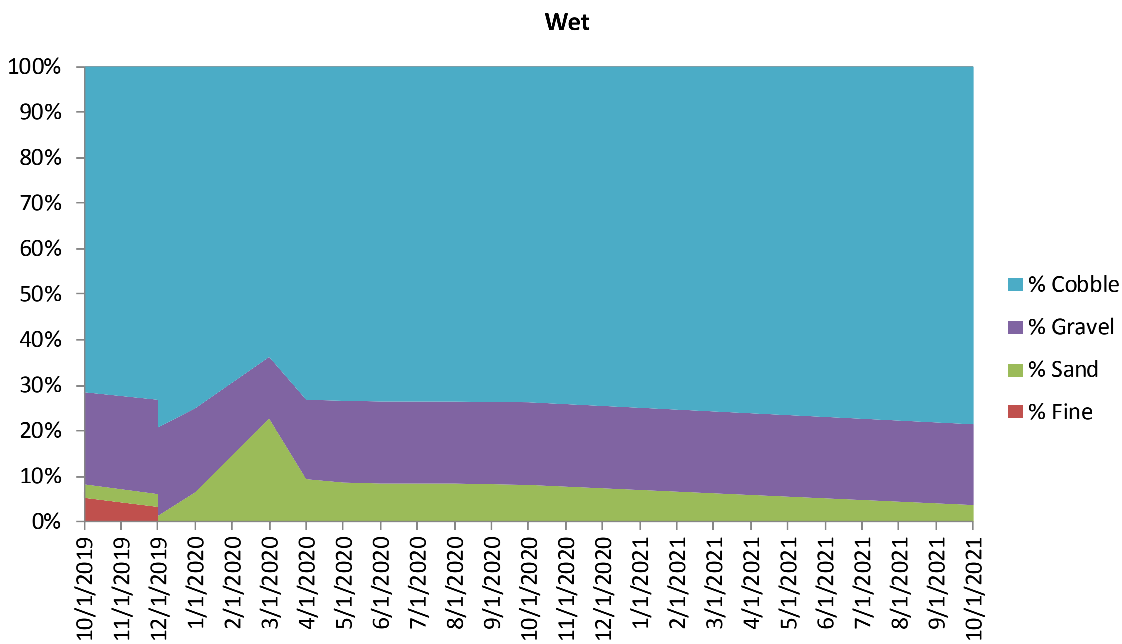


Based on simulation results provided by Reclamation, March 2012.

Figure F-6. Reach Averaged D16 and D50 in Iron Gate Reservoir Reach Following Dam Removal.

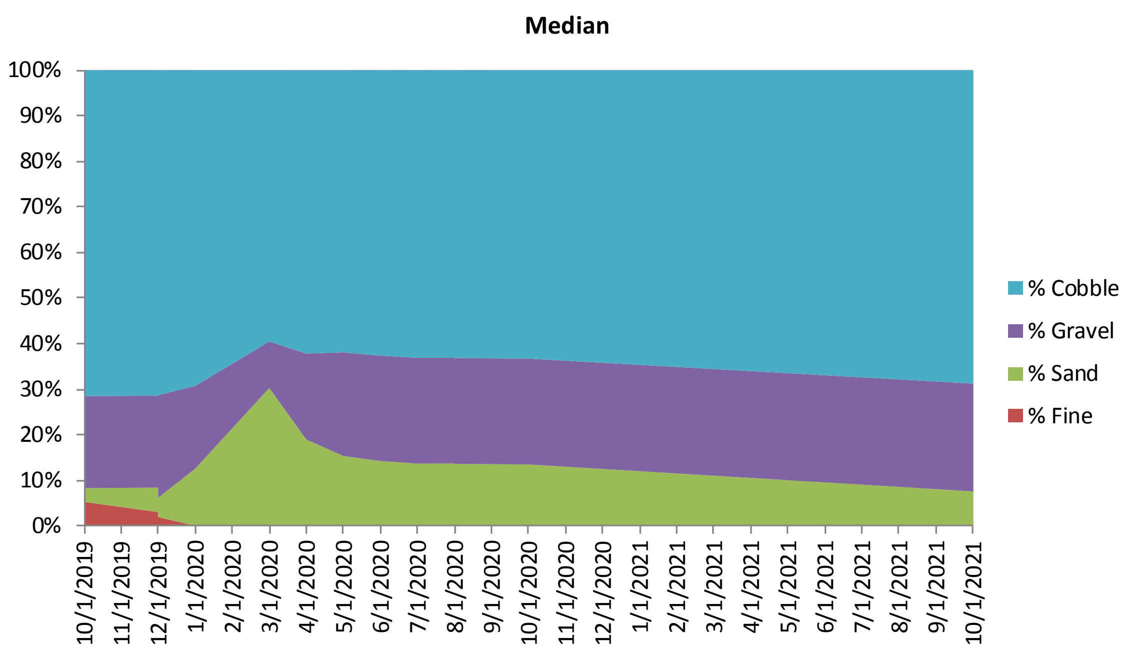
The river reaches upstream of J.C. Boyle Reservoir and from Copco 1 Reservoir to J.C. Boyle Dam show little change in bed composition during drawdown. There is practically no temporal change in bed material in response to drawdown regardless of water year upstream of J.C. Boyle Reservoir and from J.C. Boyle Dam to Copco 1 Reservoir (Attachment F-1, Figures F1-10 to F1-15). These reaches are initially predominantly cobble (90 percent) with small fractions of gravel and sand and this composition is maintained throughout the 2-yr simulation.

The Copco 2 Dam to Iron Gate Reservoir reach shows decreases in the combined proportion of sand and fine: the wet, median, and dry simulations show decreases to approximately 20, 30, and 35 percent, respectively, two years after drawdown (Figure F-7 and Figure F-8).



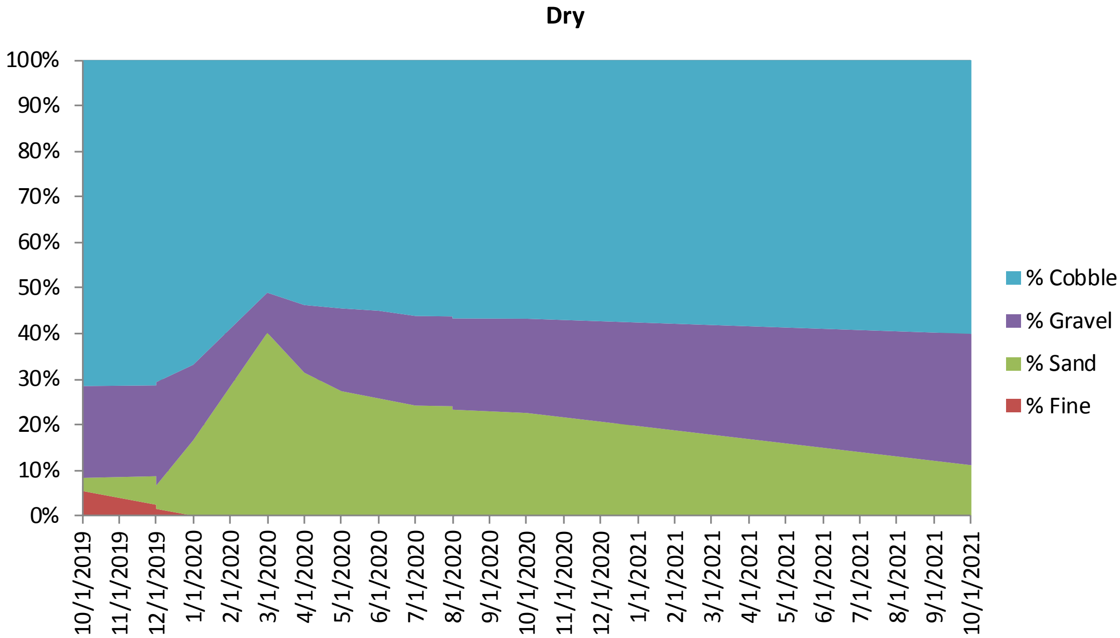
Based on simulation results provided by Reclamation, March 2012.

Figure F-7. Simulated Bed Composition from Iron Gate Reservoir to Copco 2 Dam for Two Successive Wet Water Years during and after Drawdown.



Based on simulation results provided by Reclamation, March 2012.

Figure F-8. Simulated Bed Composition from Copco 2 to Iron Gate Reservoirs for Two Successive Median Water Years during and after Drawdown.



Based on simulation results provided by Reclamation, March 2012.

Figure F-9. Simulated Bed Composition from Copco 2 to Iron Gate Reservoirs for Two Successive Dry Water Years during and after Drawdown.

Fall-Run Chinook Salmon

The Proposed Action Could Have Effects on Pool Habitat

The Proposed Action would likely erode sediment from reservoirs within the Hydroelectric Reach and, at most, cause minor (less than 0.5 ft) deposition in river reaches between reservoirs (Figure F-2 and Figure F-3). River channels within reservoir reaches would likely excavate to their pre-dam elevations within six months, and likely revert to and maintain a pool-riffle morphology, similar to the Downstream from Iron Gate Dam reach, due to restoration of riverine processes along the Hydroelectric Reach (PacifiCorp 2004). This would likely create holding and rearing habitat for anadromous salmonids. The removal of the dams would also create access to these habitats and habitats in reaches upstream. Fall-run Chinook salmon would first access the Hydroelectric Reach in fall 2020, at which time, the removal of the dam structures to stream elevation is expected to be complete.

The Proposed Action Could Have Effects on Spawning Habitat

The Proposed Action would likely increase median substrate sizes in the Hydroelectric Reach. SRH-1D results show that during fall of 2020, when fall-run Chinook salmon first return to spawn after dam removal, D50s would range from coarse gravel (16 to 32 mm) to small cobble (64 to 128 mm) (Figure F-4, Figure F-5, and Figure F-6), which is within the preferred range for Chinook salmon spawning (16 to 70 mm [Kondolf and

Wolman 1993]). As discussed above, the proportion of sand in the bed may be still be high in former reservoir reaches and in the reach from Iron Gate Reservoir to Copco 2 Dam (Figure F-9, Attachment F-1, Figures F1-1 to F1-9), which may impact spawning success (Chapman 1988), but would still provide spawning opportunities. River reaches between reservoirs would provide the preferred substrate size range for fall-run Chinook salmon, with very little sand (Attachment F-1, Figures F1-10 to F1-15), suggesting high quality spawning habitat. The removal of the dams would also create access to these habitats and habitats in reaches upstream.

Spring-Run Chinook Salmon

Spring-run Chinook salmon distribution extends from the mouth of the Klamath River upstream to the Salmon River (Stillwater Sciences 2010b). Most spawning and rearing takes place within the Trinity and Salmon rivers. The current distribution of spring-run Chinook salmon does not extend as far as the Hydroelectric Reach. Spring-run Chinook salmon would likely expand their range in response to dam removal and benefit from this action in the same manner as fall-run Chinook salmon. Because spring-run Chinook salmon generally do not spawn on the mainstem, bedload sediment benefits would be less than that for fall-run Chinook salmon.

Coho Salmon

The Proposed Action would restore access for coho salmon to the mainstem Klamath River and its tributaries upstream of Iron Gate Dam, increasing available rearing and spawning habitat. The changes to pool and spawning habitat described above for fall-run Chinook salmon may also provide suitable conditions for coho salmon spawning. Coho generally do not spawn in the mainstem, so the benefits to this species would not be as great, in terms of mainstem spawning.

Summer Steelhead

Summer steelhead distribution extends from the mouth of the Klamath River upstream to Empire Creek (RM 166.8) and may be rare above Seiad Creek (RM 130.9) due to seasonal high water temperatures (NRC 2004). With the removal of the dams, summer steelhead would be able to re-establish themselves throughout their much of their historic range, including the mainstem and tributaries within the hydroelectric reach and the Upper Basin (Hamilton et al. 2005). Under the Proposed Action improved pool habitat would benefit rearing winter steelhead, as described for other salmonids above. Winter Steelhead

Winter steelhead spawn and generally rear in the tributaries (FERC 2007). There is no record of winter steelhead spawning in the mainstem Klamath River, which is used mainly as a migration corridor for adults and juveniles (NRC 2004). With the removal of the dams, winter steelhead would be able to re-establish themselves throughout their much of their historic range, including the mainstem and tributaries within the hydroelectric reach and the Upper Basin (Hamilton et al. 2005). Under the Proposed Action improved pool habitat would benefit rearing winter steelhead, as described for other salmonids above.

Green Sturgeon

Green sturgeon distribution extends from the mouth of the Klamath River upstream to the Salmon River (RM 66.5), with some observed migrating into the Salmon River, but do not ascend past Ishi Pishi Falls (Moyle 2002, FERC 2007), nor are they expected to do so if the dams were removed. Most spawning and rearing takes place within the lower mainstems of the Klamath and Trinity rivers. Changes in bedload sediment under the Proposed Action are not anticipated to affect green sturgeon.

Redband Trout

Within the Hydroelectric Reach, redband trout migrate between tributaries, free flowing Project reaches, and reservoirs to complete their lifecycle (Hamilton et al. 2011). The Proposed Action would eliminate reservoir habitat as dams within the Hydroelectric Reach are removed and sediment moves downstream (Figure F-2 and Figure F-3). Under the Proposed Action improved pool habitat would benefit rearing redband trout, as described for other salmonids above.

Lost River and Shortnose Suckers

Federally endangered Lost River and shortnose suckers occur within the Hydroelectric Reach. The Proposed Action would eliminate reservoir habitat as dams within the Hydroelectric Reach are removed and sediment is allowed to move downstream (Figure F-2 and Figure F-3). However, there is little or no successful reproduction of either sucker species downstream from Keno Dam and contributes minimally to conservation goals or significantly to recovery (Hamilton et al. 2011). Changes in bedload sediment under the Proposed Action are not anticipated to affect Lost River and shortnose suckers.

Nonnative Reservoir Fish

As discussed above, the Proposed Action would eliminate reservoir habitat as dams are removed. Changes in bedload sediment under the Proposed Action are not anticipated to affect nonnative reservoir fish.

F.5.2 Lower Klamath River: Downstream from Iron Gate Dam

The streambed downstream from Iron Gate Dam would be affected by reservoir released sediment and reconnection of natural sediment supply from upstream. The sediment stored within the reservoirs has a high water content and 85 percent of the particles are silts and clays (less than 0.063 mm) while 15 percent are sand or coarser (greater than 0.063 mm) (GEC 2006, Stillwater Sciences 2008, Reclamation 2012). As such, most sediment eroded from the reservoirs would be silt and clay (less than 0.063 mm) with smaller fractions of sand (0.063 to 2 mm), gravel (2 to 64 mm), and cobble (64 to 256 mm) (GEC 2006, Stillwater Sciences 2010c, Reclamation 2012) (Table F-2). Silt and finer substrate, which comprise a large proportion of the volume of stored sediments, would likely be transported as suspended sediment and would travel to the ocean shortly after being eroded and mobilized (GEC 2006). Coarser (greater than 0.063 mm) sediment would travel downstream more slowly, attenuated by channel storage and the frequency and magnitude of mobilization flows. The amount of sand transported in suspension would vary with discharge, with greater proportions of sand in suspension at higher discharges. The values in Table F-2 will be different than those in included in a text box titled *Sediment Weight and Volume in the Four Facilities and Erosion with Dam Removal* in Section 2.2, because the values in Table F-2 are those showing the net sediment released below Iron Gate where as the values in the Section 2.2 table are the estimated amount of sediment eroded from each individual reservoir. The amount of sediment released below Iron Gate will generally be lower than the amount of sediment eroded from each reservoir because there will be some deposition of material in the reaches between the dams and within the reservoir themselves.

Table F-2. Estimated Mass (Tons) of Reservoir Sediment Released Below Iron Gate by Size for Wet, Median and Dry Water Year Types the First Year After Dam Removal

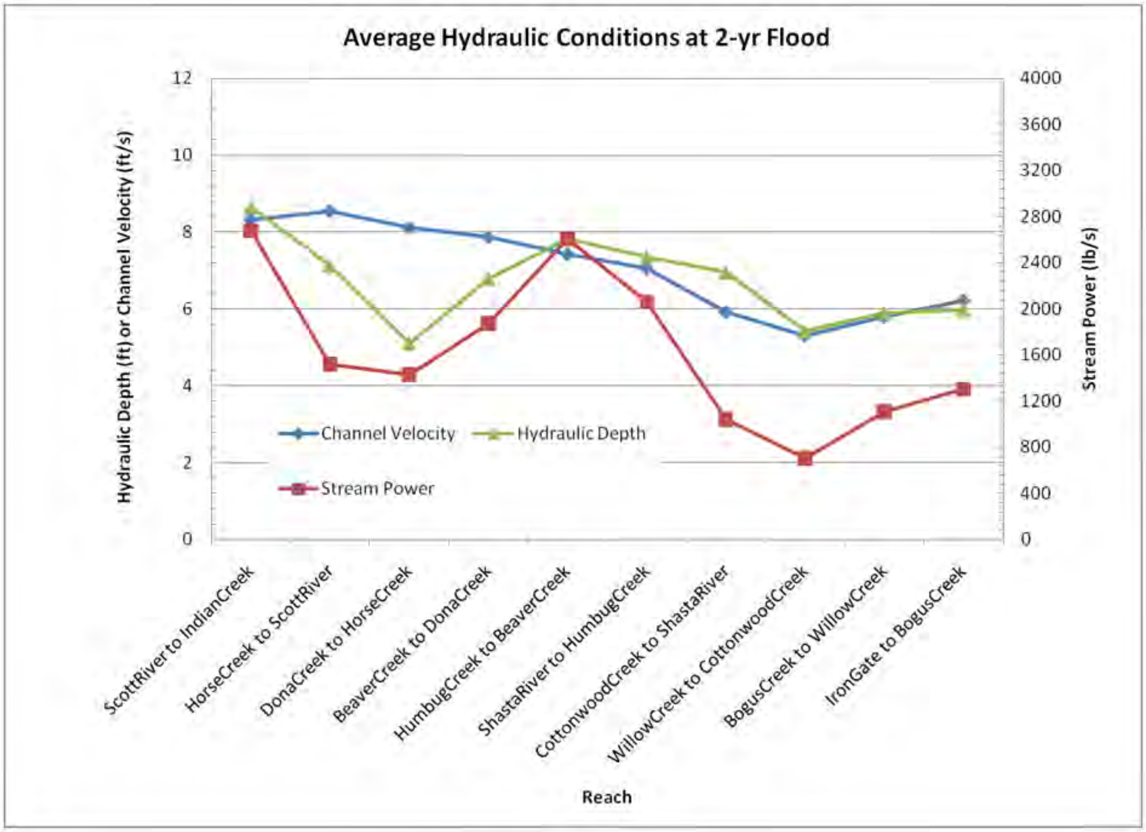
Sediment Size	Wet	Median	Dry
Silt (<0.063 mm)	2,352,233	1,808,719	1,238,525
Sand (0.063 to 2.0 mm)	185,797	276,558	124,371
Gravel (2 to 64 mm)	37,942	18,213	1,116
Cobble (64 to 256 mm)	5,889	1,513	76
Total	2,581,862	2,105,002	1,364,089

Source: Reclamation 2012

F.5.2.1 Downstream Extent of Effect

The effect of dam released sediment and sediment resupply likely extends from Iron Gate Dam to Cottonwood Creek (Reclamation 2012). Estimates of reach averaged stream power (based upon channel depth, width, and slope) show a decrease from Iron Gate Dam to Cottonwood Creek, with stream power then increasing again downstream from Cottonwood Creek (Figure F-10). The increase suggests that short- or long-term sediment deposition, either from dam release or sediment resupply, is unlikely downstream from Cottonwood Creek. Using Cottonwood Creek as the downstream extent of gravel and cobble bedload related effects, 8 miles of channel could potential be affected by sediment release and resupply. The affected channel represents 4 percent of the total channel length of the mainstem Klamath River downstream from Iron Gate Dam (190 miles).

Downstream from Cottonwood Creek this also means that the bed is expected to be overall more mobile due to the additional transport of sand as bedload from Copco I Reservoir to a distance beyond the Shasta River.



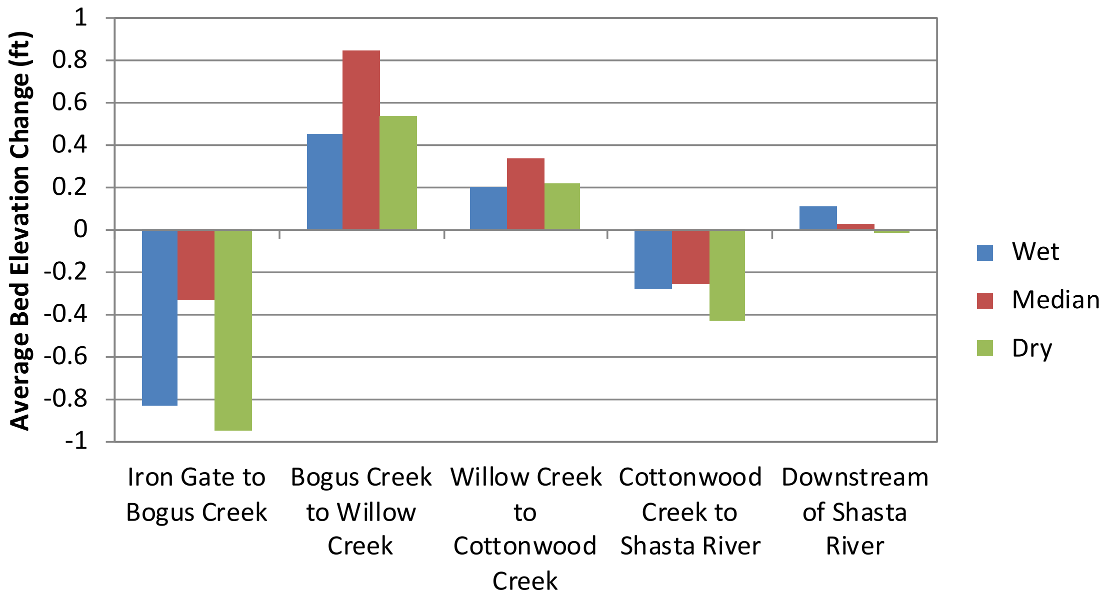
Source: Reclamation 2012.

Figure F-10. Reach Averaged Stream Power Downstream from Iron Gate Dam.

F.5.2.2 Changes in Bed Elevation

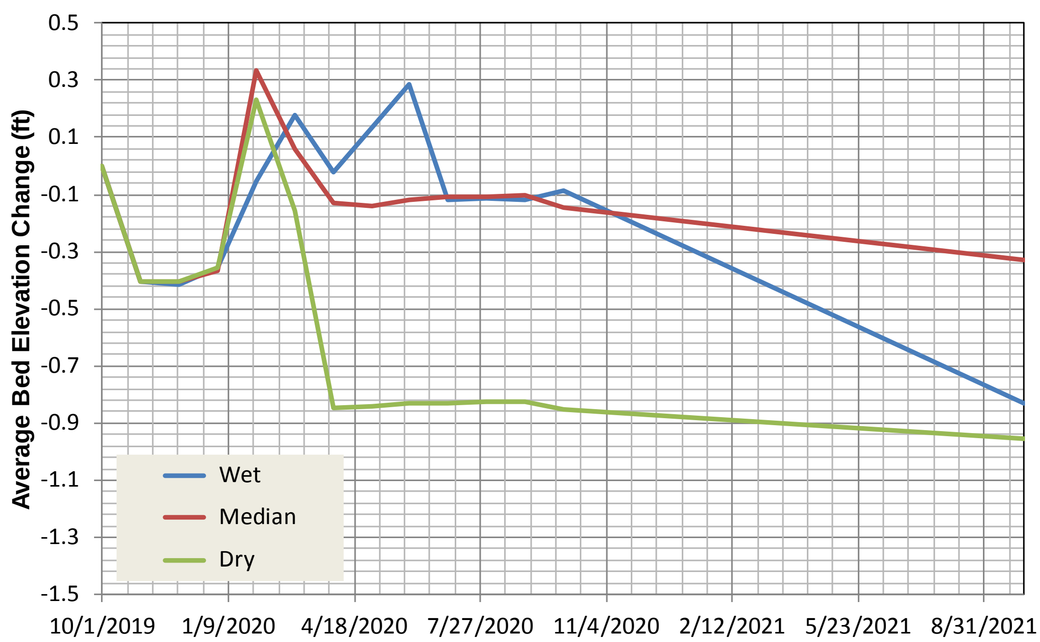
Short-term (2-yr) SRH-1D model simulations estimate up to 1 ft of reach averaged erosion between Iron Gate Dam and Bogus Creek (RM 189.8) (0.3 to 1 ft) and up to 0.8 ft of deposition between Bogus Creek and Willow Creek (RM 185.2) (0.4 to 0.8 ft). Reaches farther downstream showed no apparent change (< 0.5 ft) (Figure F-11). Reach averaged bed elevation between Iron Gate Dam to Bogus Creek fluctuates within ±1 ft of the initial elevation (Figure F-12). Similarly, the reach from Bogus Creek to Willow Creek also fluctuates within ±1 ft of the initial elevation (Figure F-13).

In the long-term (from 5 to 50 years), after downstream translation of dam released sediment, bed elevation would adjust to a new equilibrium, which includes sediment supplied by upstream tributaries that was formerly trapped by dams within the Hydroelectric Reach. Reclamation (2011) expects 2 to 3 feet of aggradation between Iron Gate Dam and Cottonwood Creek over the next 50 years.



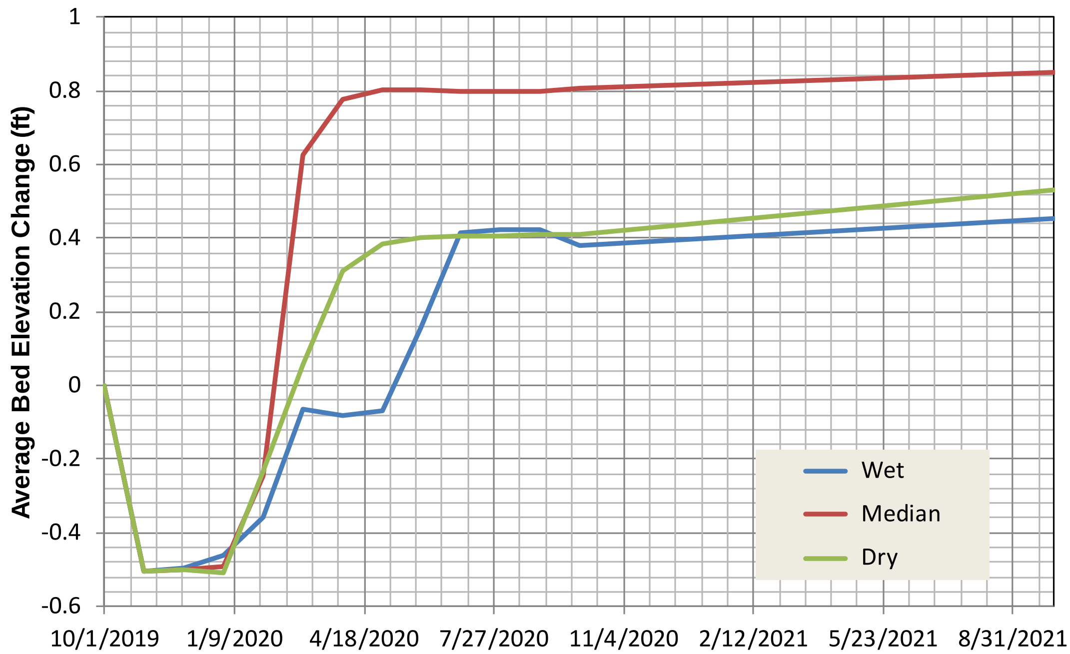
Based on simulation results provided by Reclamation, March 2012.

Figure F-11. Reach Averaged Bed Elevation Change for Two Successive Wet, Median, or Dry Water Years Following Reservoir Drawdown.



Based on simulation results provided by Reclamation, March 2012.

Figure F-12. Reach Averaged Bed Elevation Change for Two Successive Wet, Median, or Dry Water Years following Reservoir Drawdown from Iron Gate Dam to Bogus Creek.

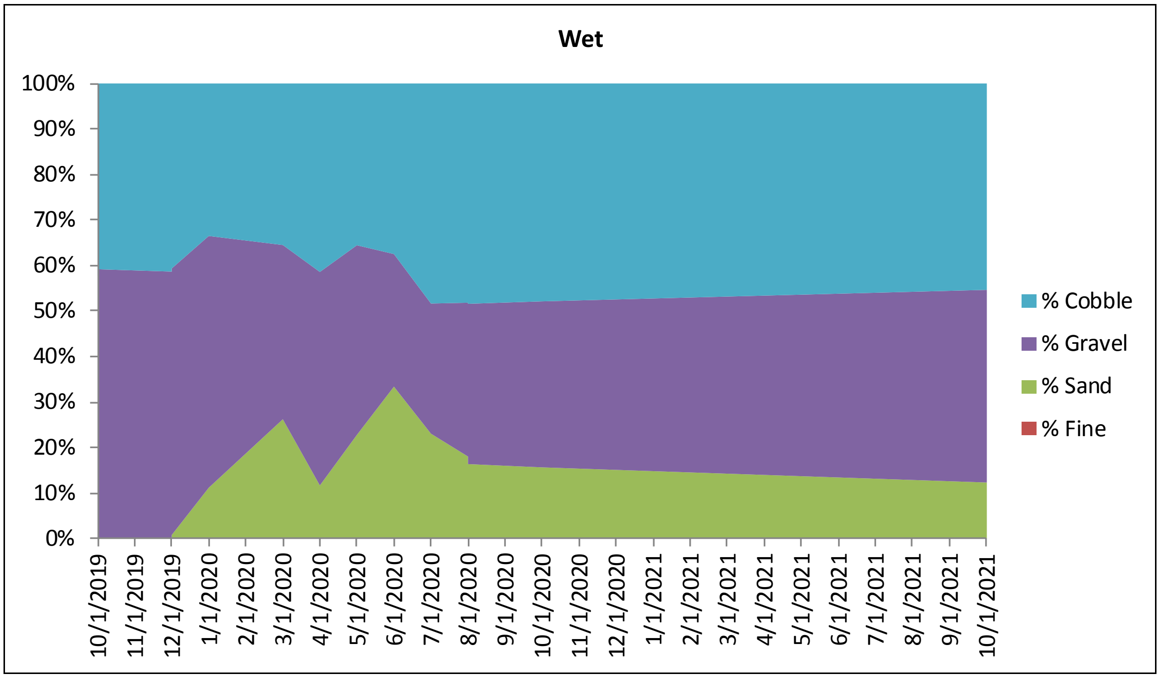


Based on simulation results provided by Reclamation, March 2012.

Figure F-13. Reach Averaged Bed Elevation Changes for Two Successive Wet, Median, or Dry Water Years following Reservoir Drawdown from Bogus Creek to Willow Creek.

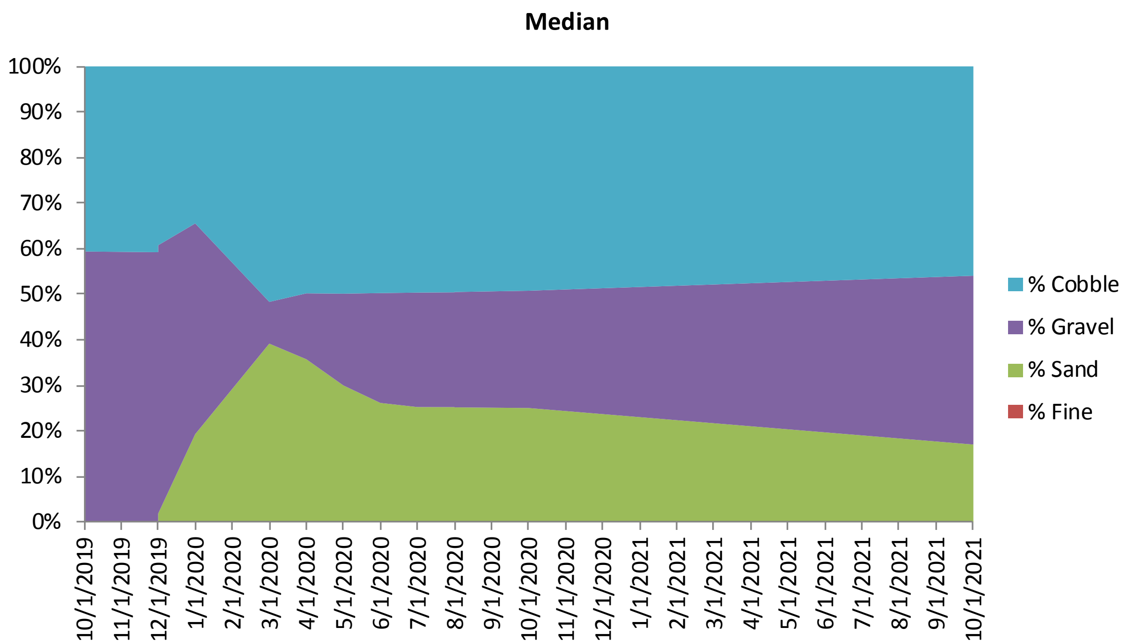
F.5.2.3 Changes in Bed Substrate

In the short-term (less than 2 years following drawdown), SRH-1D model output indicates dam-released sediment and sediment resupply would increase the proportion of sand in the river bed and decrease median bed substrate size (Reclamation 2012). Under wet, median and dry simulations, sand within the bed would increase to 30 to 35 percent by March to June 2020 following drawdown, gradually decreasing to 10 to 20 percent by September 2021, while median substrate size would fluctuate slightly before finally stabilizing to approximately the initial condition of 100 mm (Figure F-14, Figure F-15, Figure 16, and Figure F-17). The reach from Bogus Creek to Willow Creek shows an increase in the proportion of sand (up to 40 percent at times) and a decrease in median substrate size (from an initial value of approximately 80 mm down to 40 to 65 mm) (Attachment F-1 Figures F1-16 to F1-19). Similarly, Willow Creek to Cottonwood Creek shows an increase in the proportion of sand (up to 35 percent at times) and a decrease in median substrate size (from an initial value of approximately 65 mm down to 38 to 45 mm) (Attachment F-1, Figures F1-20 to F1-23). The probability of flushing dam-released fine sediment from the Iron Gate Dam to Bogus Creek reach depends upon flow. Reclamation (2011) estimated that a flow of 6,000 cfs would be necessary to flush sands and fine material from the bed following dam removal. This flow is approximately equal to the 2-yr flood at Iron Gate and therefore there is approximately a 50% probability that this flow would occur in a given year. If there is a median or dry year the year of dam removal, then it is estimated that there is a 50% probability that by the end of 2021 that the sands and finer material would be flushed from the bed. By the end of 2022, there would be approximately a 75% probability that sands would be flushed from the bed. By end of 2025, there would be over a 95% probability that sands and finer material would be flushed from the bed.



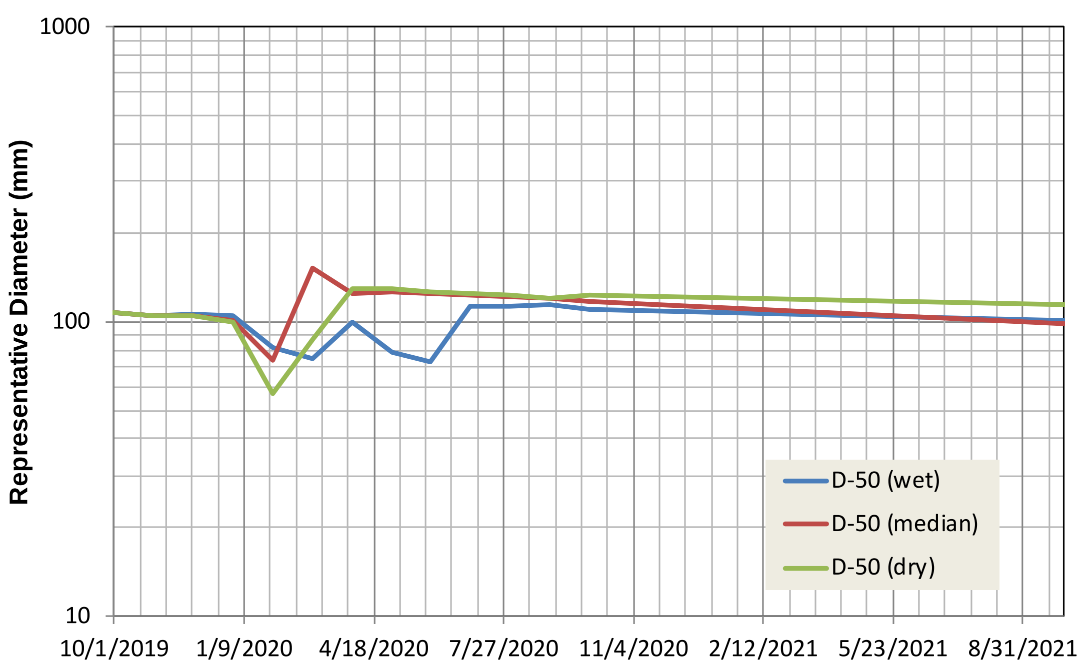
Based on simulation results provided by Reclamation, March 2012.

Figure F-14. Simulated Bed Composition from Iron Gate Dam to Bogus Creek for Two Successive Wet Water Years Following Reservoir Drawdown.



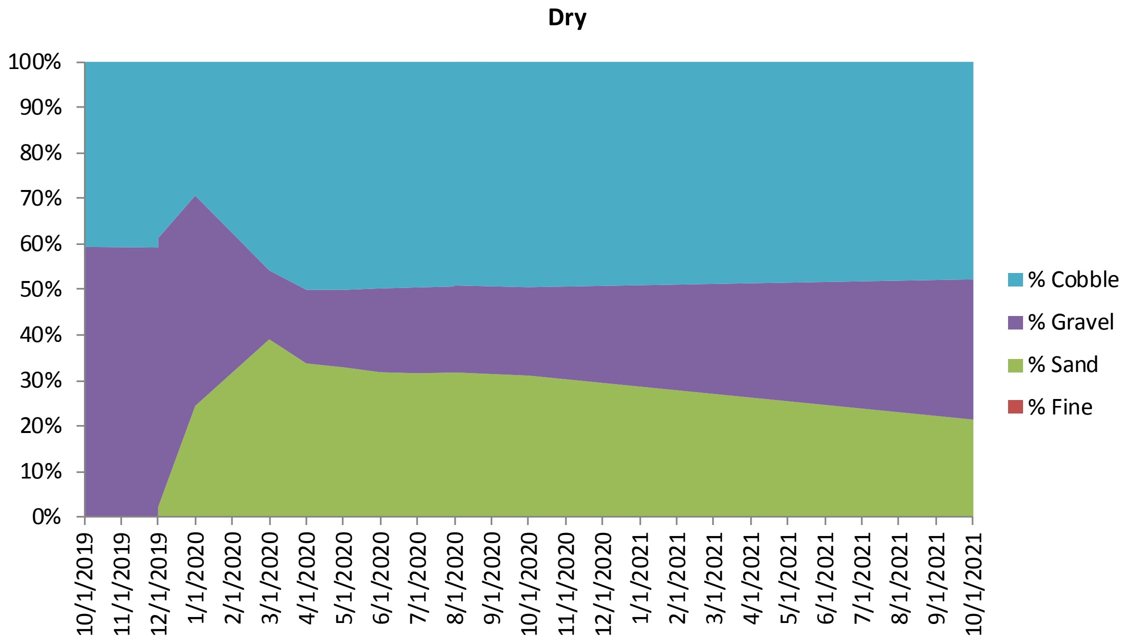
Based on simulation results provided by Reclamation, March 2012.

Figure F-15. Simulated Bed Composition from Iron Gate Dam to Bogus Creek for Two Successive Wet Water Years Following Reservoir Drawdown.



Based on simulation results provided by Reclamation, March 2012.

Figure F-16. Simulated D50 (mm) From Iron Gate Dam to Bogus Creek for Successive Wet, Median, and Dry Water Years Following Reservoir Drawdown.



Based on simulation results provided by Reclamation, March 2012.

Figure F-17. Simulated Bed Composition from Iron Gate Dam to Bogus Creek for Two Successive Dry Water Years Following Reservoir Drawdown.

Longer-term (5, 10, 25, and 50 years) simulations show increases in the proportion of sand to 5 to 22 percent and decreases in D50 to approximately 50 to 55 mm (Attachment F-1, Figures F1-24 to F1-30) after five years that stabilize and continue through to year 50. Reaches downstream from Cottonwood Creek showed no long-term changes to bed composition or substrate size (Reclamation 2012).

Under the Proposed Action, the flows required to mobilize bed sediment would decrease as the bed would become finer due to dam released sediment and sediment resupply from upstream tributaries. Reclamation (2011) estimated the magnitude and return period of flows required to mobilize sediment downstream from Iron Gate Dam 10 years after dam removal using reach averaged predicted grain sizes from long-term SRH-1D simulations. The estimates show that under the Proposed Action, sediment mobilization flows from Bogus Creek to Willow Creek and from Willow Creek to Cottonwood Creek would range from 3,000 to 7,000 cfs (1.5 to 2.5 year return period) and 5,000 to 9,000 cfs (1.5 to 3.2 year return period), respectively, lower than current conditions or the No Action/No Project Alternative. Downstream from the Shasta River, there would be no difference in bed mobilization flows or return period between the Proposed Action and current conditions or the No Action/No Project Alternative.

Bedload sediment aquatic species effects

Fall-run Chinook Salmon

The Proposed Action Could Have Short-Term Effects On Spawning Habitat

When fall-run Chinook salmon fry spawned in 2019 would emerge, the proportion of sand in the bed is anticipated to be higher than under existing conditions (Figure F-17) in the short-term. Increased sand composition could negatively impact embryo survival to emergence (Chapman 1988). The high sand content to Cottonwood Creek would be a small proportion of the total channel length (8 mi; 4 percent of current total channel length) and sediment deposition lessens downstream from Bogus Creek to Cottonwood Creek (Figure F-11). Further, the effects would only occur in successive median or dry years (Figure F-15 and Figure F-17), with less of an effect in successive wet years (Figure F-14). Reclamation (2011) estimated that a flow of 6,000 cfs would be necessary to flush sands and fine material from the bed following dam removal. This flow is approximately equal to the 2-yr flood at Iron Gate and therefore there is approximately a 50% probability that this flow would occur in a given year. If there is a median or dry year the year of dam removal, then it is estimated that there is a 50% probability that by the end of 2021 that the sands and finer material would be flushed from the bed. By the end of 2022, there would be approximately a 75% probability that sands would be flushed from the bed. By end of 2025, there would be over a 95% probability that sands and finer material would be flushed from the bed. Flume experiments conducted by Wooster et al. (2008) also found that the amount of fine sediment infiltrating into a static channel bed during sediment pulses decreased with depth below the surface, with significant deposition only observed to a shallow depth (< 1 D90). The results suggest that fine sediment infiltration into the gravel bed (and potential spawning gravel) during dam removal would be minimal and short-lived, able to be transported downstream during subsequent high flows (Stillwater Sciences 2008).

Short-term (2–yr) aggradation of sediment from the dams could be substantial below Iron Gate Dam downstream to Willow Creek (Figure F-12 and Figure F-13). The amount of deposition within these reaches is expected to bury any salmonid redds and associated eggs to such a depth that alevin emergence would likely be adversely affected. Farther downstream, depositional depths are such that alevins in the gravel would likely not be affected.

Adult fall-run Chinook salmon returning to spawn the Iron Gate Dam to Cottonwood Creek reach in 2020, and potentially in 2021 would encounter a higher proportion of sand in the substrate than what was present prior to dam removal (Figure F-14, Figure F-15, Figure F-17). Salmonids are naturally adapted to select spawning habitat that maximizes egg survival and do so in response to geomorphic processes alter river channels from year to year. Adults returning in 2020 or 2021 would still spawn in the Iron Gate Dam to Cottonwood Creek reach if suitable habitat was present. If no suitable habitat exists, adults could choose to spawn in downstream reaches or newly accessible (due to dam removal) upstream reaches with suitable habitat. Because of this behavioral adaptation, eggs of fall-run Chinook salmon returning in 2020 or 2021 (or after) would likely be unaffected by the changes described above.

Fall-run Chinook salmon eggs deposited in the fall of 2019 in the reach from Iron Gate Dam to Willow Creek could be lost; and less substantial losses may continue to occur downstream to the vicinity of Cottonwood Creek. However, the changes described above affect a small proportion of the total habitat available to the species on the mainstem below Iron Gate Dam (8 miles or 4 percent of current total channel length, Figure F-10) and do not affect tributaries that may provide additional habitat. Finally, these effects are likely to occur in only a single year.

The Proposed Action Could Have Long-Term Effects on Spawning Habitat

Five years after dam removal, SRH-1D estimates that the proportion of sand in the bed would be less than 15 percent and median substrate sizes decrease from existing conditions to near 55 mm in all reaches from Iron Gate Dam to Cottonwood Creek (Attachment F-1, Figures F1-24 to F1-30) (Reclamation 2012). Less than 15 percent sand in spawning gravel is not expected to substantially reduce survival to emergence and 55 mm falls within the observed range for Chinook salmon spawning (16 to 70 mm [Kondolf and Wolman 1993]). Changes in bed elevation are not expected to negatively affect fall-run Chinook salmon spawning. Overall, changes in bedload sediment will benefit fall-run Chinook salmon in the long-term.

The Proposed Action Could Have Short-Term Effects on Pool Habitat

Deposition associated with the Proposed Action may aggrade pools or overwhelm other habitat features used for adult holding or juvenile rearing in the 8 mile reach downstream from Iron Gate Dam, especially within the 5.1 mile reach from Iron Gate Dam to Willow Creek (Figure F-11 and Figure F-12). This may affect the depth and area of available pool habitat. The SRH-1D model estimates reach average changes and is not capable of providing data on a morphologic unit-scale (e.g., pool), or describing how sediment is distributed along the channel (Reclamation 2012). Flume experiments conducted by Stillwater Sciences (2008) found that a coarse-bedded channel with pool-riffle morphology, similar to that found in the Klamath River below Iron Gate Dam, would maintain pool topography during temporary channel filling (i.e., during pulses of fine and coarse sediment). Pools are erosional features, evacuating sediment pulses before other morphologic units (e.g., riffles), and would likely return to their pre-sediment release depth after downstream translation of the pulse (Stillwater Sciences 2008). These results suggest that effects on pool habitat would likely be minor. The most severe effects would also be limited to a small proportion of the total channel length to Willow Creek (less than 3 percent [5.1 mi]), as sediment deposition lessens downstream from Willow Creek to Cottonwood Creek (Figure F-11). The lifestages of fall-run Chinook salmon that use pools, adults, juveniles, and fry are not tied to specific pools and are capable of seeking desirable areas.

The Proposed Action Could Have Long-Term Effects on Pool Habitat

In the long-term (from 5 to 50 years), after downstream translation of dam released sediment, bed elevation would adjust to a new equilibrium that includes sediment supplied by upstream tributaries (sediment that was formerly trapped by dams within the Hydroelectric Reach). The river would likely revert to and maintain its natural pool-riffle morphology, similar to current condition, and pool frequency, size, and depth would likely remain similar.

Spring-Run Chinook Salmon

It is anticipated that under the Proposed Action spring-run Chinook salmon distribution would extend upstream of Iron Gate Dam. Although mainstem spawning is not anticipated, some spring-run Chinook salmon may be affected by short- and long-term effects on pool habitat, as described above for fall-run Chinook salmon.

Coho Salmon

The Proposed Action Could Have Short-Term Effects on Spawning Habitat

Most coho salmon spawn in tributaries to the Klamath River. Most rearing occurs on these tributaries as well, although some coho juveniles may rear in the mainstem when conditions in the tributaries become unsuitable. The effects of bedload and sediment composition changes would likely eradicate any coho salmon eggs that were spawned on the mainstem above Willow Creek in 2019 (as described for fall-run Chinook salmon above), although the number is expected to be low because most spawning occurs in tributaries. In subsequent years, coho salmon would be able to behaviorally adapt to bed composition changes (i.e., disperse to suitable spawning habitat), and no effect would be expected.

The Proposed Action Could Have Long-Term Effects on Spawning Habitat

Five years after dam removal, SRH-1D estimates that the proportion of sand in the bed would be less than15 percent and median substrate sizes decrease in all reaches from Iron Gate Dam to Cottonwood Creek (Attachment F-1, Figures F1-24 to F1-30) (Reclamation 2012). The decrease in median substrate size may increase mainstem spawning of coho salmon, although the majority of spawning would still be anticipated to occur in tributaries. The increase in sand composition (less than 15 percent sand) within spawning gravel is not expected to substantially reduce survival to emergence (Chapman 1988).

The Proposed Action Could Have Short-Term Effects on Pool Habitat

The effects to coho salmon resulting from short-term filling of pools in the mainstem would be minor and short term for the same reasons described for fall-run Chinook salmon.

The Proposed Action Could Have Long-Term Effects on Pool Habitat

The effects to coho salmon resulting from long-term filling of pools in the mainstem would be negligible for the same reasons described for fall-run Chinook salmon.

Summer Steelhead

Summer steelhead currently occupy the Klamath River downstream from Empire Creek (RM 166.8). This run of steelhead spawns in tributaries, although some fish may rear in the mainstem. Based on current distribution, no short-term bedload sediment effects associated with dam removal are expected for summer steelhead, and long-term benefits are similar to those described for coho salmon above.

Winter Steelhead

Winter steelhead adults and juvenile use the mainstem Klamath River mainly as a migration corridor (NRC 2004), but access the river all the way to Iron Gate Dam. Like summer steelhead, spawning occurs in tributaries (NRC 2004). Changes in bedload and geomorphology would not impact spawning or incubation habitat and would have minimal effect on rearing habitat as described for fall-run Chinook salmon and summer steelhead above.

Green Sturgeon

Current green sturgeon distribution extends from the mouth of the Klamath River upstream to the Ishi Pishi Falls (Moyle 2002, FERC 2007), with some observed migrating into the Salmon River. As discussed above, bedload sediment effects related to dam released sediment or sediment resupply likely extend as far as the Cottonwood Creek, and therefore are not anticipated to affect green sturgeon.

F.5.3 Klamath River Estuary

As discussed in above, bedload sediment effects related to dam released sediment or sediment resupply likely do not extend as past Cottonwood Creek. Therefore, there would be no bedload related effects to aquatic species in the Klamath River Estuary Reach under the Proposed Action.

F.5.4 Pacific Ocean Near Shore Environment

As discussed above, bedload sediment effects related to dam released sediment or sediment resupply likely do not extend as far downstream as Cottonwood Creek (RM 180). There would be no bedload related effects to aquatic species in the Pacific Ocean near shore environment under the Proposed Action.

F.6 Partial Facilities Removal of Four Dams Alternative

Alternative 3-Partial Facilities Removal would remove enough of each dam to allow free-flowing river conditions and volitional fish passage at all times. Under the partial removal alternative, portions of each dam would remain in place along with ancillary buildings and structures such as powerhouses, foundations, tunnels, and pipes, all of which would be outside of the 100-year flood prone width. Under this alternative, embankment/earth-filled dam and concrete dam structures would be removed (see Chapter 5) similar to the Proposed Action, allowing release of dam-stored sediment. Effects to bedload sediment under the Partial Facilities Removal Alternative are expected to be the same as those for the Proposed Action.

F.7 Fish Passage at Four Dams Alternative

Under Alternative 4, Fish Passage at Four Dam, fish passage structures would be installed at each dam to allow for upstream fish passage (see Chapter 5). No portion of the dams would be removed under this alternative and sediment would continue to be stored behind Project dams, similar to the No Action/No Project Alternative. Effects to bedload sediment under the Partial Facilities Removal Alternative are expected to be the same as under the No Action/No Project Alternative.

F.8 Fish Passage at J.C. Boyle and Copco 2, Remove Copco 1 and Iron Gate

Under this alternative, J.C. Boyle Dam would continue to store sediment, but the storage capacity of Copco 2 Dam would likely be filled by the release of sediments during the Copco 1 Dam. This scenario has not been modeled, but the effects of bedload sediment movement under the Fish Passage at J.C. Boyle and Copco 2, Remove Copco 1 and Iron Gate Alternative are expected to be similar to, but of slightly lesser magnitude, than under Alternative 2 Proposed Action: Full Facilities Removal.

F.9 Mitigation Measure Analysis: Proposed Action with Mechanical Sediment Removal

The Lead Agencies conducted an analysis on Mechanical Sediment Removal (dredging) as a potential mitigation measure as part of investigation of feasibility of potential mitigation measures during the formulation of alternatives. This potential measurewould remove sediment from J.C. Boyle, Copco 1, and Iron Gate Reservoirs prior to and during dredging. Dredging would occur where the sediment would be most easily eroded during drawdown of the reservoirs according to the following assumptions:

Historical river channel would be eroded to its pre-dam elevation

Historical tributaries would be eroded to their pre-dam course and elevation

Narrow and steep canyons would erode

The reservoir side slopes erode at a slope of 10 Horizontal: 1 Vertical

The volume of sediment removed under the Mechanical Sediment Removal mitigation measure is shown in Table F-3.

Table F-3. Estimated Volume (yd^3) and Mass (Tons) of Sediment Currently Stored within Hydroelectric Reach Reservoirs

Reservoir	Sediment Volume (yd^3) Dredged Pre-Drawdown	Sediment Volume (yd^3) Dredged During Drawdown	Sediment Volume (yd^3) Dredged Total
J.C. Boyle	335,900	219,500	555,400
Copco 1	176,600	1,277,500	1,454,100
Copco 2	0	0	0
Iron Gate	106,100	733,100	839,200
Total	618,600	2,230,100	2,848,700

Source: Reclamation 2012

The Mechanical Sediment Removal mitigation measure would reduce the amount of sediment released downstream compared to the Proposed Action. Most sediment eroded from the dams would still be silt and clay (less than 0.063 mm) with smaller fractions of sand (0.063 to 2 mm), gravel (2 to 64 mm), and cobble (64 to 256 mm), but 35-40 percent less overall mass would be released downstream than under the Proposed Action (Table F-4). The discussion below focuses on the reach from Iron Gate Dam to Bogus Creek, which had the greatest changes in bed elevation and bed substrate composition (compared to downstream reaches) under the Proposed Action.

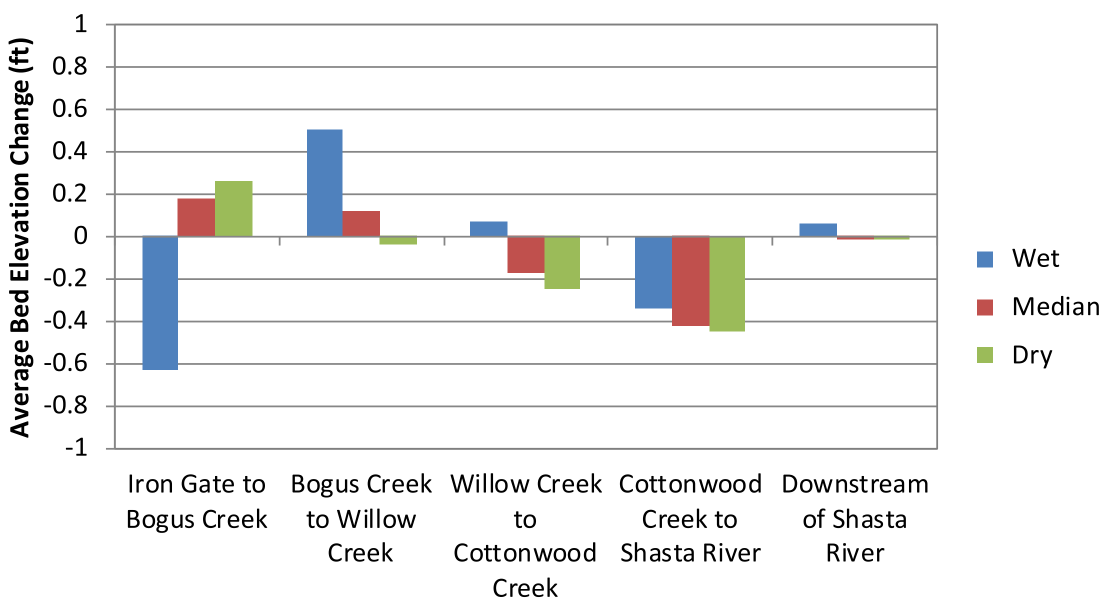
Table F-4. Estimated Mass (Tons) of Reservoir Released Sediment by Size Under Wet, Median and Dry Water Years

Substrate Size	Wet	Median	Dry
Silt (<0.063 mm)	1,617,174	1,213,062	783,952
Sand (0.063 to 2.0 mm)	117,119	134,544	39,718
Gravel (2 to 64 mm)	8,841	7,074	15
Cobble (64 to 256 mm)	1,196	518	3
Total	1,744,331	1,355,199	823,688

Source: Reclamation 2012

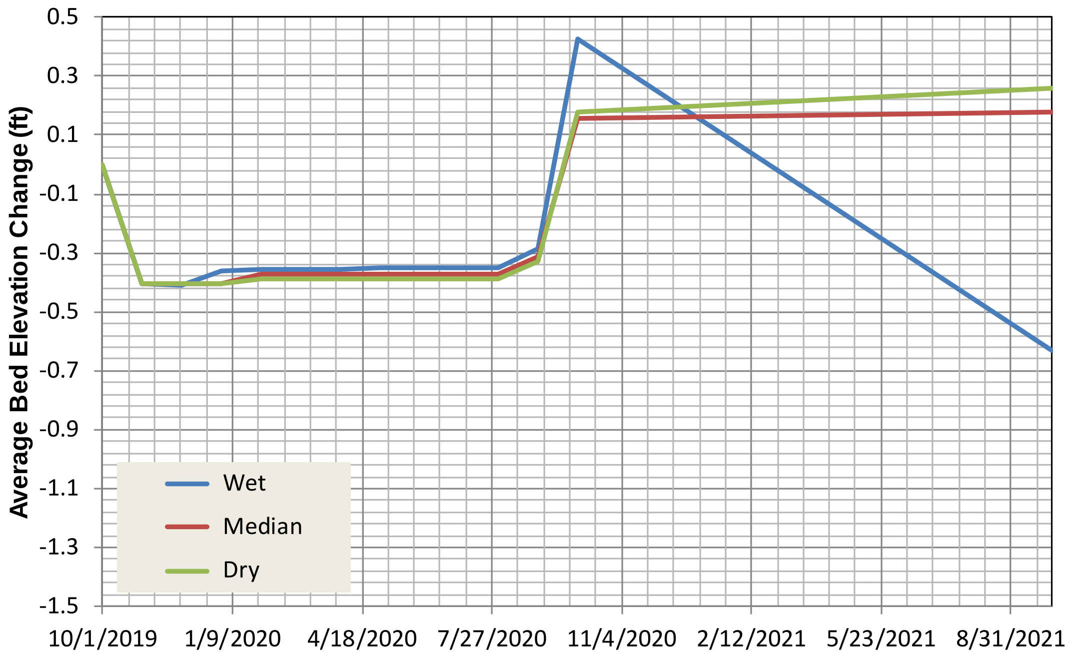
F.9.1 Changes in Bed Elevation

Under the Mechanical Sediment Removal mitigation measure, short-term (less than 2 years following drawdown) SRH-1D model simulations estimate up to 0.6 ft of reach averaged erosion between Iron Gate Dam and Bogus Creek (compared to nearly 1 foot under the Proposed Action); up to 0.5 ft of channel aggradation would occur between Bogus Creek and Willow Creek (compared to less than 0.8 feet under the Proposed Action) (Figure F-18 and Figure F-11). Reach averaged bed elevation between Iron Gate Dam to Bogus Creek would fluctuate within 1 foot of the initial elevation (Figure F-19 and Figure F-12).



Based on simulation results provided by Reclamation, April 2012.

Figure F-18. Reach Averaged Bed Elevation for Two Successive Wet, Median, or Dry Water Years Following Reservoir Drawdown with Dredging.

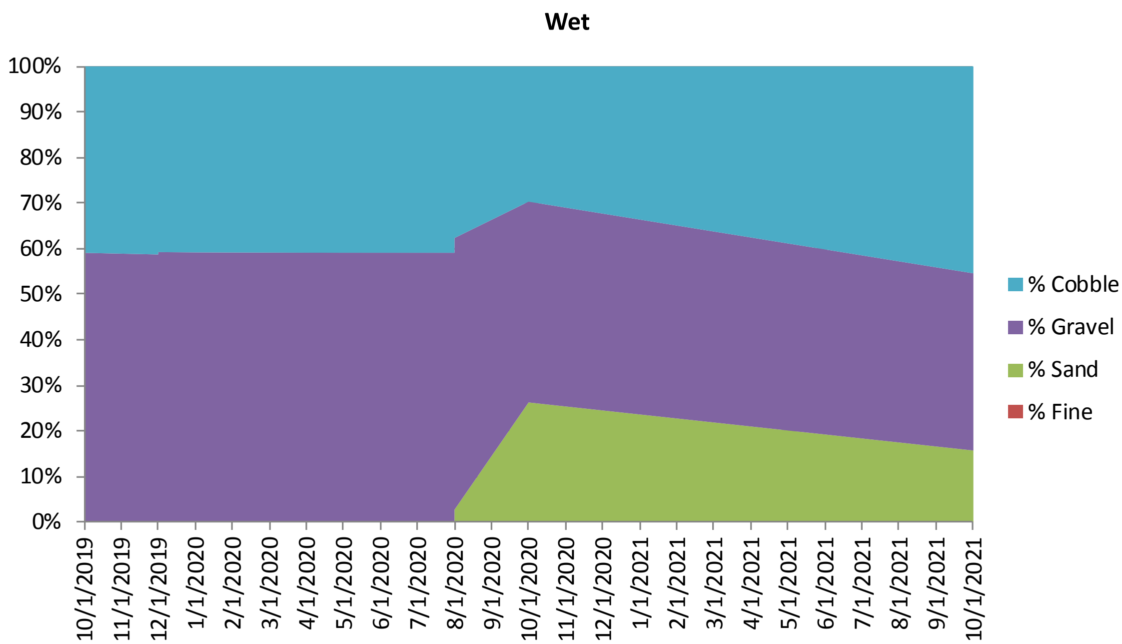


Based on simulation results provided by Reclamation, April 2012.

Figure F-19. Reach Averaged Bed Elevation with Dredging for Two Successive Wet, Median, or Dry Water Years Following Reservoir Drawdown from Iron Gate Dam to Bogus Creek.

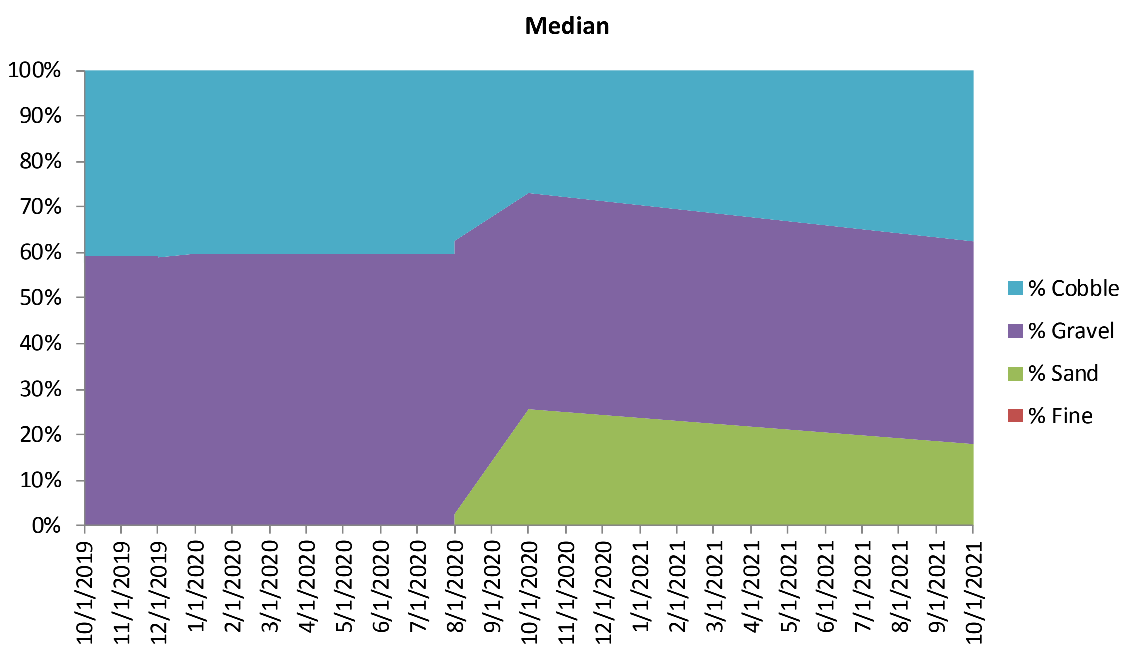
F.9.2 Changes in Bed Substrate

Mechanical Sediment Removal would still result in increases in the proportion of sand in the bed and decreases in median bed substrate size, although the changes would be less than under the Proposed Action. SRH-1D estimated that sand within the bed from Iron Gate Dam to Bogus Creek would increase to 20 to 30 percent by March 2020 after reservoir drawdown, gradually decreasing to 10 to 25 percent by September 2021 (Figure F-20, Figure F-21 and Figure F-22). Median substrate size would decrease to 45 to 60 mm and gradually increase to 70 to 100 mm (Figure F-23). Reclamation (2011) also predicted that most, if not all, sand and smaller substrate would be flushed from the reach within 3 years.



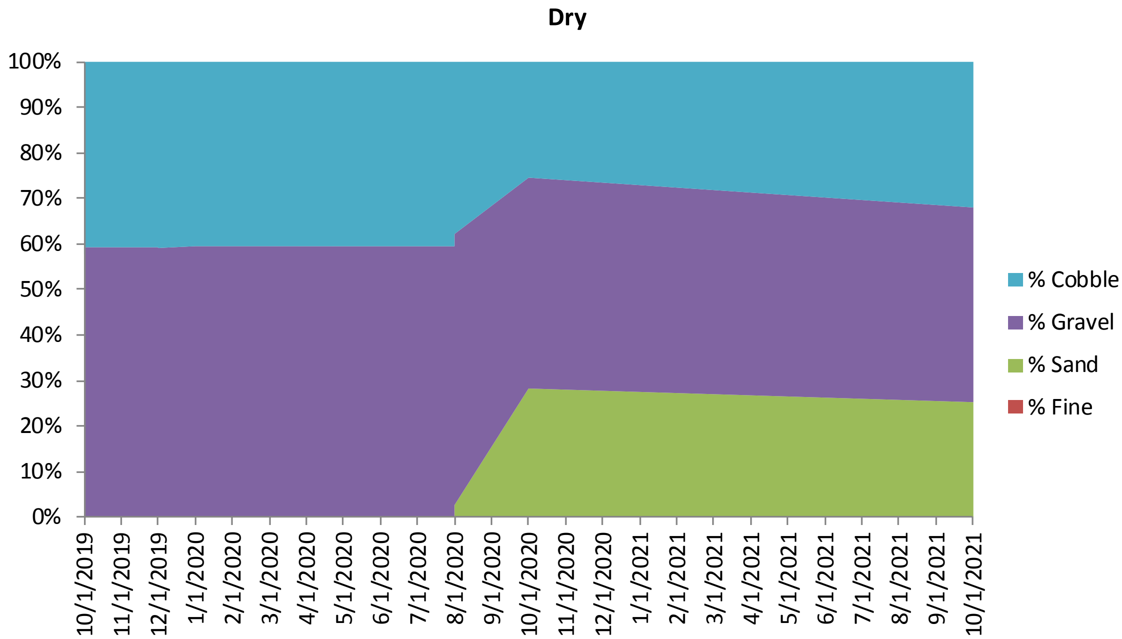
Based on simulation results provided by Reclamation, April 2012.

Figure F-20. Simulated Bed Composition from Iron Gate Dam to Bogus Creek for Two Successive Wet Water Years Following Reservoir Drawdown with Dredging.



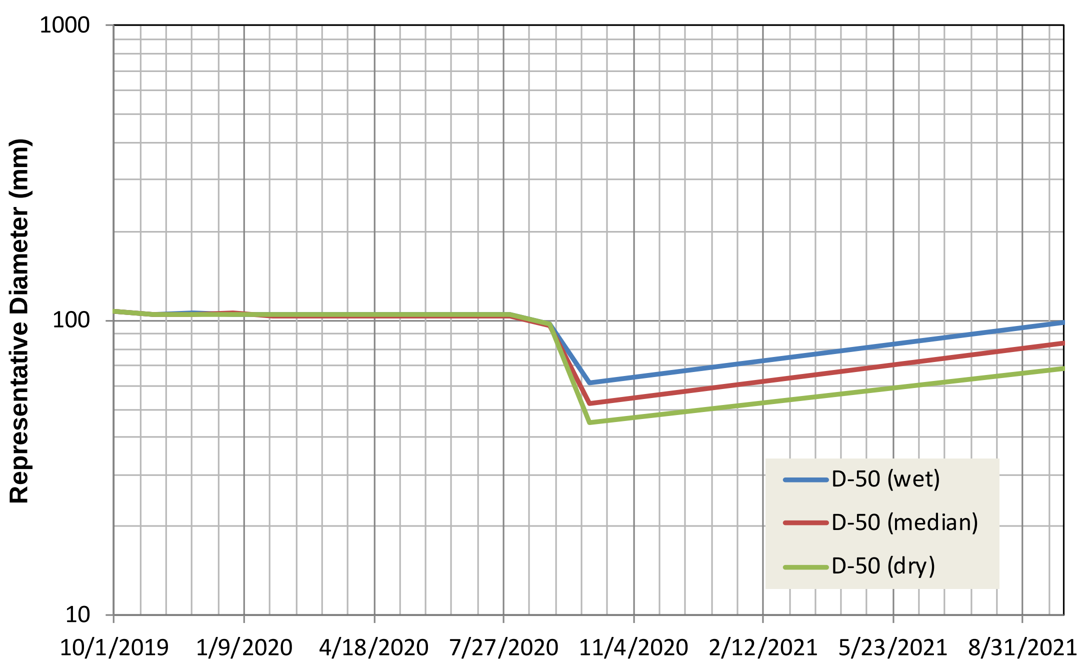
Based on simulation results provided by Reclamation, April 2012.

Figure F-21. Simulated Bed Composition from Iron Gate Dam to Bogus Creek for Two Successive Wet Water Years Following Reservoir Drawdown with Dredging.



Based on simulation results provided by Reclamation, April 2012.

Figure F-22. Simulated Bed Composition from Iron Gate Dam to Bogus Creek for Two Successive Dry Water Years Following Reservoir Drawdown with Dredging.



Based on simulation results provided by Reclamation, April 2012.

Figure F-23. Simulated D50 (mm) From Iron Gate Dam to Bogus Creek for Successive Wet, Median, and Dry Water Years Following Reservoir Drawdown with Dredging.

Overall, the Mechanical Sediment Removal mitigation measure, relative to the Proposed Action, would result in less deposition downstream from Iron Gate Dam, less sand within the bed, and greater median substrate sizes in downstream reaches. These changes would lessen the severity of effects associated with dam released sediment native fish in the mainstem Klamath River.

F.10 References

Bjornn, T.C., and D.W. Reiser. 1991. Habitat requirements of salmonids in streams. Pages 83–138 in W.R. Meehan, editor. Influences of Forest and Rangeland Management on Salmonid Fishes and Their Habitats. American Fisheries Society Special Publication No. 19, Bethesda, Maryland.

Buer, K. 1981. Klamath and Shasta rivers spawning gravel enhancement study. Department of Water Resources, Northern District, Red Bluff, California.

Bureau of Reclamation. 2012. "Hydrology, Hydraulics and Sediment Transport Studies for the Secretary's Determination on Klamath River Dam Removal and Basin Restoration," Technical Report No. SRH-2011-02. Prepared for Mid-Pacific Region, Bureau of Reclamation, Technical Service Center, Denver, CO.

Chapman, D.W. 1988. Critical Review of Variables Used to Define Effects of Fines in Redds of Large Salmonids. Transactions of the American Fisheries Society 117: 1-21.

Federal Energy Regulatory Commission. 2007. Klamath Hydroelectric Project (FERC Project No. 2082-027). Final environmental impact statement for hydropower license. FERC, Office of Energy Projects, Washington, DC.

Gathard Engineering Consulting. 2006. Klamath River dam and sediment investigation. Technical Report. Prepared by GEC, Seattle, Washington.

Hamilton, J.B., G.L. Curtis, S.M. Snedaker, and D.K. White. 2005. Distribution of anadromous fishes in the Upper Klamath River watershed prior to hydroelectric dams--a synthesis of historical evidence. Fisheries 30(4):10-20.

Hamilton, J., Quinones, R., Rondorf, D., Schultz, K., Simondet, J., Stresser, S. 2011. Biological synthesis for the secretarial determination on potential removal of the lower four dams on the Klamath River. Draft report. Prepared by the Biological Subgroup for the Secretarial Determination Regarding Potential Removal of the Lower Four Dams on the Klamath River.

Hetrick, N.J., Shaw, T.A., Zedonis, P., Polos, J.P. 2009. Compilation of Information to inform USFWS Principals on technical aspects of the Klamath Basin Restoration Agreement relating to fish and fish habitat conditions. Arcata Fisheries Technical Report TR 2009-11, U.S. Fish and Wildlife Service, Arcata Fish and Wildlife Office: 191 p.

Huang, J.V., and B. Greimann. 2010. User's Manual for SRH-1D 2.5 (Sedimentation and River Hydraulics – One Dimension, Version 2.5). Sedimentation and River Hydraulics Group, Technical Service Center, Bureau of Reclamation, Denver, CO 80225.

Kondolf, G.M. 2000. Assessing Salmonid Spawning Gravel Quality. Transactions of the American Fisheries Society 129: 262-281.

Kondolf, G.M., and M.G. Wolman. 1993. The Sizes of Salmonid Spawning Gravels. Water Resources Research 29: 2275-2285.

Montgomery, D.R., and J.M. Buffington. 1997. Channel-reach morphology in mountain drainage basins. Geological Society of America Bulletin 109: 596–611.

Moyle, P.B. 2002. Inland Fishes of California. Berkeley, CA: University of California Press. 502 pp.

NRC (National Research Council). 2004. Endangered and threatened fishes in the Klamath River Basin: causes of decline and strategies for recovery. The National Academies Press, Washington, DC. http://www.nap.edu/catalog.php?record_id=10838.

PacifiCorp. 2004. Final Technical Report, Klamath Hydroelectric Project, (FERC Project No. 2082): Water Resources. PacifiCorp, Portland, Oregon.

Stillwater Sciences. 2008. Klamath River dam removal study: sediment transport DREAM-1 simulation. Technical Report, Prepared for California Coastal Conservancy, 1330 Broadway, 13th Floor, Oakland, CA 94612, 73 pages, October.

Stillwater Sciences. 2010a. Anticipated sediment release from Klamath River dam removal within the context of basin sediment delivery. Prepared by Stillwater Sciences, Arcata, California for California Coastal Conservancy, Oakland, California.

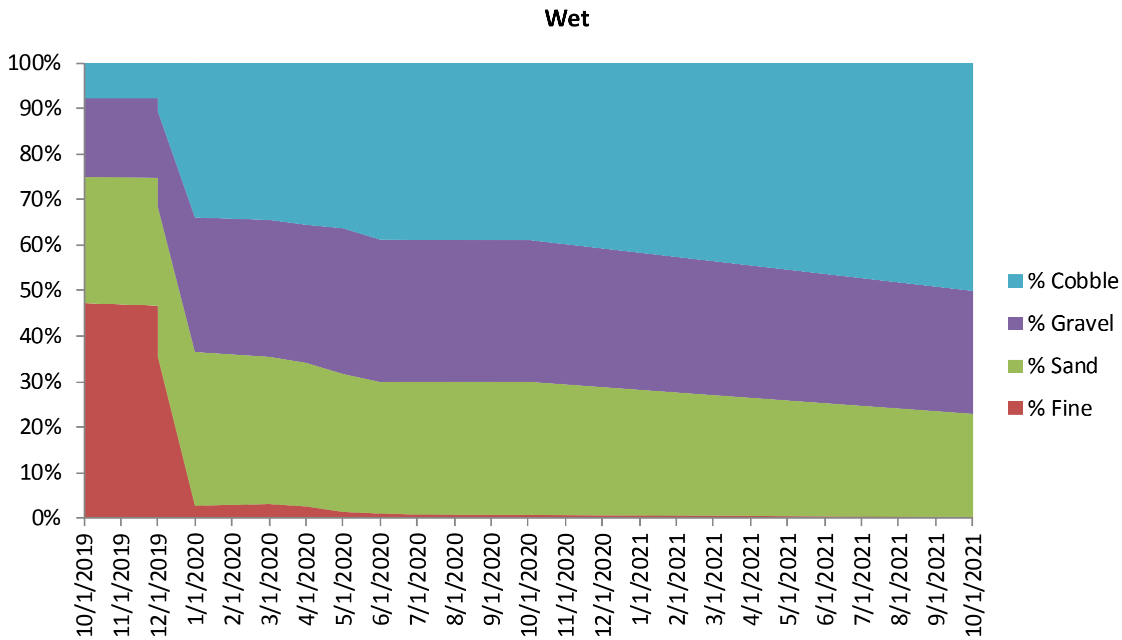
Stillwater Sciences. 2010b. Potential responses of spring-run Chinook salmon downstream from Iron Gate Dam to No-Action and Dam-Removal alternatives for the Klamath Basin. Prepared by Stillwater Sciences, Arcata, California for U.S.D.I. Bureau of Reclamation in support of the Biological Subgroup for the Klamath Basin Secretarial Determination. Arcata, California

Stillwater Sciences. 2010c. Potential responses of coho salmon and steelhead downstream from Iron Gate Dam to No-Action and Dam-Removal alternatives for the Klamath Basin. Prepared by Stillwater Sciences, Arcata, California for U.S.D.I. Bureau of Reclamation in support of the Biological Subgroup for the Klamath Basin Secretarial Determination. Arcata, California.

Varyu, D. Pers. comm., January 4, 2011.

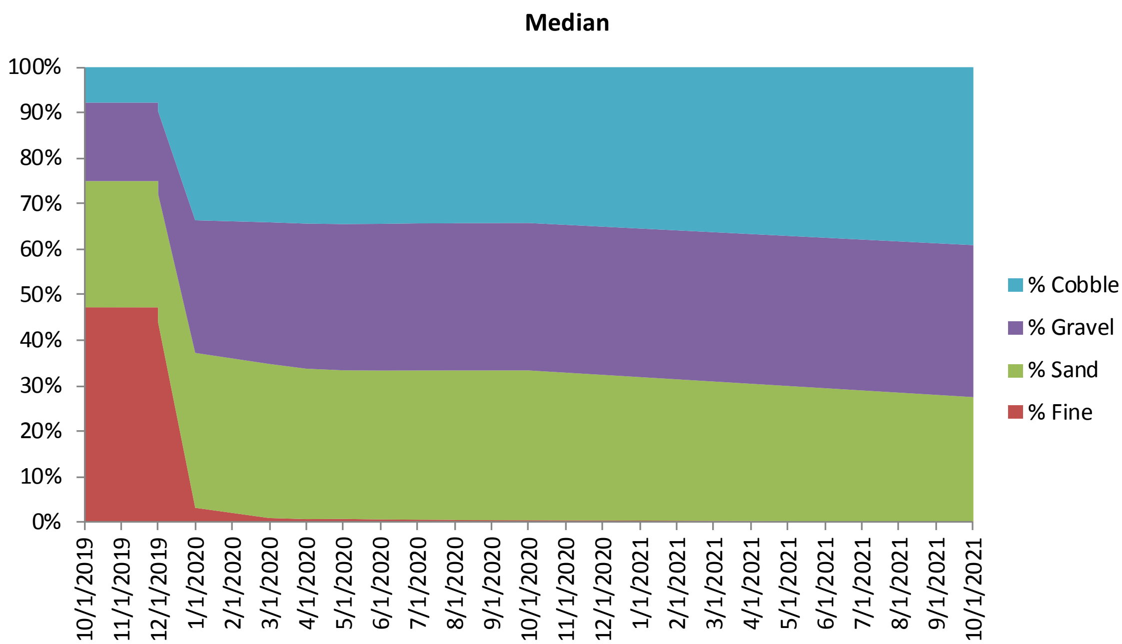
Wooster J.K., Dusterhoff, S.R., Cui, Y., Sklar, L.S., Dietrich, W.E., Malko, M. 2008. Sediment supply and relative size distribution effects on fine sediment into immobile gravels. Water Resources Research 44, W0324, doi:10.1029/2006WR005815.

Attachment F-1
Bedload Sediment Effects in the Hydroelectric Reach and the Lower Klamath River Downstream from Iron Gate Dam to Cottonwood Creek



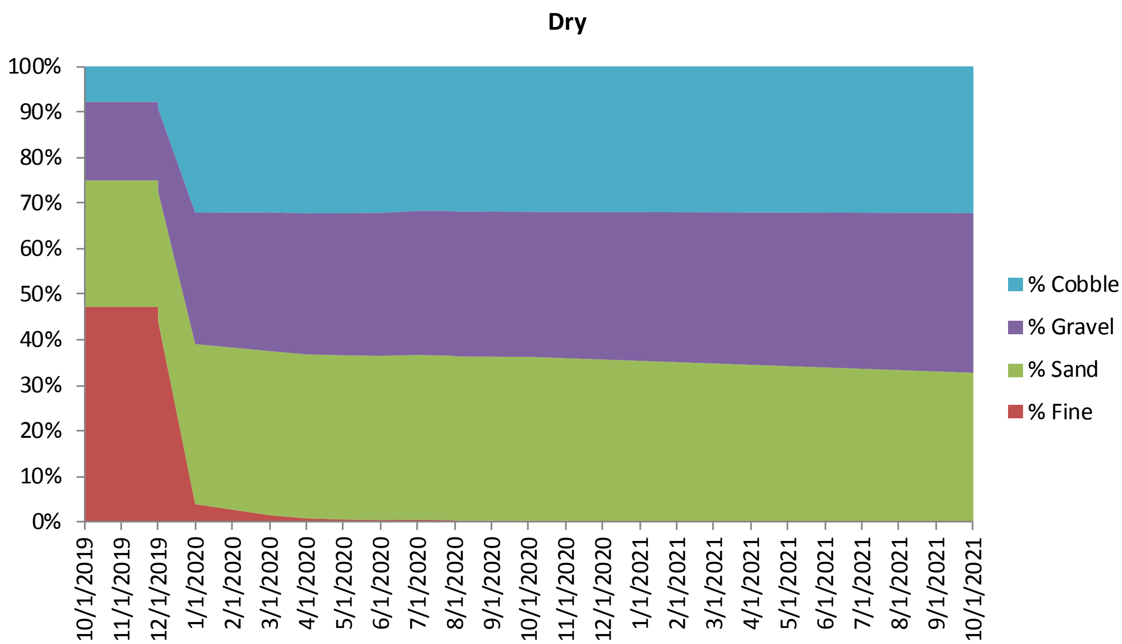
Based on simulation results provided by Reclamation, March 2012.

Figure F1-1. Simulated Bed Composition for J.C. Boyle Reservoir for Two Successive Wet Water Years Following Reservoir Drawdown.



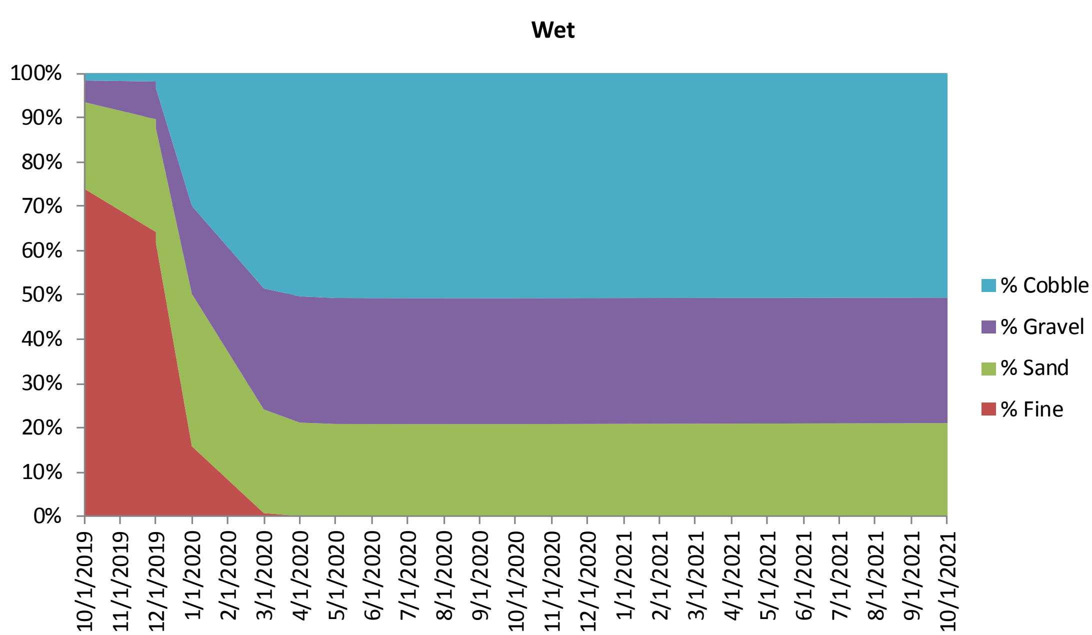
Based on simulation results provided by Reclamation, March 2012.

Figure F1-2. Simulated Bed Composition for J.C. Boyle Reservoir for Two Successive Median Water Years Following Reservoir Drawdown.



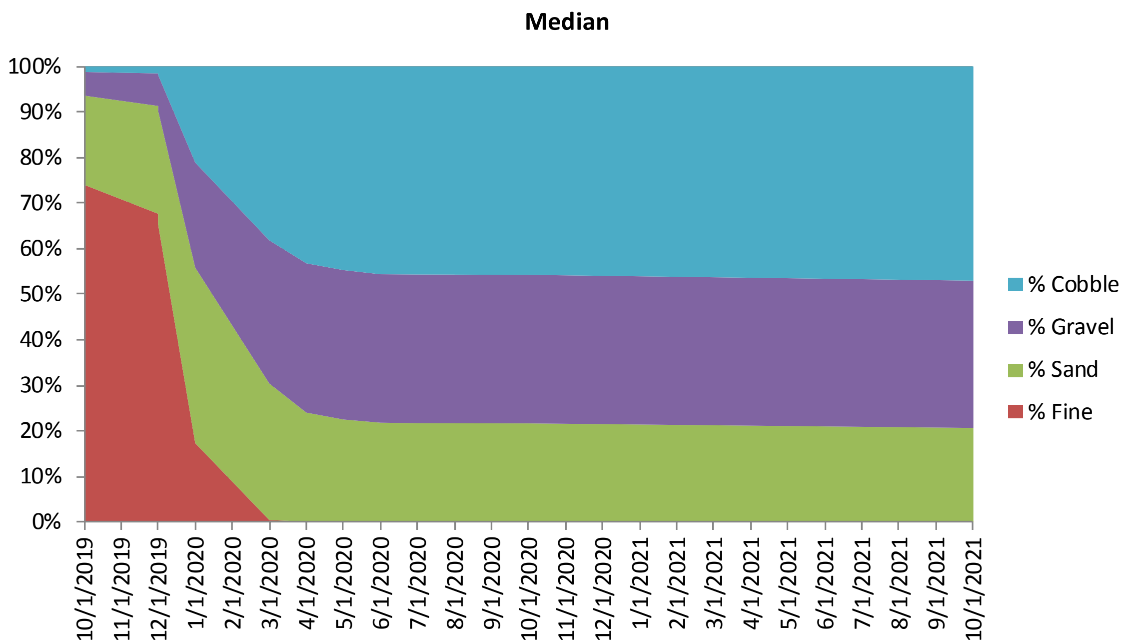
Based on simulation results provided by Reclamation, March 2012.

Figure F1-3. Simulated Bed Composition for J.C. Boyle Reservoir for Two Successive Dry Water Years Following Reservoir Drawdown.



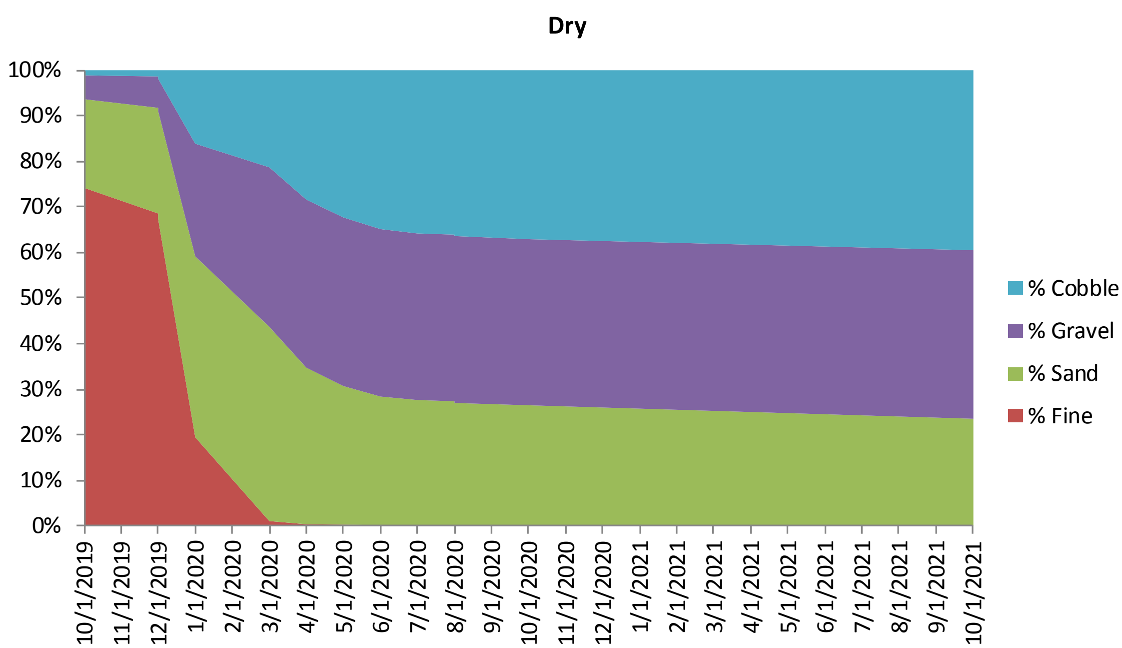
Based on simulation results provided by Reclamation, March 2012.

Figure F1-4. Simulated Bed Composition for Copco 1 Reservoir for Two Successive Wet Water Years Following Reservoir Drawdown.



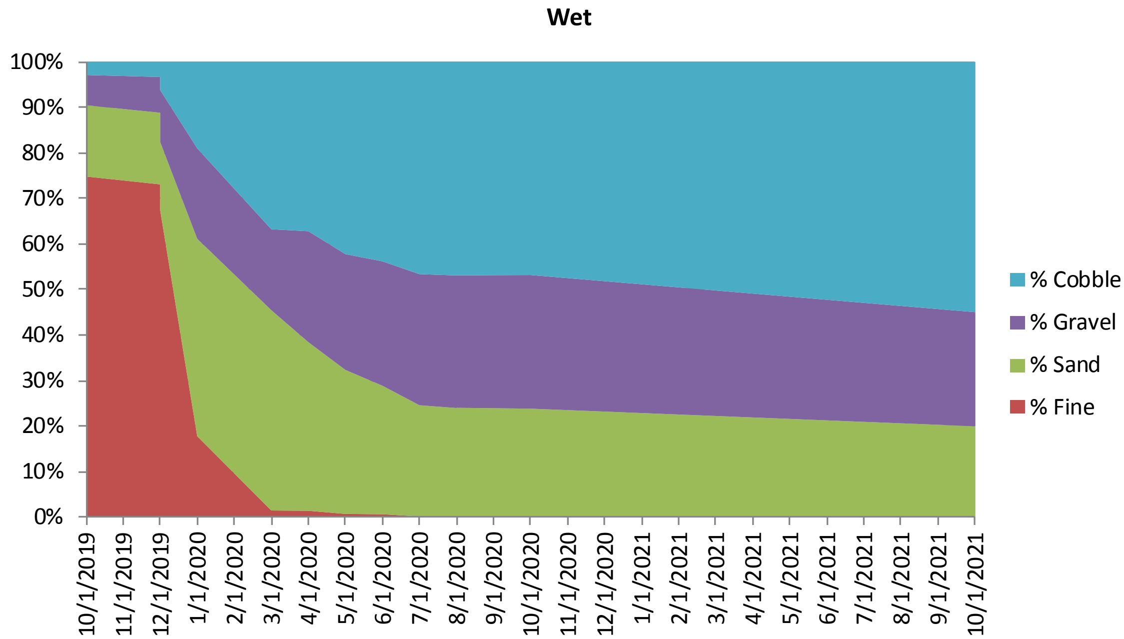
Based on simulation results provided by Reclamation, March 2012.

Figure F1-5. Simulated Bed Composition for Copco 1 Reservoir for Two Successive Median Water Years Following Reservoir Drawdown.



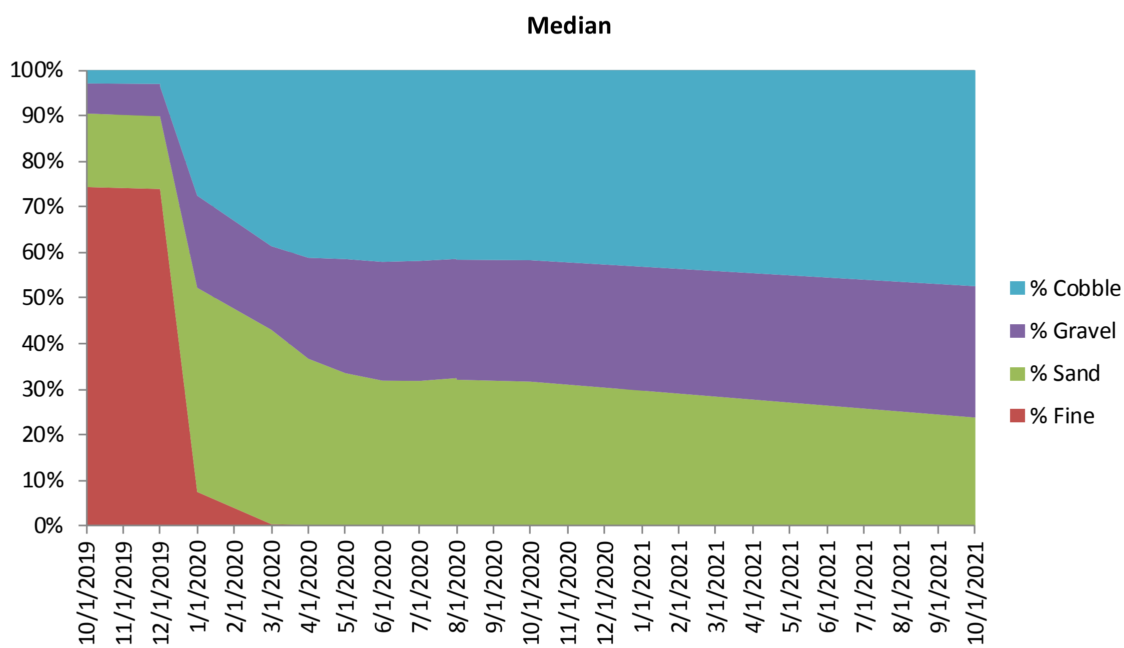
Based on simulation results provided by Reclamation, March 2012.

Figure F1-6. Simulated Bed Composition for Copco 1 Reservoir for Two Successive Dry Water Years Following Reservoir Drawdown.



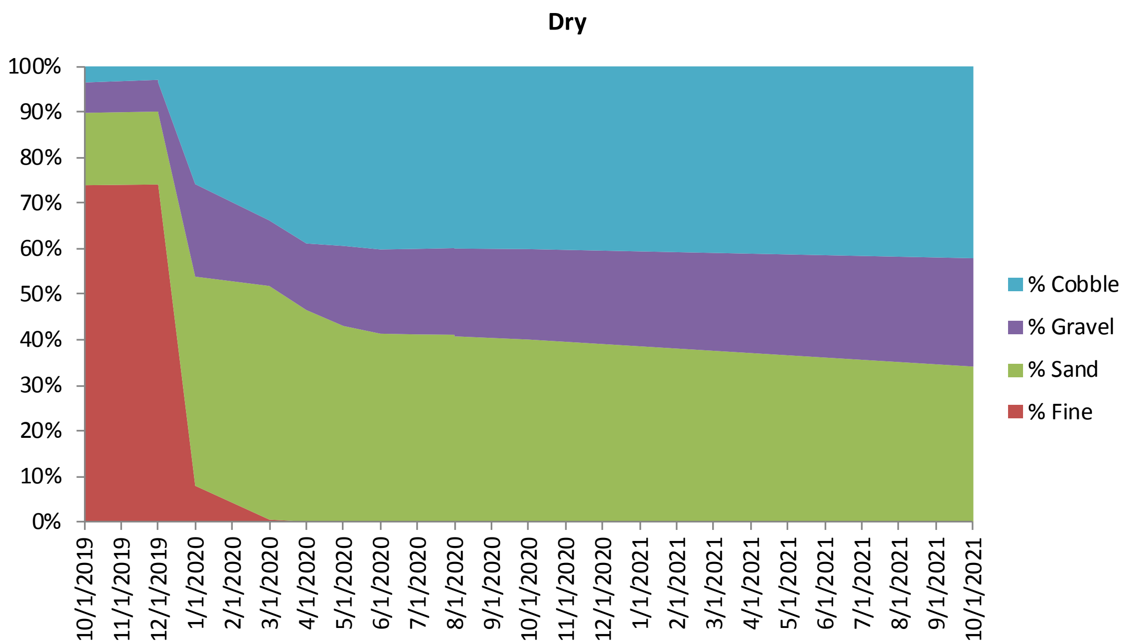
Based on simulation results provided by Reclamation, March 2012.

Figure F1-7. Simulated Bed Composition for Iron Gate Reservoir for Two Successive Wet Water Years Following Reservoir Drawdown.



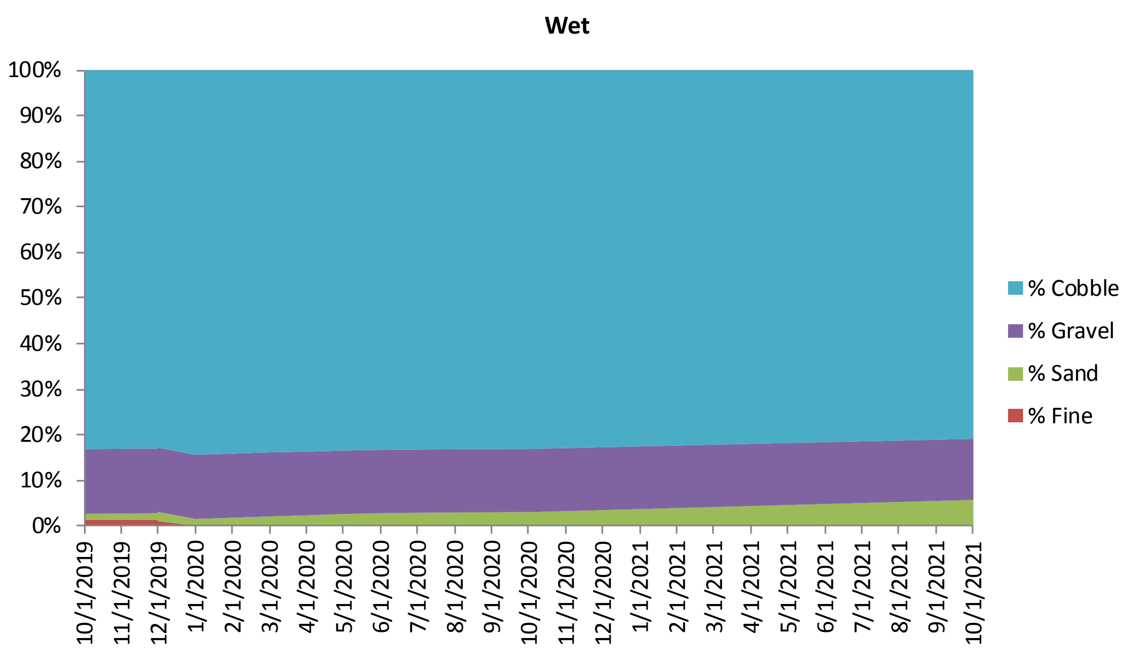
Based on simulation results provided by Reclamation, March 2012.

Figure F1-8. Simulated Bed Composition for Iron Gate Reservoir for Two Successive Median Water Years Following Reservoir Drawdown.



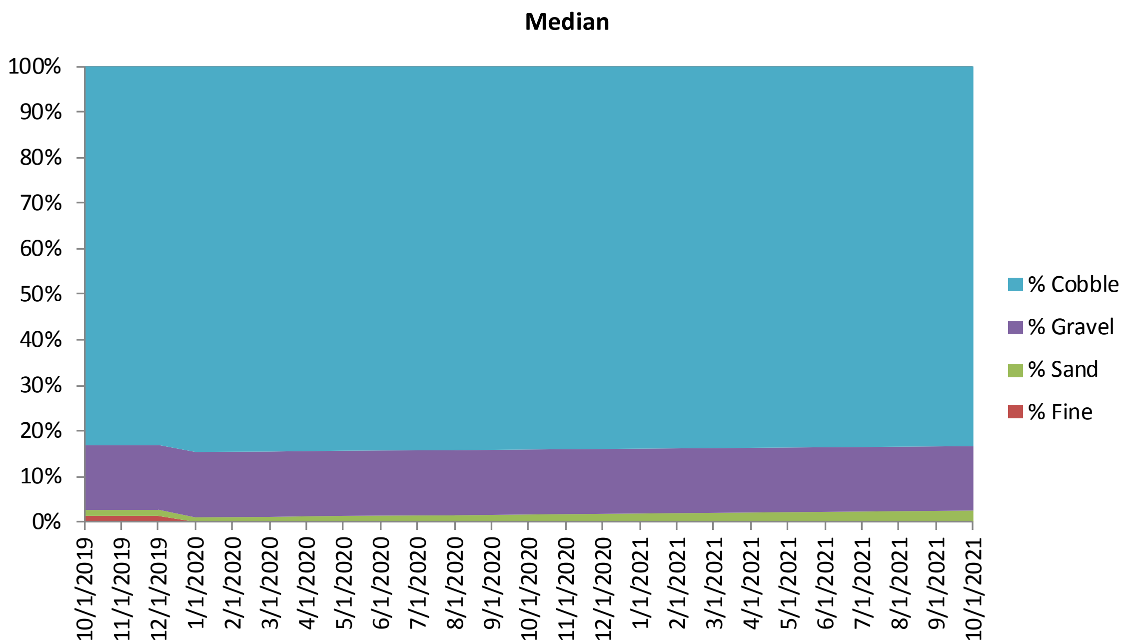
Based on simulation results provided by Reclamation, March 2012.

Figure F1-9. Simulated Bed Composition for Iron Gate Reservoir for Two Successive Dry Water Years Following Reservoir Drawdown.



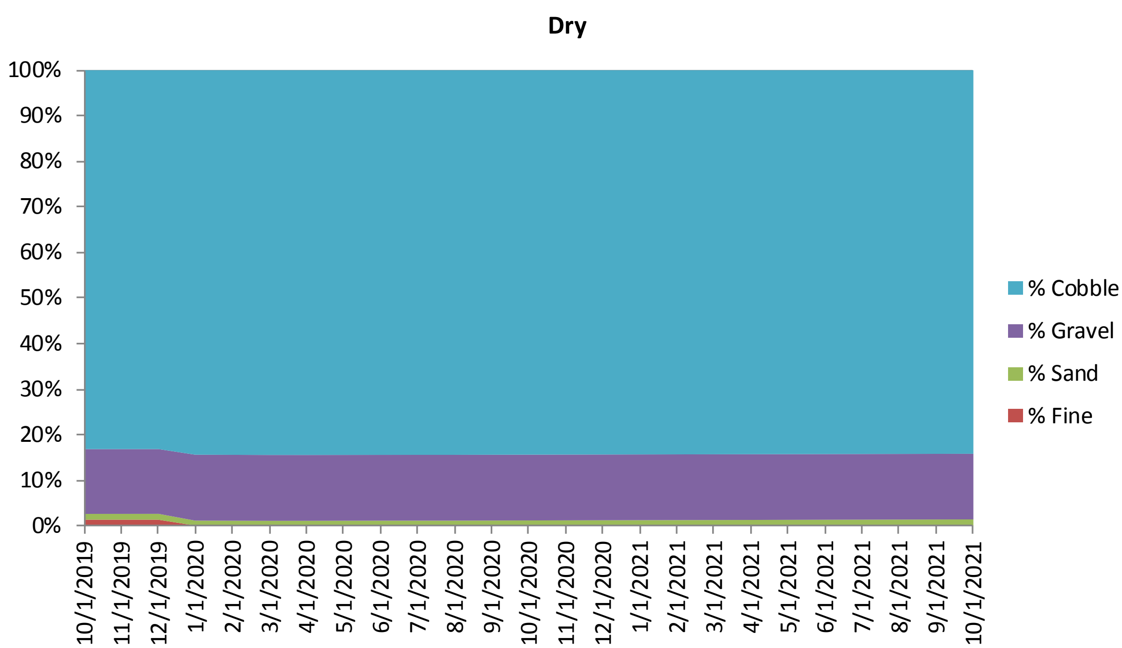
Based on simulation results provided by Reclamation, March 2012.

Figure F1-10. Simulated Bed Composition Upstream of J.C. Boyle Reservoir for Two Successive Wet Water Years Following Reservoir Drawdown.



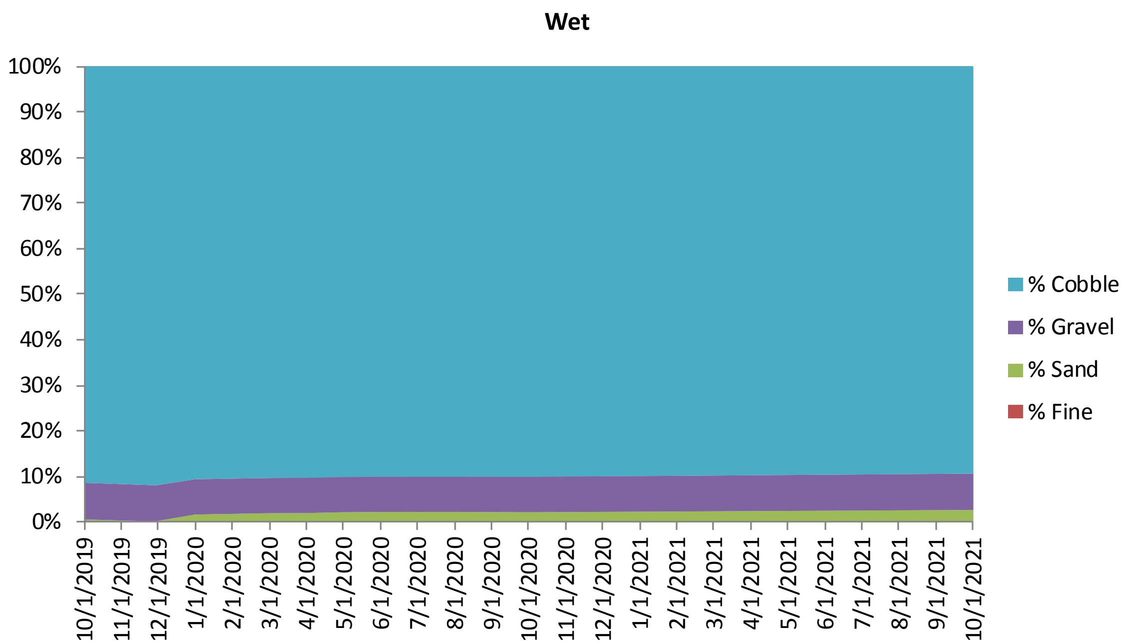
Based on simulation results provided by Reclamation, March 2012.

Figure F1-11. Simulated Bed Composition Upstream of J.C. Boyle Reservoir for Two Successive Median Water Years Following Reservoir Drawdown.



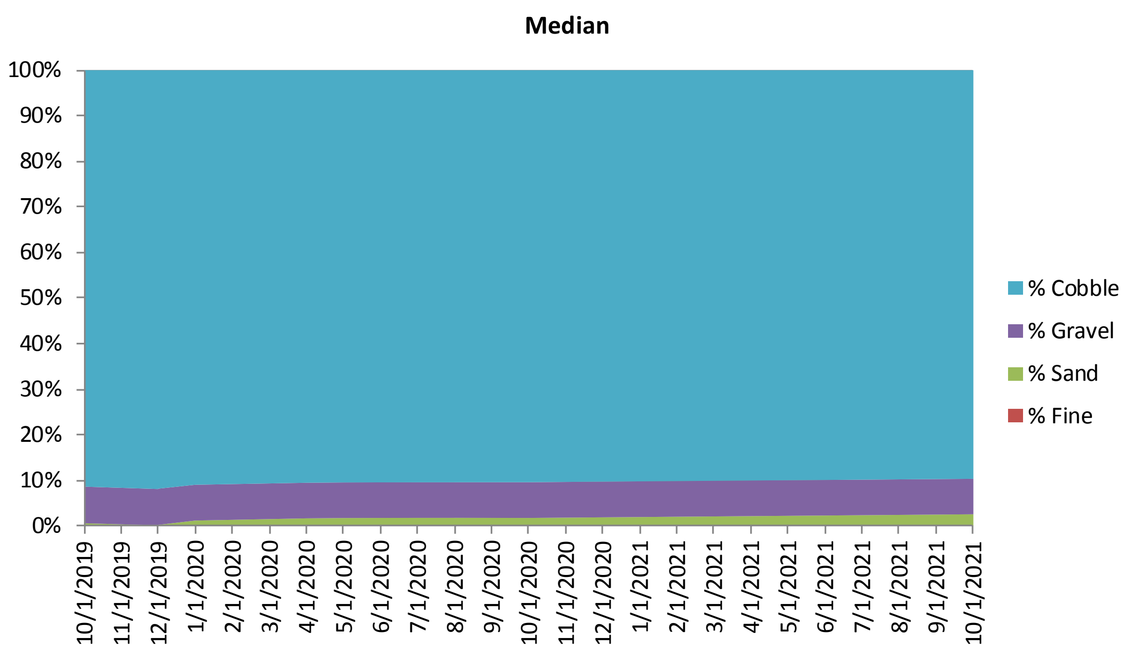
Based on simulation results provided by Reclamation, March 2012.

Figure F1-12. Simulated Bed Composition Upstream of J.C. Boyle Reservoir for Two Successive Dry Water Years Following Reservoir Drawdown.



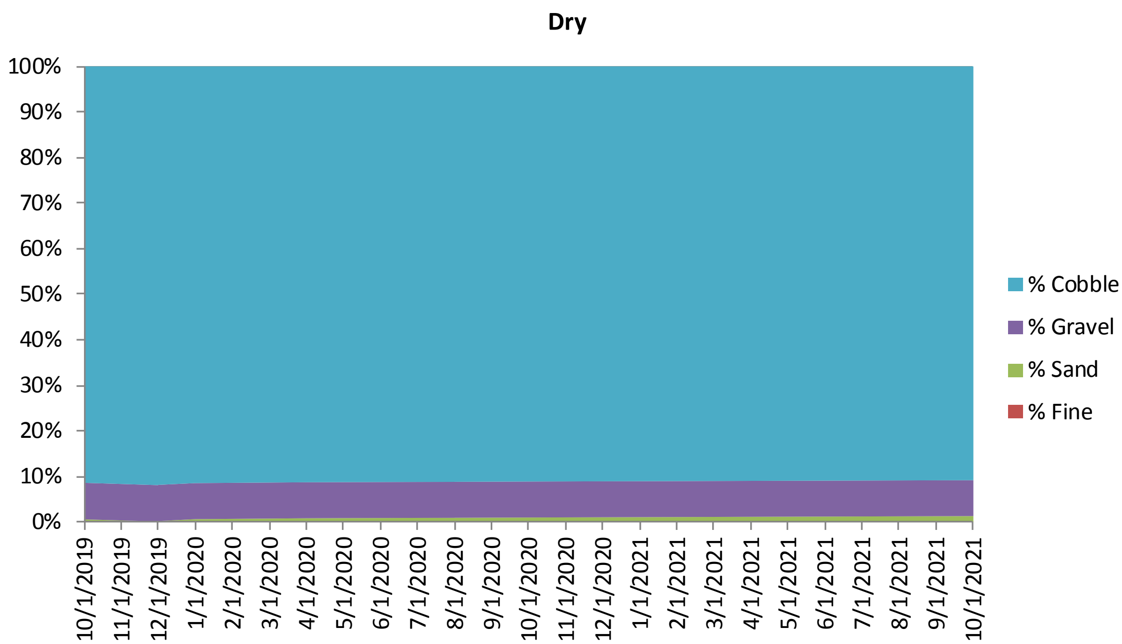
Based on simulation results provided by Reclamation, March 2012.

Figure F1-13. Simulated Bed Composition from J.C. Boyle to Copco 1 Reservoirs for Two Successive Wet Water Years Following Reservoir Drawdown.



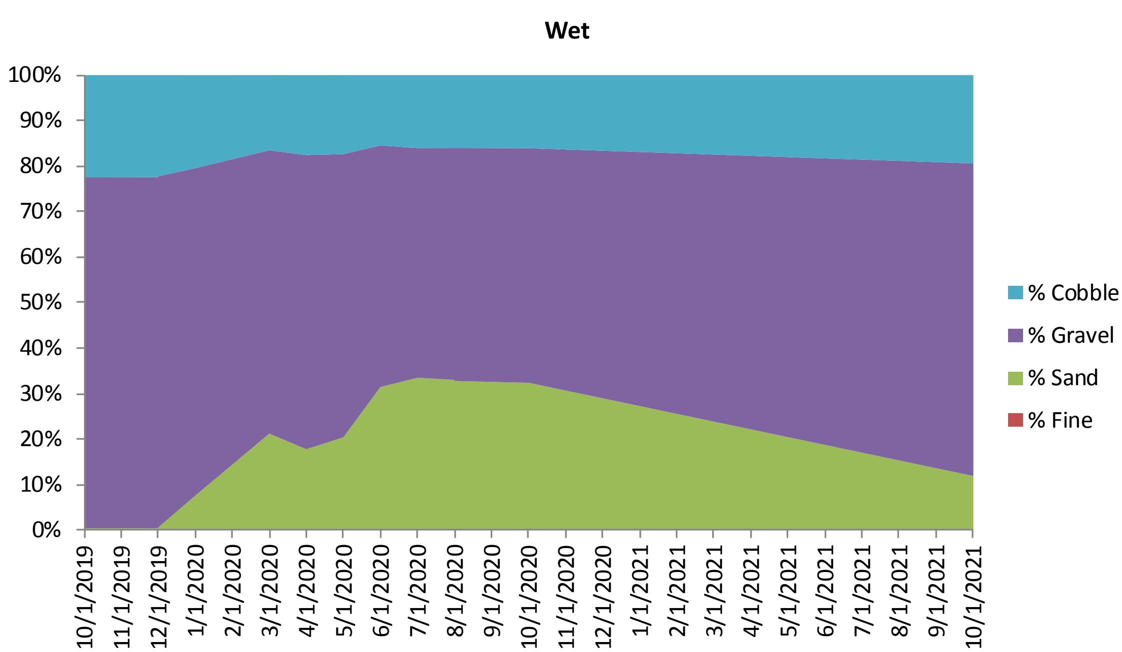
Based on simulation results provided by Reclamation, March 2012.

Figure F1-14. Simulated Bed Composition from J.C. Boyle to Copco 1 Reservoirs for Two Successive Median Water Years Following Reservoir Drawdown.



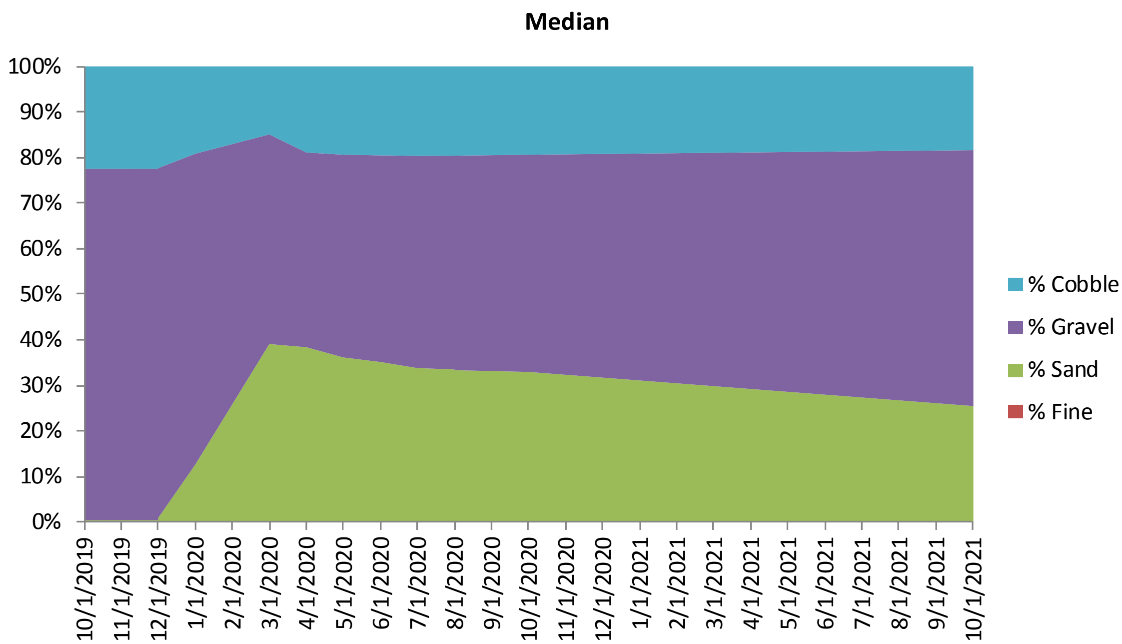
Based on simulation results provided by Reclamation, March 2012.

Figure F1-15. Simulated Bed Composition from J.C. Boyle to Copco 1 Reservoirs for Two Successive Dry Water Years Following Reservoir Drawdown.



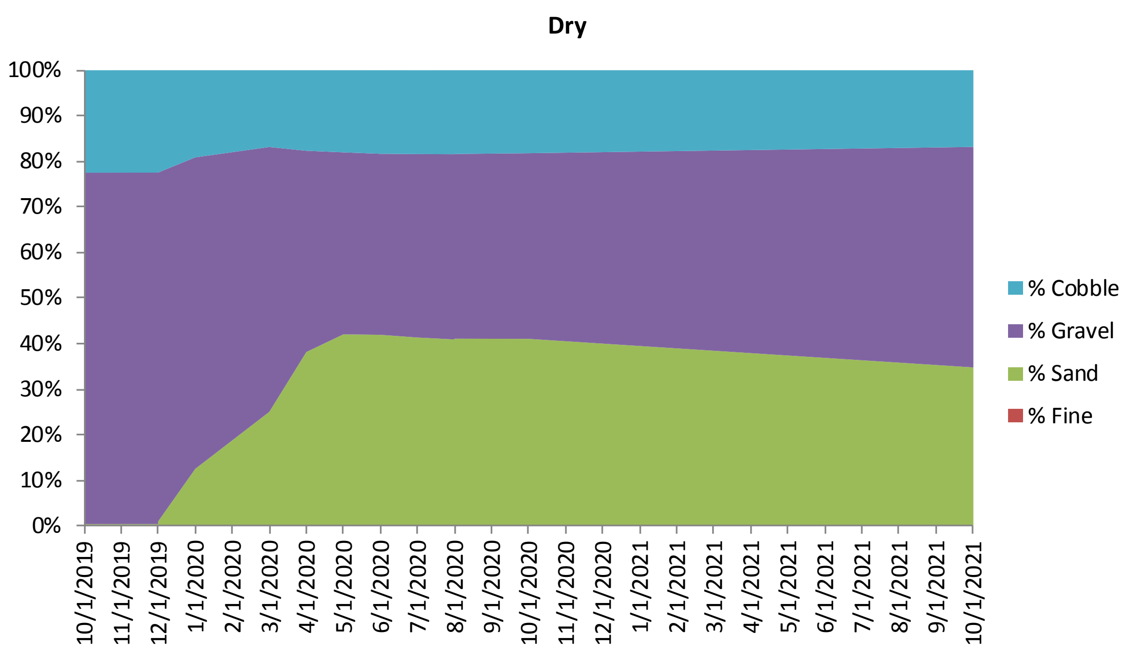
Based on simulation results provided by Reclamation, March 2012.

Figure F1-16. Simulated Bed Composition from Bogus Creek to Willow Creek for Two Successive Wet Water Years Following Reservoir Drawdown.



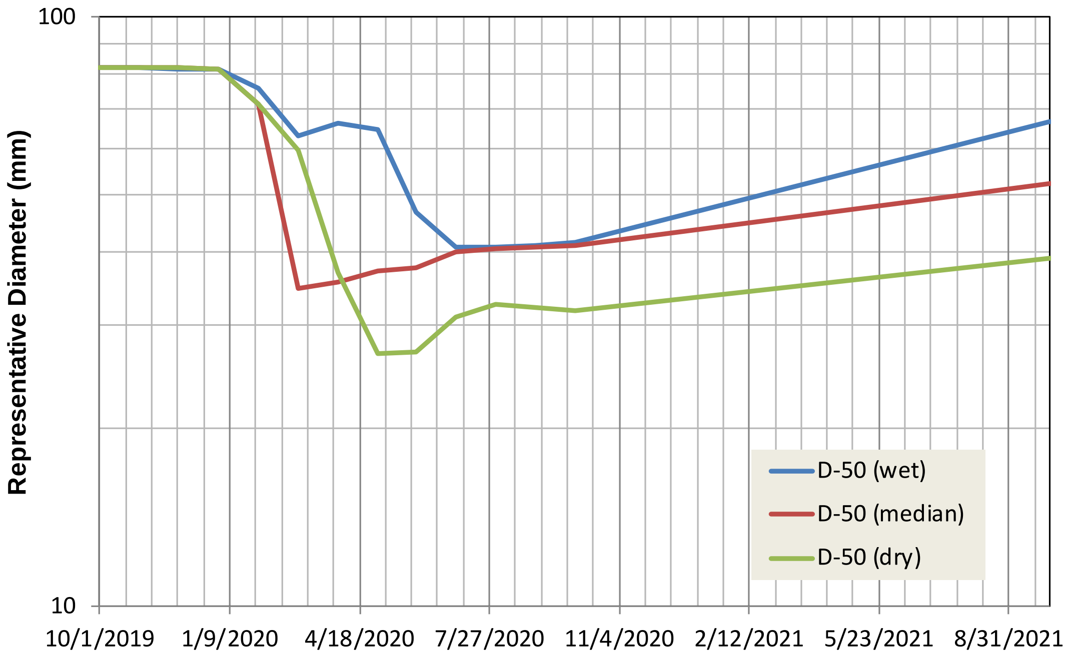
Based on simulation results provided by Reclamation, March 2012.

Figure F1-17. Simulated Bed Composition from Bogus Creek to Willow Creek for Two Successive Median Water Years Following Reservoir Drawdown.



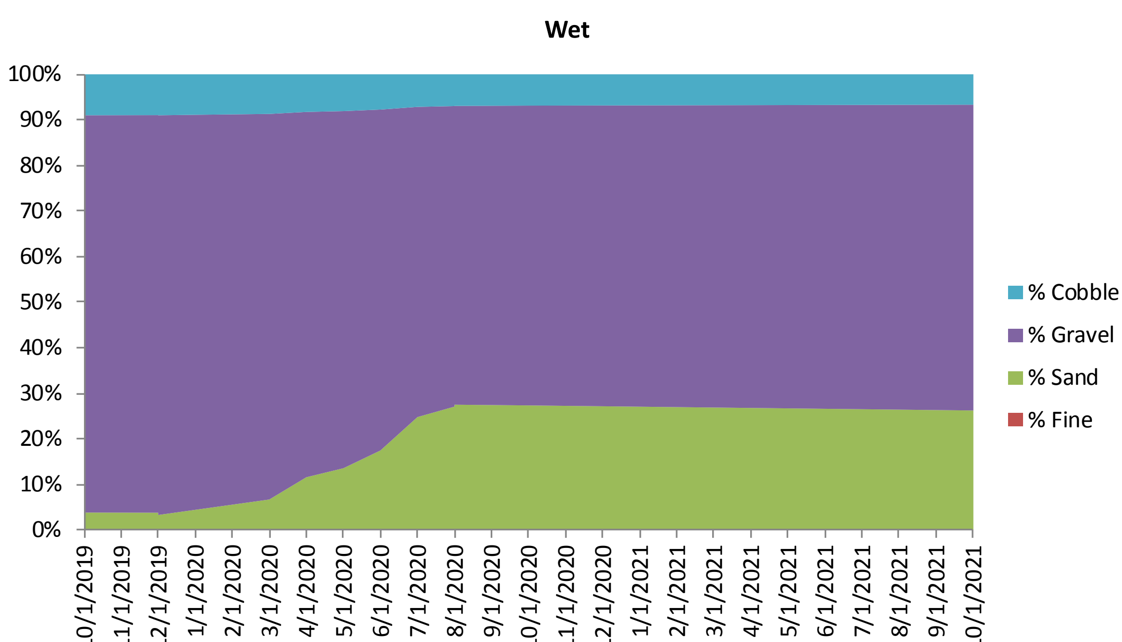
Based on simulation results provided by Reclamation, March 2012.

Figure F1-18. Simulated Bed Composition from Bogus Creek to Willow Creek for Two Successive Dry Water Years Following Reservoir Drawdown.



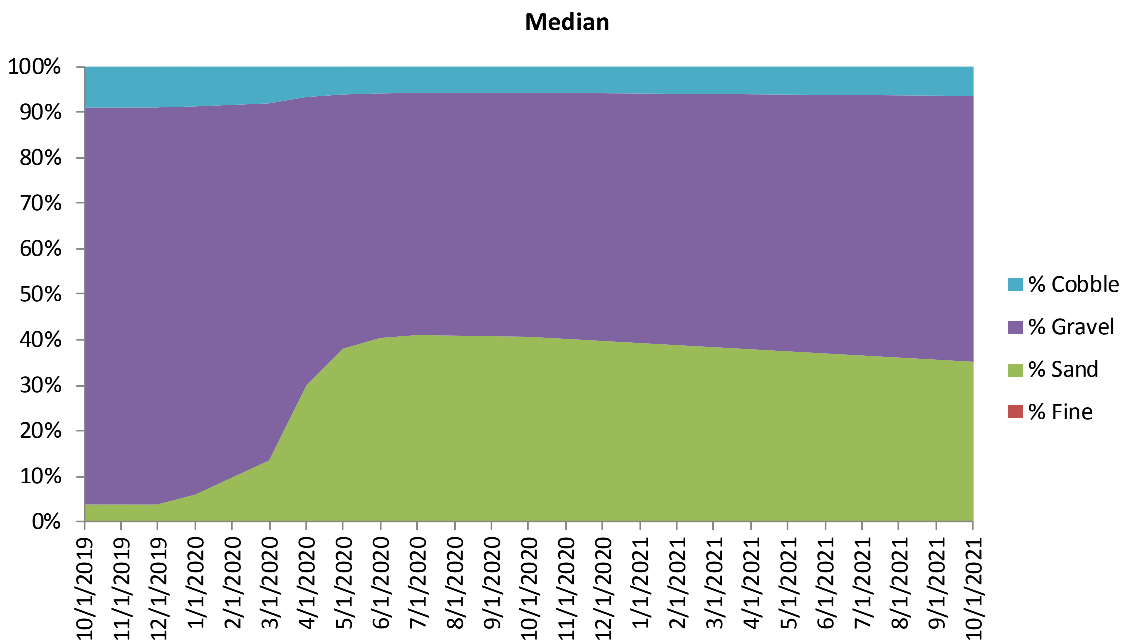
Based on simulation results provided by Reclamation, March 2012.

Figure F1-19. Simulated Bed Substrate Size from Bogus Creek to Willow Creek for Successive Wet, Median, and Dry Water Years Following Reservoir Drawdown.



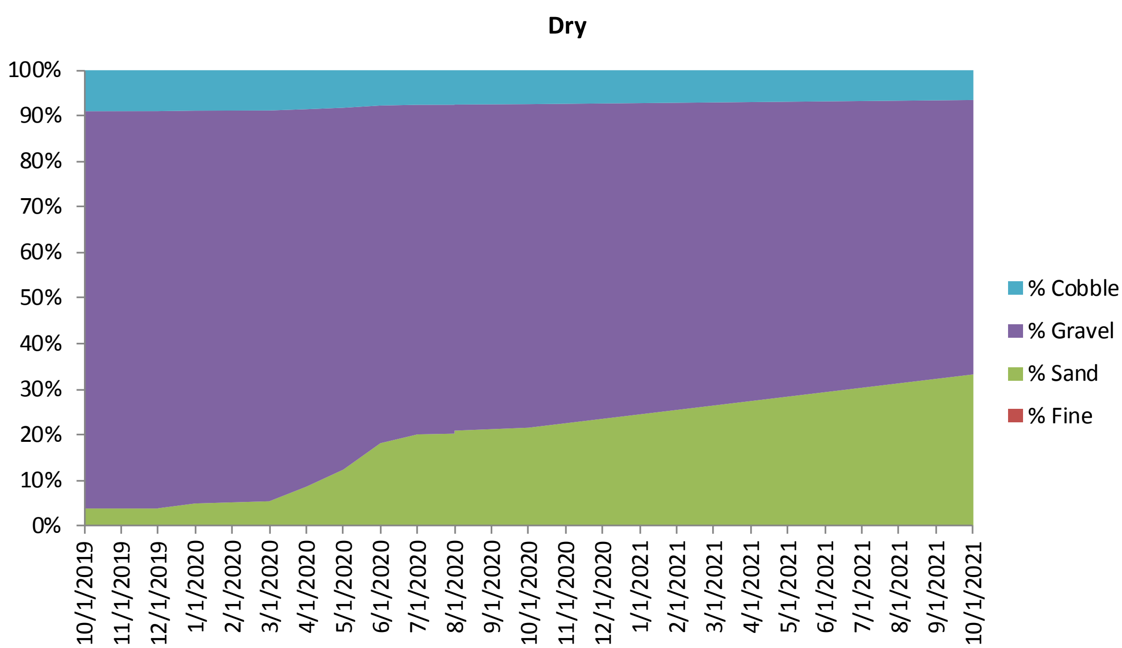
Based on simulation results provided by Reclamation, March 2012.

Figure F1-20. Simulated Bed Composition from Willow Creek to Cottonwood Creek for Two Successive Wet Water Years Following Reservoir Drawdown.



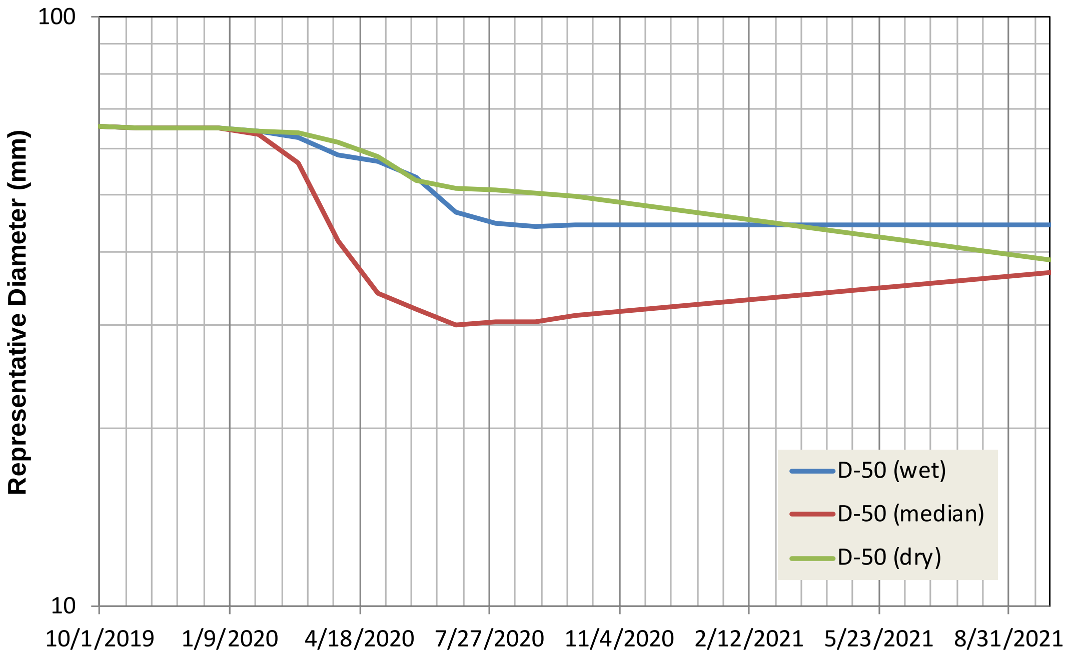
Based on simulation results provided by Reclamation, March 2012.

Figure F1-21. Simulated Bed Composition from Willow Creek to Cottonwood Creek for Two Median Water Years Following Reservoir Drawdown.



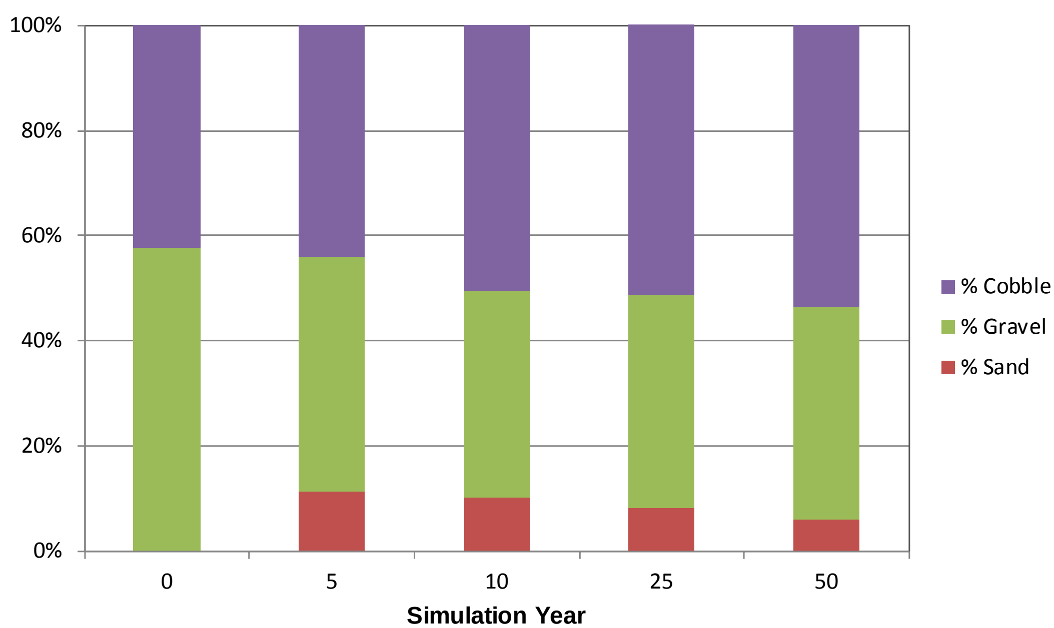
Based on simulation results provided by Reclamation, March 2012.

Figure F1-22. Simulated Bed Composition from Willow Creek to Cottonwood Creek for Two Dry Water Years Following Reservoir Drawdown.



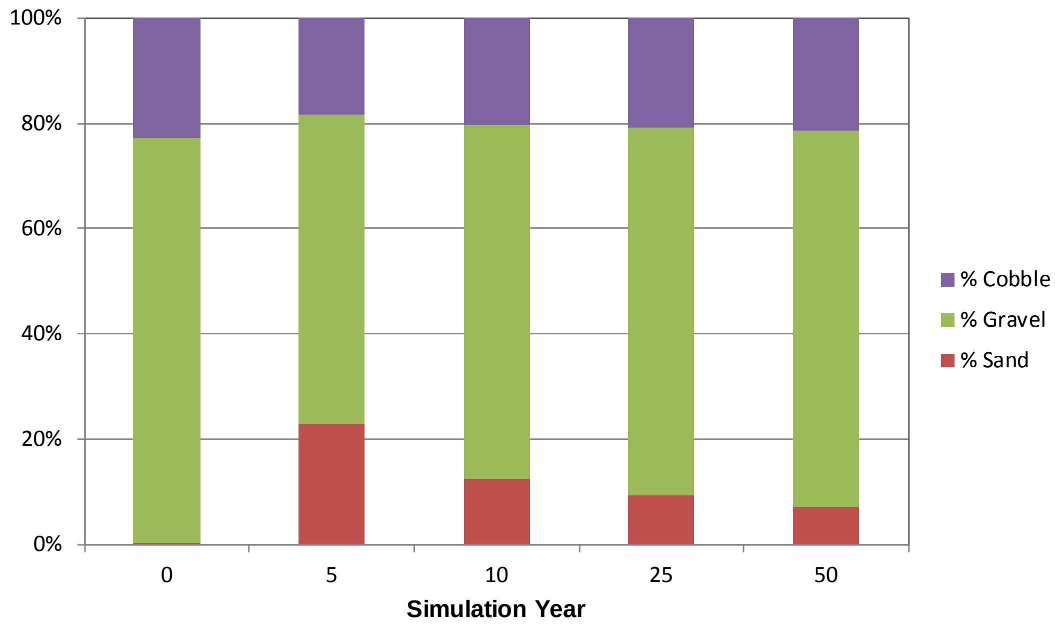
Based on simulation results provided by Reclamation, March 2012.

Figure F1-23. Simulated Bed Substrate Size from Willow Creek to Cottonwood Creek for Successive Wet, Median, and Dry Water Years Following Reservoir Drawdown.



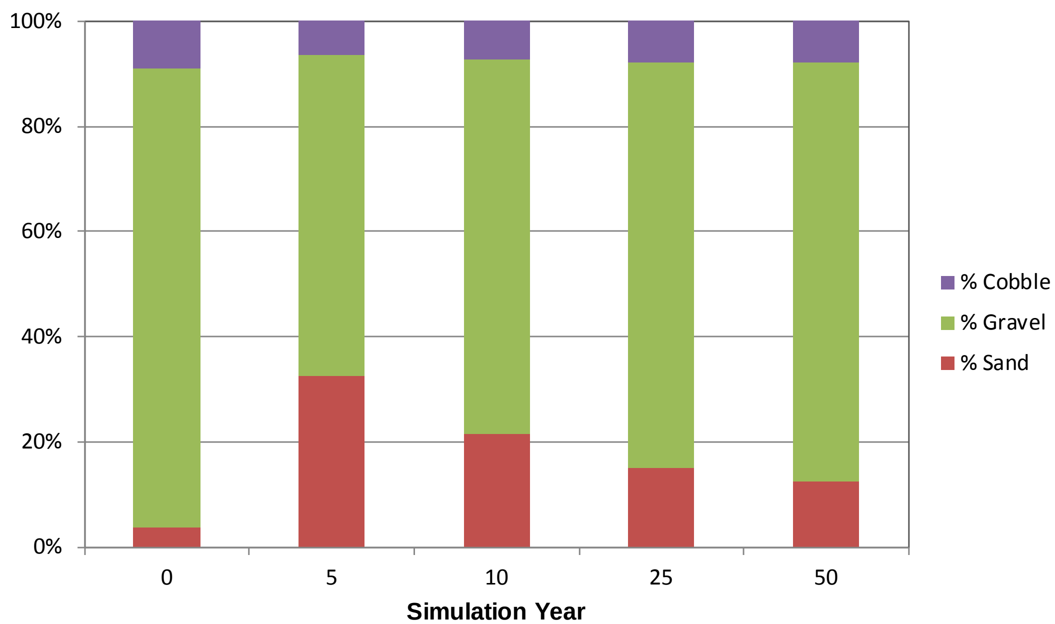
Based on simulation results provided by Reclamation, March 2012.

Figure F1-24. Simulated Bed Composition of Iron Gate Dam to Bogus Creek Reach 5, 10, 25, and 50 Years Following Reservoir Drawdown.



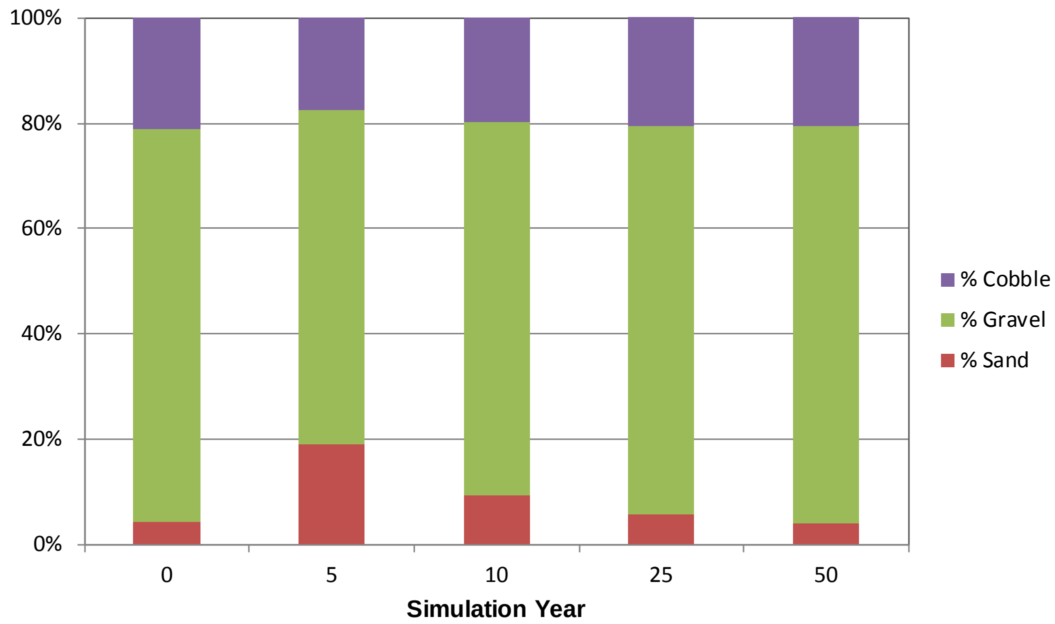
Based on simulation results provided by Reclamation, March 2012.

Figure F1-25. Simulated Bed Composition of Bogus Creek to Willow Creek Reach 5, 10, 25, and 50 Years Following Reservoir Drawdown.



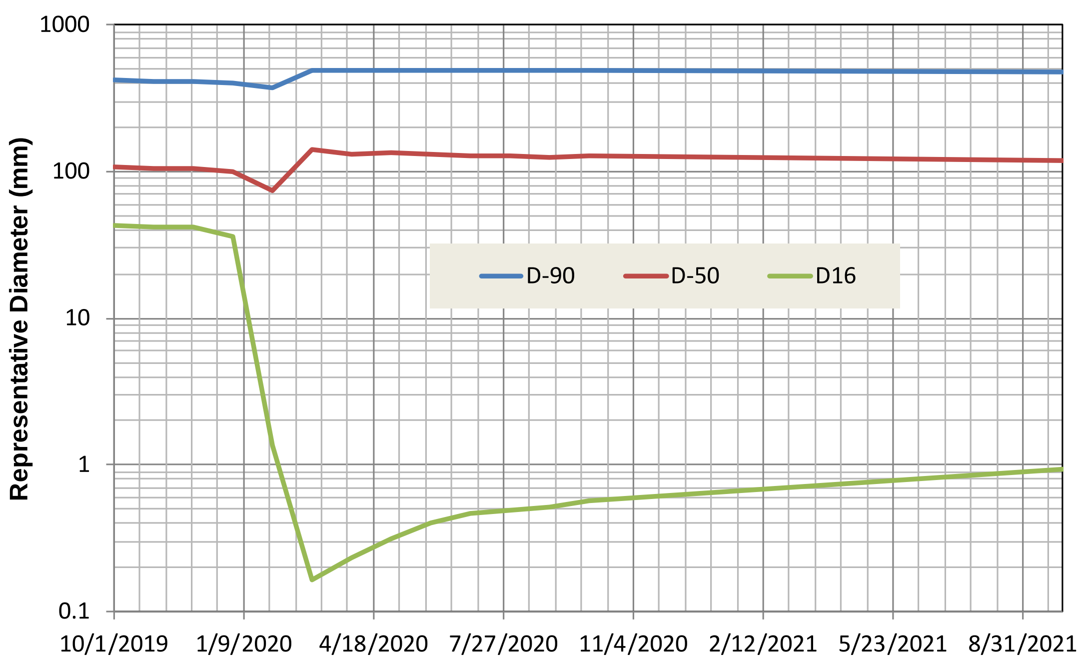
Based on simulation results provided by Reclamation, March 2012.

Figure F1-26. Simulated Bed Composition of Willow Creek to Cottonwood Creek Reach 5, 10, 25, and 50 Years Following Reservoir Drawdown.



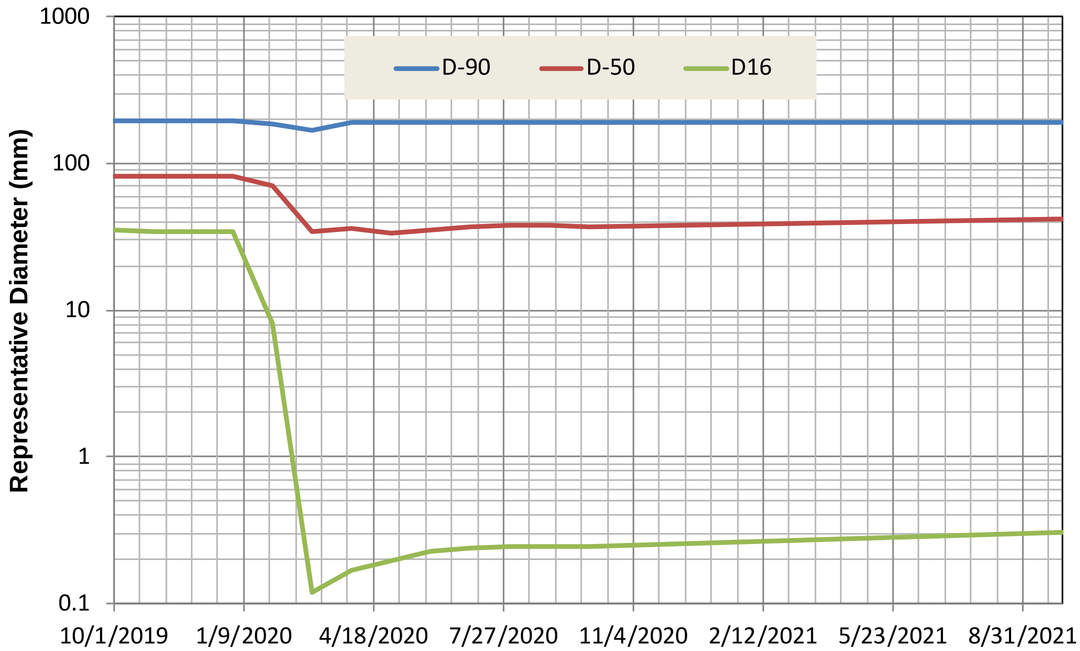
Based on simulation results provided by Reclamation, March 2012.

Figure F1-27. Simulated Bed Composition of Cottonwood Creek to Shasta River Reach 5, 10, 25, and 50 Years Following Reservoir Drawdown.



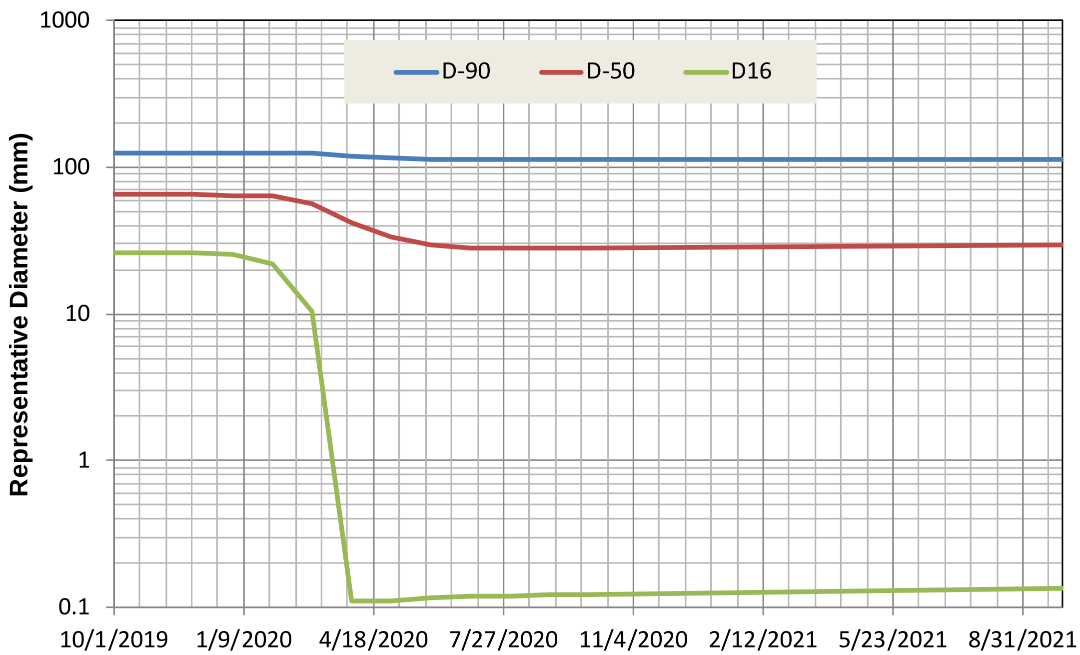
Based on simulation results provided by Reclamation, March 2012.

Figure F1-28. Simulated Bed Substrate Size from Iron Gate Dam to Bogus Creek Following Reservoir Drawdown.



Based on simulation results provided by Reclamation, March 2012.

Figure F1-29. Simulated Bed Substrate Size from Bogus Creek to Willow Creek Following Reservoir Drawdown.



Based on simulation results provided by Reclamation, March 2012.

Figure F1-30. Simulated Bed Substrate Size from Willow Creek to Cottonwood Following Reservoir Drawdown.