Feasibility, Risk and Uncertainty of Mechanical Sediment Removal with the Proposed Action (Full Facility Removal)

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SUBJECT: Summary of potential mitigation impacts associated with mechanical sediment removal when implemented with the Proposed Action (full facility removal).

1 INTRODUCTION

The United States Department of the Interior (DOI), as the National Environmental Policy Act (NEPA) lead agency, and the California Department of Fish and Game (DFG), as the California Environmental Quality Act (CEQA) lead agency, are currently developing an Environmental Impact Statement/ Environmental Impact Report (EIS/EIR) for the Klamath Hydroelectric Settlement Agreement (KHSA) and the Klamath Basin Restoration Agreement (KBRA). The EIS/EIR will evaluate the environmental and social effects of a set of alternatives that may include removing all or portions of four dams on the Klamath River in order to provide volitional fish passage to aid in restoring salmonid fisheries. The Proposed Action, as defined in the EIS/EIR, is full facilities removal of four dams with controlled sediment erosion and downstream transport.

The KHSA stipulates that a determination must be made by the U.S. Secretary of the Interior regarding whether removal of the four dams will enhance salmonid fisheries and will be in the public interest. The four dams are J.C. Boyle, Copco 1, Copco 2, and Iron Gate dams. Three of the reservoirs created by the dams (J.C. Boyle, Copco 1, and Iron Gate) have accumulated large amounts of sediment over time. Under the provisions of the KHSA, the sediment would be naturally eroded and released to the Klamath River with dam removal. The EIS/EIR will address the effects to the aquatic resources from the release of sediment to the downstream river.

Mechanical removal of sediment from the reservoirs, prior to and during dam removal, could help mitigate or reduce downstream impacts to aquatic resources and water quality in the Klamath River. The purpose of this technical memorandum is to briefly summarize the holistic effects and risks associated with mechanical removal of potentially erodible reservoir sediments. This technical memorandum is primarily a synthesis of other reports and information available in the EIS/EIR document.

2 SUMMARY OF CDM SEDIMENT REMOVAL PAPER

CDM and the consulting team prepared a Sediment Management in the Reservoirs report (CDM 2011) to provide planning-level analysis of reservoir sediment removal and disposal feasibility. The report evaluated methodologies that could be undertaken to remove sediment from the three reservoirs, consistent with the KHSA dam removal and reservoir drawdown Scenario 8 developed by the Bureau of Reclamation's (Reclamation) Technical Services Center. Drawdown Scenario 8 was specifically developed to minimize impacts to Southern Oregon/Northern California Coast (SONCC) coho salmon, a threatened species not as resilient to increased turbidity levels and habitat impacts as Chinook salmon and steelhead. Table 1 provides the schedule for the KHSA Proposed Action with drawdown Scenario 8.

Table 1. Summary of drawdown Scenario 8 used in the Sediment Management in the Reservoirs report.

	J.C. Boyle	Copco Phase 1	Copco Phase 2	Copco Phase 3	Iron Gate
Start Date	1/1/2020	11/1/2019	1/1/2020	2/5/2020	1/1/2020
Start Elev. (ft)	3,793	2,606	2,590	2,529	2,328
End Date	2/1/2020	11/17/2019	2/4/2020	2/24/2020	2/11/2020
Ending Elev. (ft)	3,762	2,590	2,529	2,484	2,202
Elev. Difference (ft)	31	16	61	45	126
Avg. Drawdown (ft/day)	1	1	1.75	2.25	3

The bulk of stored reservoir sediment eroded and transported downstream would occur during the reservoir drawdown process. During drawdown, the fine silts and sediment would be mobilized and the remaining sediments would stabilize at an equilibrium slope. Erodible sediment estimates provided in the CDM report varied from the Reclamation estimates. The cause of this difference is due to the calculation methods that were used in the two analyses. The CDM method applied a volumetric approach by creating a pre-dam surface model and another surface model based on core drilling depths taken in 2010, for each reservoir. The erodible sediment volume was determined by subtracting out the historical channel corridor and creating stable reservoir sediment side slopes of 10 horizontal to 1 vertical (10H:1V) along the historical channel corridor. The Reclamation method used reservoir sediment core drillings and field knowledge of the sites to establish sediment depth profiles. Erodible sediment volume estimates were based on these sediment depths. Table 2 provides a summary of the erodible sediment volumes that were developed using the two methods.

Table 2. Reclamation and CDM estimates for erodible reservoir sediment.

		Volume of Erodible Sediment (cubic yards)		
		J.C. Boyle	Copco	Iron Gate
Reclamation (2010)	Range	520,000 - 680,000	3,800,000 - 6,700,000	2,300,000 - 2,600,000
	Ave Estimate Amount	600,000	5,250,000	2,450,000
	Erodible Sediment Volume as % of Total Sediment Volume	60%	71%	52%
CDM (2011)	Estimate Amount	940,000	2,700,000	2,830,000
	Erodible Sediment Volume as % of Total Sediment Volume	94%	36%	60%

Although both erodible sediment calculations methods were deemed acceptable by Reclamation, the modeling methods produced varied results for determining how much erodible sediment is located in the three reservoirs.

Removing the erodible sediment in the reservoirs would be done with barge mounted hydraulic suction dredges. Sediment removal would occur simultaneously at the three reservoirs in two stages using multiple hydraulic suction dredges with cutter head attachments. The hydraulic dredges would suck a mixture of fine sediment and water, approximately 15% sediment and 85% water by volume, that would be conveyed through pipelines to containment ponds where the sediment could settle out of suspension. The maximum depth of dredging below the water surface for the hydraulic suction dredges was estimated at 25 ft. Due to this limited depth, dredging was proposed to happen in two stages.

The first stage would happen before drawdown and would attempt to dredge all of the erodible sediment in the reservoirs to a depth of 25 ft. The second stage would happen during reservoir drawdown and the dredges would continue to remove erodible sediment as water levels lower and provide access to deeper sediments and more areas. Sediment dredging production rates were estimated at 700 cy/hr of sediment for each dredge which is equivalent to pumping the slurry mix at a rate of 35 cubic feet per second (cfs) to get the equivalent sediment quantity. The slurry mix would be pumped to earthen containment structures built nearby using available lands. Earthen berms would be built to a height of 20 ft to create containment structures that would allow the slurry mixture to separate out the sediment using gravity to settle solids. A minimum of 590 acres would be required for the sediment disposal containment structures. An estimated 43% of the total *erodible* sediment, or approximately 22% of the total reservoir sediment, could be removed using hydraulic suction dredges.

3 IMPACTS OF SEDIMENT REMOVAL ON FISHERIES

A technical memorandum prepared by Stillwater Sciences (Stillwater 2011) evaluated the potential effects of mechanical sediment removal on focal fish species inhabiting the Klamath River downstream from Iron Gate Dam. The technical memorandum provided information for the Proposed Action (Scenario 8 drawdown), Proposed Action (Scenario 8 drawdown) with sediment removal, and a third concept that is the same as the Proposed Action with sediment removal but used a slower Scenario 8 drawdown rate. Drawdown Scenario 8 was specifically developed to minimize impacts to coho salmon by performing reservoir drawdown primarily in January and February. Stillwater Sciences used the 1-dimensional hydraulic model SRH-1D (Huang et al. 2010), to evaluate these three scenarios and the corresponding suspended sediment concentrations. Predicted suspended sediment concentrations were used to assess impacts to focal fish species based on life history stage at multiple locations in the middle and lower Klamath River below Iron Gate Dam. The Sediment Management in the Reservoirs report (CDM 2011) did not look at the third option of a slower Scenario 8 drawdown.

SRH-1D modeling results indicated that suspended sediment concentrations would be reduced when reservoir sediment removal (i.e., dredging) is provided with the Proposed Action (Scenario 8 drawdown) versus the Proposed Action that allows sediment to naturally erode. However, even with dredging, suspended sediment concentrations in the Klamath River downstream from Iron Gate Dam would remain high for several months following dam removal. Additionally, the modeling results suggested there would be little to no benefit of removal of reservoir sediments for *most* fish species and life history stages (Stillwater 2011). Tables 3 and 4 from the Stillwater Sciences technical memorandum provide a summary of the predicted benefits for the Proposed Action with sediment removal under the *most-likely* and *worst-case* scenarios. The most-likely condition is analogous to the median model prediction, for which there is a 50% probability of modeled sediment concentrations and durations being equaled or exceeded during the year of facility removal (Reclamation 2011). The worst-case condition is when a 10% probability that the modeled sediment concentrations will be equaled or exceeded during the facility removal.

Some benefits were identified for specific life stages and species as a result of dredging. These benefits are specific to the following: 1) a small proportion of Type III fall-run Chinook salmon outmigrants and Type III spring-run Chinook salmon outmigrants would experience less severe sublethal impacts, 2) a larger proportion of coho salmon smolts outmigrating would experience less severe sublethal impacts, and 3) decreased mortality rates for juvenile steelhead and Pacific lamprey ammocoetes rearing in the mainstem Klamath River. Therefore, the Proposed Action with mechanical sediment removal reduces overall suspended sediment concentrations below Iron Gate Dam and provides some fisheries benefits.

Table 3. Summary of key differences between anticipated impacts of high suspended sediment concentrations under the Proposed Action (Scenario 8 drawdown) versus the Proposed Action (Scenario 8 drawdown) with mechanical sediment removal for the "most likely" suspended sediment release scenario (i.e., 50% exceedance probabilities). (Stillwater 2011)

Species/Run	Life history stage	Predicted benefit of Scenario 8 drawdown with dredging as compared to Scenario 8 drawdown (Proposed Action)	Notes
Fall Chinook salmon	Type III outmigration	20% mortality **reduced** to sublethal effects	Applies to ~1% of production
Spring Chinook salmon	Type III outmigration	20% mortality **reduced** to sublethal effects	<1% of Salmon River production
Coho salmon	Age 1+ winter rearing	No difference	Applies to juveniles in mainstem (assume <1% of production).
	Early spring outmigration	20% mortality **reduced** to sublethal effects	Applies to smolts coming from tributaries in upper mainstem in early spring (~44% of production)
	Late spring outmigration	Degree of stress **reduced**	Applies to smolts coming from tributaries in the upper mainstem in late spring (~56% of production)
Steelhead	Adult migrants	No difference	Applies to adults spawning in mid- and upper-Klamath tributaries (~80% of run), proportion migrating prior to Dec. 15th (~20%) will not be affected
	Age 1+ mainstem rearing	52% mortality **reduced** to 20% mortality	Applies to juveniles in mainstem (~60% of juveniles)
	Age 2+ mainstem rearing	52% mortality **reduced** to 20% mortality	Applies to juveniles in mainstem (~60% of juveniles)
	Outmigrants	Degree of stress **reduced**	~47% outmigrate from Trinity River and will have less exposure
Pacific Lamprey	Adult migration	No difference	Later-returning adults and those returning to lower tribs will have less exposure.
	Ammocoete rearing	52% mortality **reduced** to 20% mortality	Applies to multiple year-classes of ammocoetes in mainstem; majority rear in tribs and won't suffer mortality

Table 4. Summary of key differences between anticipated impacts of high suspended sediment concentrations under the Proposed Action (Scenario 8 drawdown) versus the Proposed Action (Scenario 8 drawdown) with mechanical sediment removal for the "worst-case" likely suspended sediment release scenario (i.e., 10% exceedance probabilities). (Stillwater 2011)

Species/Run	Life history stage	Predicted benefit of Scenario 8 drawdown with dredging as compared to Scenario 8 drawdown (Proposed Action)	Notes
Fall Chinook salmon	Type III outmigration	71% mortality **reduced** to 52% mortality	Applies to ~1% of production
Spring Chinook salmon	Type I outmigration	No difference	Applies to Type I fry from Salmon R. (<1% of Salmon R. production)
	Type III outmigration	No difference	
Coho salmon	Age 1+ rearing	No difference	Applies to juveniles in mainstem (assume <1% of production)
	Early spring outmigration	49% mortality **reduced** to 20% mortality	Applies to smolts coming from tributaries in upper mainstem in early spring (~44% of production)
Summer steelhead	Adult migrants	20% mortality **reduced** to sublethal effects	Applies to fish spawning in mid- and upper-Klamath tributaries (~53% of run)
Winter steelhead	Adult migrants	71% mortality **reduced** to 52% mortality	Applies to fish spawning in mid- and upper-Klamath tributaries (~80% of run). The proportion migrating prior to December 15th (~20%) will not be affected.
	Adult runbacks	No difference	Effects dependent on duration of exposure when in the mainstem
Summer and winter steelhead	Age 0+ rearing	No difference	Applies to juveniles in mainstem (~60% of juveniles)
	Age 1+ rearing	71% mortality **reduced** to 52% mortality	
	Age 2+ rearing	71% mortality **reduced** to 52% mortality	
Pacific lamprey	Adult migration	71% mortality **reduced** to 52% mortality	Later-returning adults and those returning to lower tributaries will have less exposure
	Ammocoete rearing	71% mortality **reduced** to 52% mortality	Applies to multiple year classes of ammocoetes in mainstem; majority rear in tributaries and will not suffer mortality

4 IMPACTS OF SEDIMENT REMOVAL ON WATER QUALITY

Water quality parameters documented in the EIS/EIR include water temperature, suspended sediment, nutrients, dissolved oxygen, pH, algal toxins and chlorophyll-a, and inorganic and organic contaminants. Mechanical removal of reservoir sediment in conjunction with the Proposed Action has an effect on these water quality parameters, particularly suspended sediment and dissolved oxygen as over 80% of the reservoir is fine sediment consisting of silt, clays, and organics (Reclamation 2011).

Sediment modeling was performed using SRH-1D as previously described in Section 3. Model results showed that dredging would reduce overall suspended sediment concentrations in the Klamath River immediately downstream of Iron Gate Dam by roughly 50% compared to the Proposed Action of full dam removal with natural erosion of reservoir sediments. For all water year types, peak suspended sediment concentrations (occurring in February 2020) would be reduced by roughly 50% from 9,000 - 13,000 mg/L to approximately 5,000 mg/L. Sediment concentrations at other times would be reduced by anywhere from approximately 10% to 70% depending on water year type (i.e. wet or dry year) and month. This decrease in suspended sediments would also decrease peak oxygen demand to levels that would support concentrations greater than 5 mg/L at all locations and throughout the drawdown period.

Model results for the Proposed Action indicate that dilution in the lower river would decrease suspended sediment concentrations to 60% - 70% of their initial value by Seiad Valley (RM 129) and to 40% of their initial value by Orleans (RM 59). Within an uncertainty factor of 2 for the model results, it can be conservatively assumed that suspended sediment concentrations in the lower Klamath River would still be sufficient (>30 mg/L) following dredging to adversely affect beneficial uses throughout the lower Klamath River and the Klamath Estuary for 4 to 6 months following drawdown (Reclamation 2011).

Sediment modeling with SRH-1D showed that removal of reservoir sediment before drawdown and during drawdown would lower suspended sediment concentrations in the Klamath River downstream of the dams. Despite the decreases in overall suspended sediment concentrations that would occur downstream of the dams and the shortened periods of time when concentrations exceed 30 mg/L or 100 mg/L, suspended sediment concentrations downstream of Iron Gate Dam would still remain above 30 mg/L for a sufficient duration (i.e., at least 4 weeks) to have a significant impact on water quality (Administrative Draft EIS/EIR 2011).

5 IMPACTS OF SEDIMENT DISPOSAL ON PLANTS AND TERRESTRIAL WILDLIFE

Disposal of mechanically removed sediments would require containment structures at each of the reservoirs. These containment structures would be built on existing land with earthen berms to create pond areas to hold the sediment slurry. An estimated footprint of 590 acres would be required to contain the volume of sediment slurry that could be removed from the reservoirs using hydraulic suction dredges (CDM 2011).

Potential locations for sediment containment structures were identified in the Sediment Management in the Reservoirs report (CDM 2011). These areas are in close proximity of the reservoirs and are located in transitional and upland areas that contain special-status (i.e., federal or state protection) plant and wildlife species as identified in the Administrative Draft EIS/EIR (2011). Protected status wildlife that could potentially be within the footprint or surrounding areas of the containment structures include bald eagle, willow flycatcher, and greater sandhill crane. Nesting sites for bald eagle and greater sandhill crane are also within these areas. Protected status plants include Egg Lake monkeyflower, Green's mariposa lily, and Pendulus bulrush. In addition to the known special-status plants and wildlife, many more species are potentially present with details identified in the EIS/EIR.

Sediment disposal using nearby land for containment structures would result in direct and indirect impacts to plants and wildlife. Examples of direct impacts could include construction vehicle collisions with wildlife, burial and loss of terrestrial wildlife within the containment structures, loss of native vegetation, and loss of habitat by land clearing. Indirect impacts could include loss or change of habitat due to alteration of environmental conditions (e.g., soil moisture), introduction of invasive species from reservoir sediment and land disturbances, alteration/compaction of soils, and short-term impacts to air quality and noise pollution.

Alteration of habitats and impacts to terrestrial wildlife would occur during initial sediment disposal and would lead to permanent displacement of habitat by leaving the sediment containment structures in place. Additional restoration actions for the sediment deposits and containment structures would be necessary to reduce long-term impacts and reduce the potential for invasive vegetation colonization of the disturbed areas. The restoration actions would likely include grading and contouring sediment disposal sites to blend into existing topography to minimize long-term maintenance and down-gradient impacts to wildlife such as overland erosion and runoff. Planting the sites with native vegetation would also be included as a necessary restoration action to avoid propagation of non-native plant species.

6 FEASIBILITY OF RESERVOIR SEDIMENT REMOVAL

Although impacts to plant and terrestrial wildlife would occur, mechanical sediment removal may be an option to mitigate impacts to fisheries and water quality. Several aspects of mechanically dredging reservoir sediments need to be further analyzed to adequately ascertain the feasibility of this endeavor. The following sections give a brief overview of important features that directly impact the feasibility of sediment removal.

6.1 Additional Sediment Accumulation

As summarized in Section 2 and in the CDM report, erodible sediment volumes were calculated using current sediment core drillings and historical topographic surface elevations from pre-dam conditions. This method for determining erodible sediment is sound and produces acceptable results for erodible sediment volumes based on conditions in 2010. However, the Proposed Action with mechanical sediment removal would not proceed until 2020 and would allow for 10 additional years of sediment accumulation in the reservoirs. The additional accumulation is anticipated to increase the sediment volumes in the reservoirs by 24% at Iron Gate, 12% at Copco, and 22 % at J.C. Boyle (Reclamation 2011). It is estimated that there will be 15 million cubic yards of total sediment stored behind the three reservoirs by 2020.

It is not known how much of the additional accumulation of reservoir sediment would be erodible. However, the volume of additional sediment is on the order of 2 million cubic yards and even if less than 50% is erodible, it represents a significant increase in the amount of sediment that would have to be removed with hydraulic dredging. The additional sediment removal would have impacts on containment structure sizes, restoration of disturbed areas, and overall costs and feasibility of reservoir sediment removal.

6.2 Site Restoration

The minimum land required for containment structures exceeds 590 acres and would require a minimum of three containment areas and more likely six, two at each reservoir, to accommodate dredging activities. This estimate does not include the access roads to and from the containment areas and does not account for the footprint for ancillary structures necessary for transfer pipelines and construction equipment staging areas. In addition, borrow sites may have to be created outside the containment structures to generate adequate quantities of material to construct containment berms. After the containment structures are filled, it is estimated that over 2.8 million cubic yards of sediment would be stored in the containment structures.

The CDM report (CDM 2011) identifies potential containment structures sites but does not account for restoration of the areas after sediment disposal. Once the sediment removal process is completed, the containment sites and disturbed areas would likely require restoration to suitable conditions for long term safety and suitability for the surrounding environment. This would likely include reducing the height of the sediment and containment berms by spreading and recontouring to fit the natural topography and shape of the land. Revegetation of the disturbed sites would be necessary to minimize colonization by unwanted vegetation and invasive weeds. Little or no accounting of these associated environmental impacts have been reviewed for this disturbance around the reservoir areas as described in Section 5 of this report. The potentially large amount of restoration associated with sediment disposal on surrounding lands could offset some of the benefits realized by reservoir sediment removal by creating air quality impacts, wildlife impacts, cultural resources impacts, and similar unforeseen consequences.

6.3 Containment Berm Construction and Siting

One of the most critical links in the sediment removal process is having adequate area and structural confinement to contain the large amount of sediment slurry water. The CDM report (2011) states that over 590 acres of land will be required to contain the sediment slurry by building 20 ft high containment berms. The berms would be built in areas that have topographic slopes less than 20% (ideally less than 10%) and would be built using on-site native materials. Side slopes of the containment berms would be built at 2H:1V with an 8 ft top width.

Initial field review of potential containment structure sites by River Design Group revealed that many of the sites contain rocky soils that would make it difficult or impossible to generate material to create containment berms. As a result, borrow sites would have to be created that contain adequate soils with favorable soil properties to build sound containment berms. Several other potential sites that were reviewed contained dense stands of trees that would require clearing and disposal. These additional measures that would be necessary to make the sites suitable for containment structures would likely enlarge the disturbance footprint well over the 590 acres required for containment and would also require additional site restoration of disturbed areas.

7 RISKS AND UNCERTAINTIES OF RESERVOIR SEDIMENT REMOVAL

The term *risk* is associated with the ability to predict and define the outcome of an action versus the actual outcome. *Uncertainty* is associated with the knowledge of specific variables and information that are used to select an action. These terms are often used interchangeably to help convey the level of certainty with information that goes into project decisions and the ability to predict the outcome. With all large construction projects, there are inherent risks and uncertainties associated with construction techniques and work schedules. The following sections highlight some of the more significant risks and uncertainties associated with sediment removal and modeling in the reservoirs.

7.1 Weather Conditions

Weather conditions can play a major role in construction productivity and therefore provides an element of risk for dredging reservoir sediment. For example, cold weather conditions overnight could cause sediment slurry transport pipelines to freeze, containment ponds could freeze, snow and ice could make it difficult or impossible for construction workers to access the sites, and the J.C. Boyle reservoir water surface could freeze as has been documented in the past. These are a few of the potential complications that could severely impact sediment removal efficiency. In order to gain insight into this potential risk, an understanding of average weather conditions is necessary.

Although several weather stations exist at or near the dam locations, the stations do not have long term statistics; hence, only representative weather stations in the project area vicinity with long term observations (>75 years) were used to gain insight into expected climatic conditions during construction. Table 5 contains average monthly temperature and precipitation statistics for nearby weather stations during the proposed drawdown and sediment removal period of November 1st through June 30th. The selected weather stations have long periods of record and provide good predictions for probable conditions.

Table 5. Summary of monthly temperature and precipitation patterns from weather stations in the Upper Klamath Basin. Each weather station has a period of record greater than 75 years. Data provided by the Western Regional Climate Center.

	Avg. Min. Temperature (°F)			**Avg. Max. Temperature (°F)**			**Avg. Snowfall (in)**		
	Yreka	Keno	K. Falls	Yreka	Keno	K. Falls	Yreka	Keno	K. Falls
November	29.4	27.7	28.2	53.6	44.5	48.3	1.8	6.3	3.8
December	25.4	15.9	22.7	44.4	33.9	39.4	4.7	13.6	9.1
January	24.0	22.4	20.6	44.3	34.8	38.1	6.5	16.3	12.1
February	27.0	22.3	24.5	50.5	41.4	44.0	2.9	9.6	6.0
March	30.1	25.6	28.1	56.7	45.2	50.8	1.7	6.3	3.8
April	34.2	25.9	32.5	63.7	51.8	59.3	0.5	2.1	1.2
May	40.2	33.3	39.0	72.8	65.1	67.5	0.0	0.2	0.2
June	46.4	42.0	45.0	82.5	76.1	75.7	0.0	0.0	0.0

Based on the average minimum temperatures calculated from the weather station data, freezing temperatures during the night persist for most of the drawdown and sediment removal period. Likewise, measureable snowfall would be expected throughout most of the reservoir sediment dredging timeframe. Current workforce projections estimate that each dredge would require 4 workers (2 on the barge, 2 on the shore) to operate each dredge for 16 hours/day, 6 days/week (CDM 2011). Inclement weather conditions would likely have an impact on the ability to work the proposed shifts and could pose a significant risk and area of uncertainty for sediment removal production. Likewise, the ability to consistently reach the upper end of the manufacturer's production rates of 700 cy/hr of sediment removal is highly uncertain due to weather and lack of daylight hours.

7.2 Cultural Resources

The EIS/EIR identifies five known cultural resource sites that are submerged in the reservoirs (Administrative Draft 2011). Impacts (e.g., a loss of integrity) to these sites could occur during sediment dredging as a result of disturbing sediment and unearthing areas that have been buried for several decades. Since the dredging would take place underwater and with little or no visibility, determining the extent of impacts to culturally significant resources would be difficult. Likewise, there is the potential for encountering undocumented sites within the reservoir work areas during dredging.

Outside of the reservoir in-water work areas, a host of ground-disturbing construction support areas would be built. Construction support areas include sediment containment structures, construction staging areas, ancillary structures and access roads necessary to support the dredging and disposal efforts. These disturbances outside the reservoir areas would vastly increase the construction footprint and could affect historic properties and resources, or human remains since most of the study area (i.e., approximately 64%) has not been surveyed for significant cultural resources (Administrative Draft EIS/EIR 2011).

Due to the potential to encounter undocumented, culturally significant sites in the reservoirs and the lack of cultural surveys in the surrounding areas that would be impacted by sediment removal operations, there is a high degree of uncertainty and risk concerning cultural resources. Encountering an undocumented cultural resource site in either the reservoirs or surrounding construction areas would cause considerable delays and reduce the amount of sediment that could be removed from the reservoirs.

7.3 Sediment Slurry Decant Process

The CDM (2011) report stated that dredged material would be transported in pipelines to containment areas and would consist of approximately 85% water and 15% sediment. In order to reduce the containment area required for sediment disposal, the report stated that the supernatant would be discharged back into the Klamath River. In order for this water to be discharged back into the river and not cause additional water quality impacts, it would have to be free of suspended sediments.

Characterization of the sediment stored in the reservoirs reveals that the majority of sediment consists of clay and silt particles with minor amounts of sand sized particles. Due to the small size of the stored sediment, the best way to separate the suspended sediment from the water is by using settling ponds (i.e. gravity) and applying flocculants to speed particle settling rates. Additional technologies that could be evaluated include parallel plate clarifiers or other emerging technologies that facilitate water-sediment separation. Physical separation of sediment using filtration techniques or screw presses would not be viable due to the small particle sizes and high production flow rate for the proposed suction dredges.

Separation of sediment can be achieved using gravity with adequate storage time in containment ponds. However, risks associated with this technique, primarily from weather conditions, could affect settling efficiency. For example, wave action on the containment ponds could increase sediment settling time which would require more containment space. Furthermore, the containment ponds could freeze during winter weather conditions making it more difficult to separate and pump supernatant from the containment ponds.

7.4 Redundancy of Construction Techniques

Underwater work and in-water work are inherently uncertain activities based on the inability to fully see and comprehend the existing conditions below the water surface. Reservoir sediment deposition has occurred over decades and it is unknown what debris could be in the deposited material. Likewise, it is standard practice to have a contingency plan or alternative construction methods to deal with unforeseen circumstances or if the techniques being used are not working appropriately or are causing undesirable effects. The CDM report discusses multiple ways to remove sediment from the reservoirs and recommends hydraulic dredging from a barge-mounted dredge. Other standard methods such as mechanical dredging with a clamshell bucket, were dismissed due to potential water quality problems and truck transportation impacts.

Hydraulic dredging is a proven technique for fine sediment removal in freshwater environments, however, documentation of this technique being used for a similar reservoir drawdown scenario is not available. In addition, the drawdown scenario does not allow flexibility in the event that one of the dredges has mechanical problems or the dredging rate is not able to keep up with the reservoir drawdown rate. The alternative methods and techniques for sediment removal would likely produce detrimental impacts that could potentially offset the benefits of sediment removal. Since there appears to be no feasible alternative technique to hydraulic dredging and no schedule float, there is a high level of risk and uncertainty if hydraulic dredging is unsuccessful with no alternative methods identified for sediment removal in the reservoirs.

7.5 Cost Estimates and Escalation

An opinion of probable construction cost (OPCC) was developed by CDM for sediment removal using hydraulic suction dredges and slurry containment structures as described above. At this point in the planning and study stage, OPCC are highly variable with accuracy in the range of -30% to +50% (CDM 2011). The initial OPCC for sediment removal with containment structures was $97 million. As stated in the estimate, it does not account for escalation of costs for the future Proposed Action that is scheduled to take place in 2020. Using an escalation rate of 3% compounded annually for the 9 year period between present day and 2020, the projected future cost in 2020 would be approximately $127 million.

In addition to a standard project escalation rate assumed for labor and construction equipment, some variables have larger degrees of uncertainty. For example, the average price of diesel in 2002 was approximately $1.40/gallon whereas the average price in 2010 was over $2.85/gallon, an increase of over 100% in 8 years according to the U.S. Energy Information Administration (www.eia.doe.gov). Prices of diesel and equipment rates are likely to continue to increase over the next 9 years and could significantly increase construction costs. Due to the high degree of uncertainty in future construction costs, there is a large amount of risk that the current OPCC of $97 million could appreciably rise to more than $127 million in 2020 dollars. Likewise, no costs were included for design engineering, construction oversight, legal fees, land acquisition fees, and similar actions necessary to carry out the sediment removal operation. These fees would likely increase the project costs by an additional 25% to 35%.

7.6 Availability of Equipment

The type of required dredges are specialized pieces of equipment not typically used in the Klamath Basin or the Southern Oregon/Northern California region. Hydraulic dredges would likely have to be imported from areas that have these types of equipment such as the Southern California or Midwest states. Hydraulic dredges would exceed a weight of 50 tons and 70 feet in length and would present a challenge transporting to the reservoirs with rail and road size and weight limits. Five dredges would be needed to operate concurrently during drawdown (CDM 2011). The availability of this many hydraulic suction dredges is highly uncertain. In addition, if maintenance and repair of a dredge is necessary, it could have a significant impact on productivity with little or no alternative equipment available for replacement.

7.7 Past Experience

Recent large dam removal projects in the western United States have allowed reservoir sediments to naturally erode during and after dam removal. Recent examples include dam removal projects on the Sandy River (Marmot Dam), Rogue River (Gold Ray Dam and Savage Rapids Dam), and the Klamath

Basin's Sprague River (Chiloquin Dam) in Oregon. Natural river erosion is a frequently employed sediment management practice associated with dam removal of all sizes (Reclamation 2006) and is the technique planned for the Proposed Action.

A common approach to reduce downstream impacts of natural reservoir sediment erosion is to excavate the stored sediments from the reservoir area. This approach typically lowers the reservoir by creating a bypass channel and then stored sediments are excavated. This technique was utilized for the recently removed Milltown Dam (Clark Fork River) in Montana where over 2 million cubic yards of contaminated reservoir sediment were removed. This technique was successful because the broad floodplain provided sufficient acreage for a bypass channel that allowed for routing up to the 100 year flood event around the stored sediments. Reservoir sediments consisted of sands and gravels, coarser material than the fine sediment that dominates the deposits in the Klamath River reservoirs. The reservoir bypass channel technique would not be feasible in the Klamath River reservoirs due to confined bedrock canyons (i.e., inadequate channel connectivity) and highly erodible reservoir deposits that would have insufficient integrity for bypass channel construction.

Based on site constraints, sediment removal from the reservoirs prior to and during drawdown using hydraulic suction dredges is a means to implement the potential mitigation measure to reduce impacts to fisheries and water quality. Although sediment removal from the reservoirs may be a worthwhile undertaking, the engineering team is unaware of a similar effort of this magnitude for fine sediment removal from deep, remote, freshwater reservoirs (CDM 2011). In addition, the dredging process would be happening simultaneously at each reservoir site making it difficult to apply lessons learned to improve efficiencies other than daily adaptive management.

7.8 Sediment Modeling

Numerical sediment modeling is a highly variable exercise when modeling fine sediments such as clays and silts as found in the three reservoirs. Stewart et al. (2002) documented a reservoir sediment release, similar to that of the Proposed Action, at Cougar Reservoir on the South Fork McKenzie River, in western Oregon. The reservoir sediment was predominantly sand and gravel with smaller amounts of silts and clays. The reservoir was lowered below minimum pool elevation in April 2002, exposing reservoir bottom sediments to natural erosion by the South Fork McKenzie and other reservoir tributaries. The erosion of these sediments resulted in a prolonged discharge of turbid water from Cougar Reservoir that was highly visible for miles downstream and even affected the turbidity of the Willamette River below the McKenzie River confluence. The U.S. Army Corps of Engineers had predicted in its EIS that turbidity would increase during drawdown (predicted levels of 30 NTUs and spikes of 100 NTUs), but they underestimated the magnitude, timing, and duration of the problem. Between April 1st and May 25th turbidity levels at the South Fork McKenzie River gauging station below the dam averaged 68 NTUs with spikes of up to 379 NTUs. The South Fork McKenzie River experienced high turbidity for approximately 2 months. In the South Fork McKenzie River example, the existing bed material downstream from the reservoir had a D_{50} of approximately 20 to 50 mm which is slightly smaller than the Klamath River bed material downstream of Iron Gate (Reclamation 2011).

Reclamation has completed a thorough and technically sound modeling effort assessing reservoir sediment impacts during the Proposed Action and the Proposed Action with mechanical sediment removal. However, as documented in a similar reservoir drawdown on the South Fork McKenzie River, sediment modeling has a high degree of variability and it is difficult to accurately predict suspended sediment concentrations during a dynamic process such as dredging during reservoir drawdown. Due to the dynamic nature of dredging, variability in sediment depositional patterns, and actual erosion patterns of reservoir sediments during drawdown, a high degree of uncertainty exists for accurately predicting suspended sediment concentrations during project implementation with mechanical sediment removal.

8 SUMMARY

The Proposed Action (full facility removal) allows for natural erosion of sediments stored within the reservoir areas. In order to minimize impacts to threatened SONCC coho salmon, reservoir drawdown Scenario 8 was developed by Reclamation to have sediment releases occur primarily in January and February. To further reduce potential impacts to fisheries and water quality, implementing the Proposed Action (full facility removal) concurrently with mechanical removal of reservoir sediment is a potential mitigation measure requiring further study. To further investigate the scope and magnitude of mechanical sediment removal, CDM and the consulting team prepared a Sediment Management in the Reservoirs report (CDM 2011) for planning-level analysis.

The CDM report evaluated methodologies that could be undertaken to mechanically remove sediment from the three reservoirs concurrently with drawdown Scenario 8. Hydraulic suction dredges would work simultaneously at each reservoir during drawdown to remove sediment and pump it to land-based, earthen containment structures. Based on assumptions in the report, it was estimated that 43% of the 6.5 million cubic yards of potentially erodible reservoir sediment could be removed using hydraulic suction dredges. This equates to approximately 22% of the total sediment volume stored in the reservoirs. Costs for mechanical sediment removal were estimated at $97 million, but did not account for escalation that would put the projected future cost in 2020 to approximately $127 million. No costs were included for design engineering, construction oversight, legal fees, land acquisition fees, and similar actions necessary to carry out the sediment removal operation. These costs would likely increase project estimate by an additional 25 - 35%.

Sediment modeling results were prepared by Reclamation (2011) and Stillwater Sciences (2011) and suggested that some fisheries and water quality benefits may be realized for specific fish species and life stages as a result of dredging reservoir sediments in conjunction with the Proposed Action versus implementing the Proposed Action and allowing natural erosion of stored sediments. However, even with mechanical dredging, suspended sediment concentrations in the Klamath River downstream from Iron Gate Dam would remain high for several months following dam removal. With the predicted high sediment concentrations, there would be, in general, little to no benefit of mechanically dredging sediments for most fish species and life history stages (Stillwater 2011). In addition, there are potential impacts to cultural resources and terrestrial wildlife around the reservoir areas during sediment disposal as well as short-term impacts from air quality and noise pollution.

The Sediment Management in the Reservoirs report (CDM 2011) was developed primarily to determine if mechanical sediment removal could be implemented as a potential mitigation measure with the Proposed Action. It was shown through sediment modeling that marginal benefits may be realized to fisheries as a result of mechanical sediment removal. However, feasibility along with risk and uncertainties associated with sediment removal make the mitigation measure risky in terms of meeting planned sediment removal targets that reduce aquatic and water quality impacts. Furthermore, a high degree of uncertainty remains about the adequacy of potential disposal sites in addition to unintended environmental impacts to terrestrial wildlife and cultural resources caused by the footprint of the sediment disposal sites and supporting infrastructure.

9 REFERENCES

CDM. 2011. Klamath Settlement Process, Sediment Management in the Reservoirs. Draft Report. Prepared by CDM, Sacramento, California.

Huang, J. V., B. Greimann, and Y. Lai. 2010. User's manual for SRH-1D 2.6, Sedimentation and River Hydraulics – One Dimension, Version 2.6. Technical Report SRH-2010-25. U. S. Bureau of Reclamation, Sedimentation and River Hydraulics Group, Technical Service Center, Denver, Colorado.

Reclamation. 2006. Erosion and Sedimentation Manual. Technical Service Center, Sedimentation and River Hydraulics Group, Denver, Colorado.

Reclamation. 2011. 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, US Bureau of Reclamation, Technical Service Center, Denver, CO.

Stewart, G., et al. 2002. Evaluation of Fine Sediment Intrusion into Salmon Spawning Gravels as Related to Cougar Reservoir Sediment Release, Prepared for Portland District Office, US Army Corp of Engineers.

Stillwater Sciences. 2011. Klamath Dam removal Drawdown Scenario 8: Potential impacts of suspended sediments on focal fish species with and without mechanical sediment removal. Final Technical Memorandum. Prepared by Stillwater Sciences, Berkeley for CDM, Sacramento, California.

U.S. Army Corps of Engineers (COE). 2008. Matilija Project: Slurry Transport and Storage of Reservoir Fines, Draft Report. Prepared by Rescan Environmental Services Ltd., Vancouver, British Columbia for the Army Corps of Engineers, Los Angeles District, California.