Klamath River

Dam and Sediment Investigation

November 2006

GATHARD ENGINEERING CONSULTING

Seattle, Washington

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1. Executive Summary

The State Coastal Conservancy (Conservancy) and the Ocean Protection Council (OPC), two agencies of the State of California, initiated this study to characterize sediment behind four dams of the Klamath River Hydroelectric Project on the Klamath River, and examine the possibility of dam removal. This study investigates removal of the four most downstream dams: Iron Gate, Copco 2, Copco 1 and J.C. Boyle.

1.1. Project Setting

The Klamath River is located in northern California and southern Oregon on the Pacific coast of the United States. The Klamath River Hydroelectric Project, owned by PacifiCorp, consists of six generating developments along the mainstem of the Upper Klamath River. The project also includes a re-regulation dam with no generation facilities, and one generating development on Fall Creek, a tributary to the Klamath River.

The Klamath River Project is now undergoing relicensing proceedings before the Federal Energy Regulatory Commission (FERC). Separate from the formal FERC relicensing process, a Settlement Group has explored future project management alternatives, and its Dam Removal Subgroup has investigated dam removal as a project management alternative.

Previous dam removal studies have suggested that downstream erosion of sediment to the marine environment would be a feasible approach to dam removal and sediment management, but this conclusion was limited by the lack of information characterizing sediment quantity, quality, and management options. Therefore, the Subgroup asked the Conservancy to conduct a detailed reservoir sediment study and dam removal investigation. The Conservancy entered into contracts with Gathard Engineering Consulting (GEC) and Shannon and Wilson, Inc., (S&W) to characterize sediment located behind the four lowermost dams, and to conduct preliminary dam removal studies.

1.2. Study Elements

The investigation included the following tasks:

- Review of the history and nature of upland river basin activities to determine possible sources of reservoir sediment contamination;
- Preparation of a plan for sampling and testing sediment;
- Retrieving sediment samples;
- Analysis of sediment samples for chemical and grain size characteristics;
- Development of a feasible method of removing the four dams;
- Review of the downstream effects of reservoir sediment erosion;
- Development of cost estimates and schedules for removal.

The Upland Contaminant Source Study (Upland Study) was conducted in early 2006, and revealed potential sources of contamination from industrial, commercial, and government activities. This study guided the development of a Sampling Plan intended to screen for various chemicals of concern, and to assess reservoir sediment contamination levels.

S&W sampled sediment and conducted other fieldwork necessary for completion of the study. Based on the Sediment Sampling Plan, reservoir sediments were sampled through a combination of over-water boring techniques and grab samples at 26 locations.

1.3. Study Results

1.3.1. Contaminants

S&W sent the sediment samples to Analytical Resources, Inc. (ARI) for laboratory chemical testing and grain size analysis. Puget Sound Dredged Disposal Analysis (PSDDA) protocols were selected as the optimum protocol for evaluating possible contaminants in the reservoir sediments. PSDDA protocols have been used for approximately 20 years as a method of assessing suitability for sediment deposition in the marine water of Washington State's Puget Sound. PSDDA chemical analysis protocols and chemicals of concern identified in the upland investigation were used as a basis for the contamination investigation and as a guide for assessing the suitability of allowing river flow to erode reservoir sediments downstream following dam removal.

Test results from ARI showed one location where chemicals in the sediment were present at concentrations exceeding PSDDA protocols. S&W reviewed ARI's test results and concluded that the chemicals involved were highly volatile and would evaporate rapidly upon exposure to air. Further examination showed that sediment chemistry would permit downstream erosion of river reservoir sediments.

1.3.2. Sediment Volume and Characterization

An analysis of information previously developed for PacifiCorp indicated that approximately 20.4 million cubic yards of sediment is trapped in three of the reservoirs. The fourth reservoir, Copco 2, does not retain sediment. The analysis of the volume of trapped sediment exceeded the volume report by JC Headwaters for PacifiCorp by approximately 6 million cubic yards, primarily due to the volume differences computed for Iron Gate Reservoir. Since no original topographic data was developed in this study the source of the difference is unknown but could have resulted from many different sources described in this report.

Sediment physical properties, analyzed by ARI and S&W, were used to assist GEC in developing a feasibility level analysis of dam removal options. Sediment grain size analysis conducted by ARI revealed that approximately 84% of the sediment would, when eroded, travel in suspension in the river water column past the mouth of the river and into the marine environment. Analysis of the overall sediment volume, river morphology, and characteristics of the sediment in the reservoirs indicates that approximately 4 million cubic yards of sediment would erode downstream due to drawdown of the reservoirs.

The investigation found that sediment in the path of river flow would erode nearly instantaneously when exposed to moving water. Suspended sediment would travel to the ocean within approximately four days after being eroded. Eroding the sediment would dramatically increase river suspended sediment concentrations immediately downstream of Iron Gate Dam for the period of time required to draw down the reservoirs.

1.3.3. Current Water Use

Investigation of water users downstream of Iron Gate Dam determined 91 locations where water was being withdrawn or could be withdrawn from the river. None of the withdrawals were large industrial or domestic uses. Water quality protection for downstream water users was not thoroughly investigated but conceptual protection measures were developed. Costs were assigned for water quality protection based on conceptual protection measures.

1.3.4. Drawdown Implications

Reservoirs would need to be drawndown before dams could be removed. Reservoirs could be drawn down sequentially or concurrently. Drawing down all the reservoirs concurrently, rather than sequentially, would reduce the overall duration of highly elevated suspended sediment levels. The shortest duration of sediment erosion would be limited by the maximum rate of reservoir drawdown. Suspended sediment concentrations were analyzed assuming that reservoirs would be drawn down over a period of 120 days, or about one foot per day. However, stability analysis of Iron Gate Dam, an earth-embankment structure, indicates that a higher rate of at least 3 feet per day may be feasible. Further analysis will be required to determine the optimum rate of drawdown for each facility, and whether higher drawdown rates can be achieved.

The highest suspended sediment concentrations would occur from eroding sediment to form a new river channel as reservoir elevations are drawn down. After reservoir drawdown, sediment eroded from the riverbanks and overbanks would continue to elevate suspended sediment levels, but would do so at much lower suspended sediment concentrations.

Determination of the best time of year for reservoir drawdown will require further analysis and consideration of effects on water quality. Cost and schedule analyses in this report were based on initiating the drawdown in October. Reservoirs would be drawn down to the maximum level possible through low level outlets and maintained at the lowest possible level. After drawdown, spring high flows may raise reservoir water elevations again, reinundating sediment deposits, and cause additional erosion of formerly deposited sediment in the future.

1.3.5. Dam Removal Approach

Reservoirs would be drawn down prior to beginning dam demolition. Iron Gate and J. C. Boyle have functional low level outlets that may be used to draw down the reservoirs. A new low level outlet would be constructed at Copco 1 Dam by constructing a tunnel through the base of the dam. Both Iron Gate and Copco 1 would require new outlet gates to draw down reservoirs at a safe rate.

Mechanical excavating equipment would be used to remove Iron Gate and J. C. Boyle, the two earth embankment dams. Copco 1 and Copco 2 dams would be demolished using drilling and blasting techniques to reduce the concrete to rubble for removal. Excavated dam material would be relocated and stabilized near the dams, within the project boundaries.

Iron Gate Dam would be removed over a period of approximately five months following spring high flows to avoid any possibility of overtopping a partially removed structure. Copco 1 Dam could be removed immediately after reservoir drawdown or following spring high flows over a period of approximately four months. Copco 2 Dam would be removed prior to drawdown by drying up the river temporarily between Iron Gate and Copco 1 dams. The reservoir at Iron Gate would be used to supply water to the river downstream.

J. C. Boyle Dam would be removed in stages. The reservoir would be drawn down and the upper portion of the dam would be removed in the summer season prior to drawdown of Copco 1 and Iron Gate reservoirs. The bottom portion of the dam along with most of the sediment in the reservoir would be eroded simultaneously with drawdown of the Iron Gate and Copco 1 reservoirs.

1.3.6. Costs

Cost for removing the dams, providing water quality protection, and developing engineering and permitting documents was estimated to be approximately $88 million.

2. Study Objectives and Background

In 2003, G&G Associates conducted a preliminary investigation of feasibility of removing four dams on the Klamath River. That report was conducted at a reconnaissance level. Removal approaches and cost were based on very limited information on dam facilities, sediment characteristics, and construction methods. Major unresolved issues in the 2003 G&G report included the character and volume of trapped reservoir sediment, engineering details of dam facilities, and water rights and use patterns downstream of the dams.

The current report, conducted at the feasibility level, has developed additional information regarding each of these issues. It makes no attempt to provide a comprehensive or final analysis of dam removal as a project management alternative. Nor does this report attempt to characterize in detail any adverse effects associated with the dam removal scenario presented.

This report:

- Characterizes sediment volumes found behind Iron Gate, Copco II, Copco I and J.C. Boyle dams;
- Characterizes grain size and location of sediment in the reservoirs;
- Identifies possible sources of contamination in and around the four lower Klamath reservoirs;
- Analyzes the sediment grain size distribution and characterize the chemistry of the sediment and level of contamination;
- Develops potential dam removal approaches to provide guidance to the subgroup;
- Identifies means of avoiding or minimizing adverse effects associated with a suggested removal approach;
- Estimates costs of dam removal and associated water quality protection measures and provide a schedule of activities.

Information used to conduct this report was specifically developed for this report, obtained from public records, or supplied by PacifiCorp, the project owner. Additional studies and analyses that would be necessary precursors to dam removal are discussed in Appendix J

3. Introduction

The Klamath River flows from its headwaters near Crater Lake, Oregon to its confluence with the Pacific Ocean at the town of Klamath, California. The Klamath River Project is a hydroelectric facility consisting of six generating developments along the mainstem of the Upper Klamath River, between river mile 190 and 254. The project also includes a re-regulation dam with no generation facilities, and one generating development on Fall Creek, a tributary to the Klamath River at about river mile 196. The Klamath River Project is now undergoing relicensing proceedings before the Federal Energy Regulatory Commission.

Outside of the traditional relicensing process, many interested parties have met to discuss future management options for the project. The Settlement Group formed a Dam Removal Subgroup in April 2005 to investigate the feasibility of dam removal as a future project management alternative. This subgroup asked Conservancy to conduct a detailed study of the sediment located behind the four lowermost dams, and to investigate dam removal and sediment management alternatives.

This report investigates the potential, at a feasibility level, for removal of the four most downstream dams of the Klamath River Project: Iron Gate, Copco 2, Copco 1 and J.C. Boyle. It provides an overview, but not a comprehensive analysis of dam removal and its effects on water quality. Much additional analysis will be required to fully evaluate dam removal as a preferred project management alternative.

The report is also intended to help guide future information gathering and analysis by providing conceptual alternatives and developing basic information regarding the chemistry and grain size distribution of reservoir sediment. A series of recommended studies and evaluations is included in Appendix J.

Many activities that would be need to be conducted to remove dams, rehabilitate the river, and restore the ecosystem around the dams are not contained or described in standard codes and regulations. Therefore, with the exception of sediment testing which was based on standard testing protocols, criteria for comparing approaches to decommissioning were based on experience gained from past decommissioning studies including the Elwha River Ecosystem Restoration Project, the Matilija Dam Removal Project, and the Milltown Dam Removal Project.

The study was divided into several key phases described in detail below. GEC and S&W cooperatively pursued the planning and implementation of the sediment evaluation and dam removal feasibility analysis in accord with their respective contracts awarded by Conservancy. The study phases are summarized below:

1) GEC initiated the dam removal evaluation, including the search for relevant project information.
2) S&W conducted an Upland Study to identify possible sources of contamination in the project area resulting from activities or natural features in the drainage surrounding the reservoirs (Appendix A).

3) GEC and S&W developed a sediment sampling plan guided partially by the Upland Study (Appendix B).
4) S&W retained a drilling contractor to extract sediment samples from the three of the four reservoirs (Appendix D).
5) The driller, under supervision of S&W, extracted samples from the reservoirs and S&W conveyed them to a laboratory for chemical testing and grain size analysis.
6) Analytical Resources Incorporated (ARI) performed laboratory tests on the samples to analyze chemical and grain size characteristics (Appendix E).
7) S&W performed Atterberg limit and water content tests on sediment samples.
8) GEC reevaluated the field results and updated earlier estimates of sediment volume.
9) Stillwater Sciences reviewed sediment volume and grain size information developed in the above activities and compared results to assumptions made in their previous analysis of downstream effects of dam removal (Appendix H).
10) GEC developed this report based upon the available information and developed a table of additional studies, analyses, and reports that would need to be conducted to complete the investigation (Appendix J).
11) PanGeo reviewed dam construction information and conducted a preliminary analysis of the stability of Iron Gate Dam during drawdown (Appendix K).

The 2003 G&G report contained an estimate of the volume of sediment trapped in the reservoirs based primarily on the results presented in a study issued in 2003 by J.C. Headwaters, Inc conducted for PacifiCorp. PacifiCorp provided digitized versions of bathymetric surveys conducted in the JC Headwaters report. These surveys were compared to digitized versions of the original topographic surveys, also provided by PacifiCorp, of the predam river canyons to analyze the volume of sediment contained in each reservoir.

Grain size analysis conducted by ARI was used to analyze the volume of each grain size classification using the Udden-Wentworth size classifications. Sediment grain size results form boring locations were extrapolated to the adjacent material to provide size distribution for all the reservoir sediments.

Results of sediment size distribution analysis and the chemical analysis were used to determine the appropriate options for removal of reservoir sediment in the river path during drawdown of the reservoirs. Dredging, natural erosion, stabilization, and revegetation of sediment are investigated as elements of sediment management in the following discussions. Hydraulic dredging, mechanical dredging, and using the river flow to erode sediment were considered as feasible approaches to removing river channel sediment.

In the report, approaches to sediment management and dam removal are based on avoiding or reducing adverse impacts by reducing duration of very high total suspended sediment (TSS) levels in the river. Duration and concentration of TSS from river erosion are roughly inversely proportional. TSS levels will decrease downstream from dilution as tributaries flow into the Klamath River.

Nonetheless, all approaches to sediment management would increase the level of TSS in the downstream river, presenting a variety of downstream effects associated with dam removal. The least expensive and most effective approach to sediment management would use river flow to erode sediment, but would also result in the highest levels of TSS in the river downstream of the dam.

The report discusses in detail the issues that affect duration of reservoir drawdown time, river water use and flow characteristics at the time of drawdown, and sequence of reservoir drawdown. The duration of highly elevated TSS was considered more important than level of concentration. Therefore, the analysis has focused on means of abbreviating the duration of downstream TSS levels to the extent possible. Further analysis will be required to analyze the effects on TSS from downstream dilution.

Earlier investigations provided detailed information related to water users downstream of Iron Gate Dam. A summary of water use information compiled for this report is contained in Appendix G. Approaches for avoiding or offsetting elevated total suspended sediment concentrations for downstream water users were developed conceptually for the purpose of assigning project costs. More detailed investigation of water-use protection will be required if decommissioning is pursued.

4. Project Description

The Klamath River, located on the United States Pacific coast in southern Oregon and northern California, is approximately 250 mi (400 km) long. It flows from its headwaters near Crater Lake, Oregon to its confluence with the Pacific Ocean at the town of Klamath, California. It drains an arid farming valley in its upper reaches, passing swiftly through the mountains in its lower reaches before emptying into the ocean. It is one of only three rivers that pass through the Cascade Mountains, and one of the longest rivers in California.

The Klamath River Project is a hydroelectric facility comprising seven dams and appurtenant facilities. Six of these dams are located on the mainstem of the Klamath River. This report investigates removal of the four downstream most dams; Iron Gate, Copco 2, Copco 1, and J. C. Boyle. Figure 1 through Figure 3 show the locations of the dams and the river. Appendix I presents details of the features of the dams. The four dams include two earthen embankment dams, Iron Gate and J. C. Boyle and two concrete dams Copco 1 and Copco 2. Two of the dams, Iron Gate and Copco 1, have large reservoirs that have trapped significant amounts of sediment. J. C. Boyle reservoir is relatively small and narrow and Copco 2 has a minor reservoir that has trapped no significant volume of sediment.

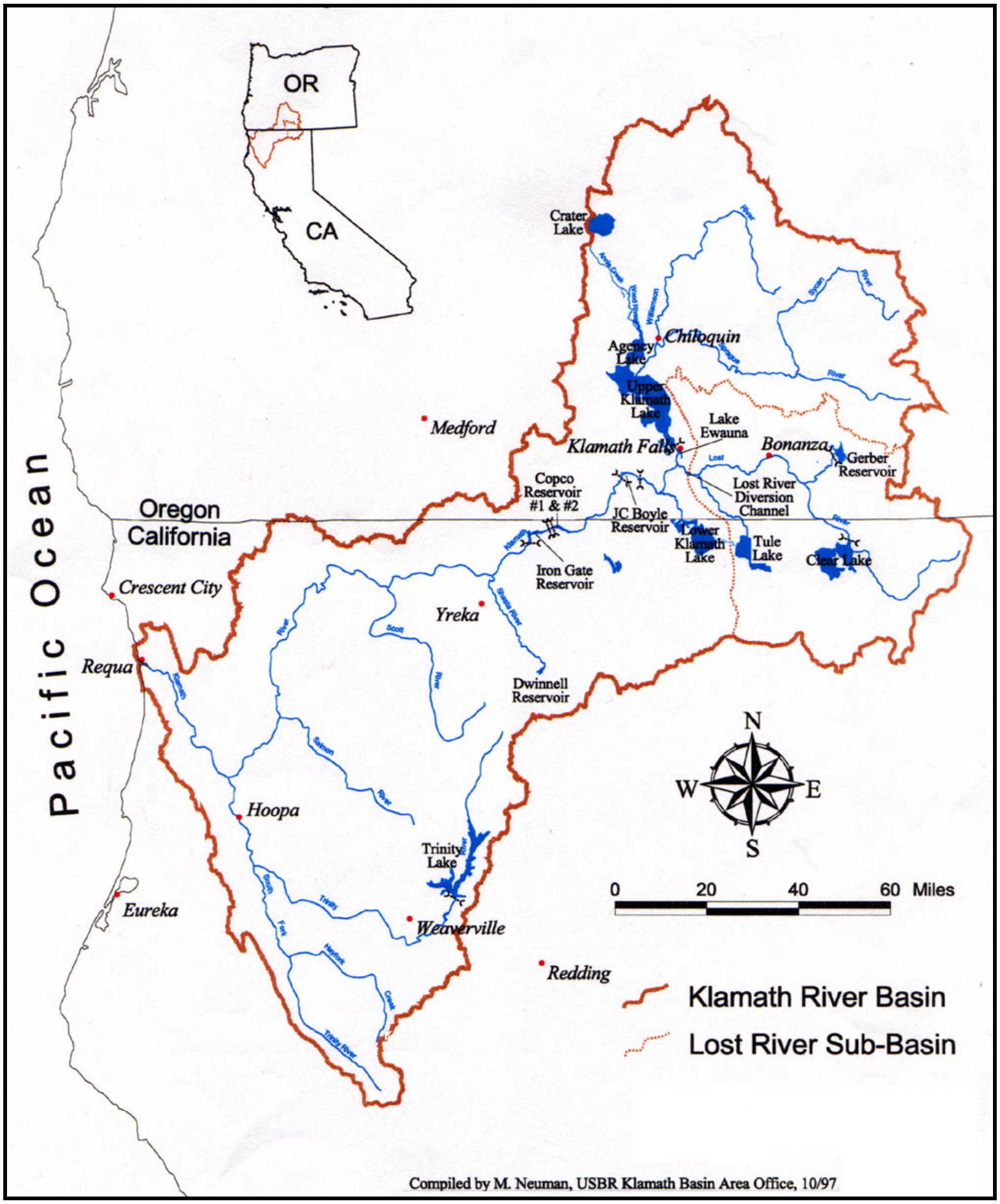

Figure 1 Klamath River Basin and Dam Location Map

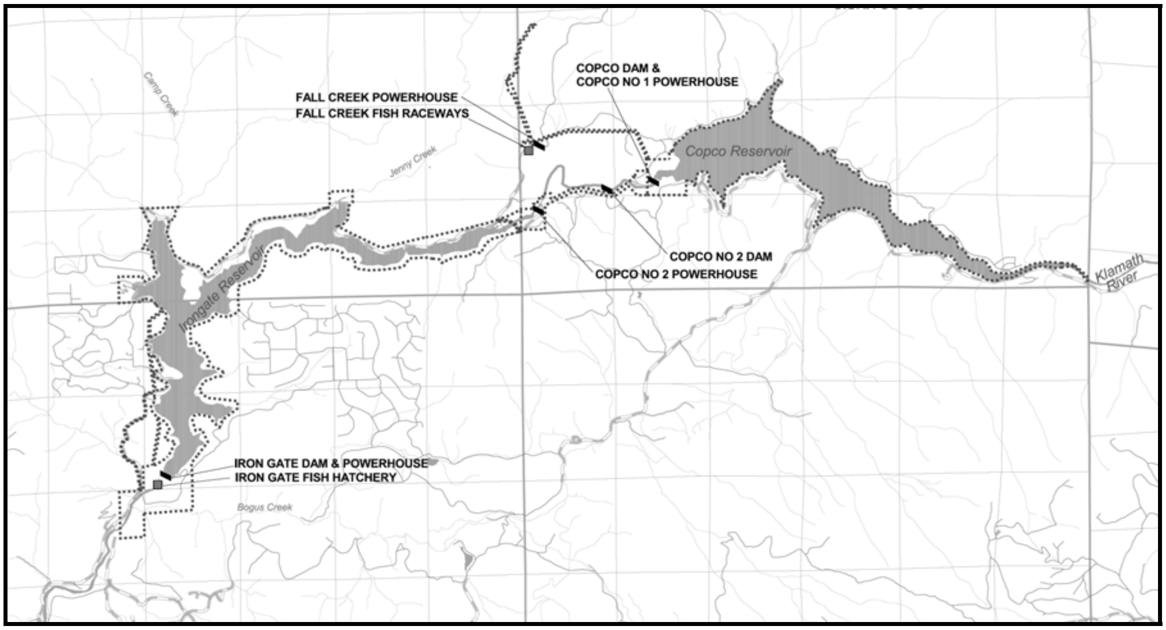

Figure 2 Iron Gate, Copco 1, and Copco 2 Dam Vicinity Map

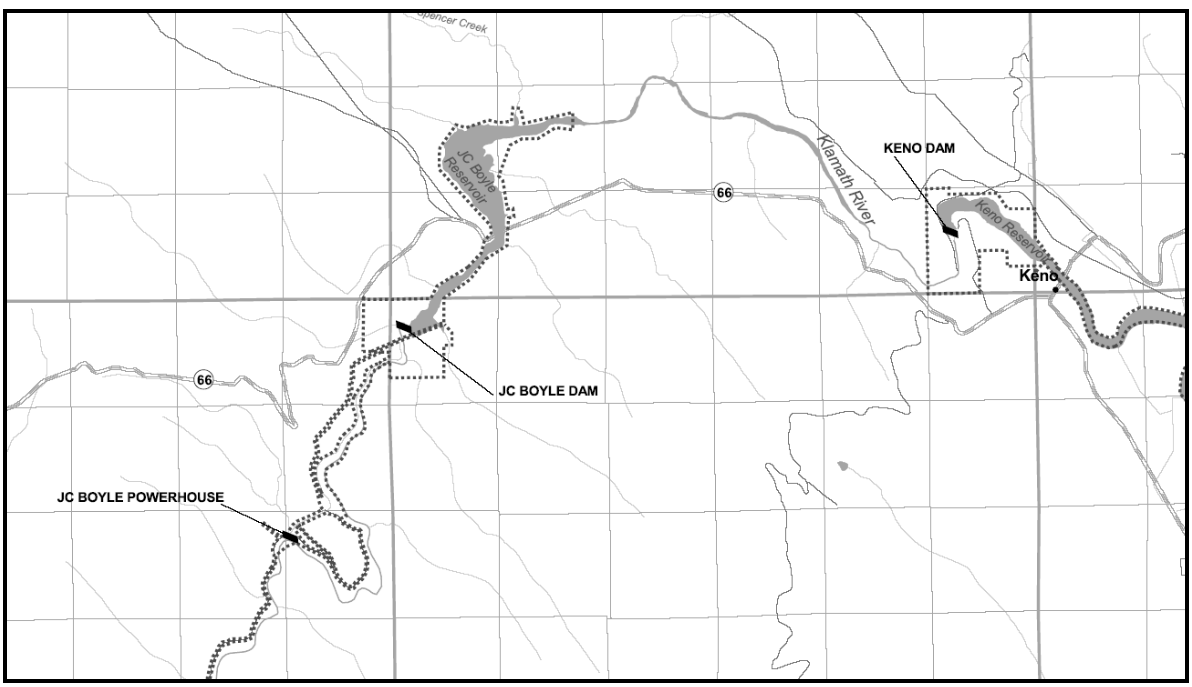

Figure 3 J. C. Boyle Vicinity Map

4.1. Hydrology

The annual and seasonal flows on the Klamath River generally reflect climatic conditions and cycles. Precipitation patterns in the basin are seasonal, with 60 percent of the total annual precipitation falling from November to March. December and January are the wettest months; the driest months are between June and September. Annual precipitation patterns historically show distinct dry and wet cycles closely related to runoff and the river's flow regime.

Stream flow gages have recorded flow on the Klamath River downstream of J. C. Boyle, Copco 1, and Iron Gate dams. Table 1 shows the location and drainage area for each gage.

Some accretion of flow occurs over the 64 miles of river where the Project facilities are located. Downstream of Iron Gate Dam numerous tributaries flow into the Klamath. Average daily flow for the period of record at gage11516530 below Iron Gate Dam is 2,019 cfs. Average daily flow near the mouth of the river at gage 11530500, for the same period of record, is 17,600 cfs. Figure 7 and Figure 8 show the flow and gage location of the downstream most USGS gage on the Klamath River. The increasing downstream flow will result in significant dilution and decreasing TSS arising from decommissioning activities. A full evaluation of downstream flow effects on TSS is beyond the scope of this investigation.

Records for the gage below Iron Gate were used to construct graphs of average, maximum, and minimum flows shown in Figure 5 and Figure 6. PacifiCorp evaluated flood frequency based records at the USGS just below Iron Gate Dam Table 2 shows the flood frequency analysis.

Table 1 USGS Gage Locations

USGS Gauge Location on Klamath River	Drainage Area (square miles)	Gauge Number	Daily Flow Period of Record
Downstream of J.C. Boyle Powerhouse	4,080	11510700	1/1/1959-9/30/1971 10/1/1974-9/30/1979 10/1/1982-9/30/1987 10/1/1988-present
Below Fall Creek near Copco	4,370	11512500	10/1/1923-9/30/1961
Downstream of Iron Gate Dam	4,630	11516530	10/1/1960-present

Table 2 Peak Annual Flows by Return Interval and Exceedance Probability

Klamath River at the Klamath River downstream of Iron Gate dam (USGS Gauge No. 11516530) as estimated using HEC-FFA [1].

Return Period (years)	Exceedance Probability (%)	Estimated Peak Annual Flows at Iron Gate Gauge (cfs)
100	1.0	38,200
50	2.0	31,100
20	5.0	23,000
10	10	17,600
5	20.0	12,700
2	50.0	6,830
1.25	80.0	3,600

[1] Water Resources FTR .DOC, Page 5-35, February 2004 PacifiCorp

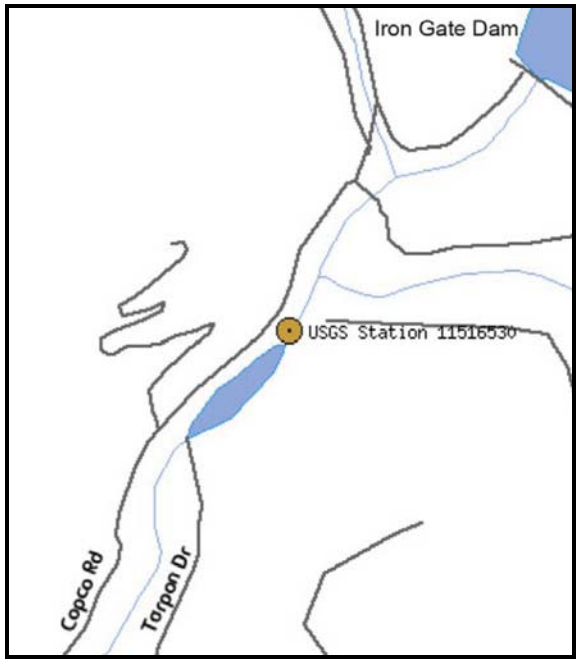

Figure 4 Location of Gage below Iron Gate Dam

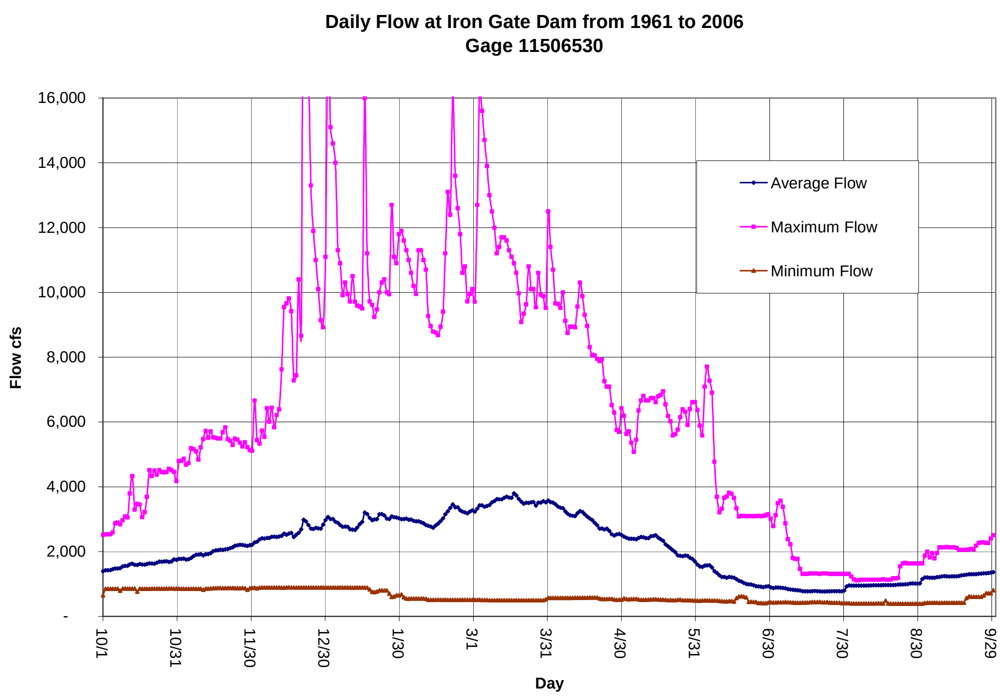

Figure 5 Range of Daily Flows Recorded below Iron Gate Dam

GEC
40031st Ave NW
Seattle, WA

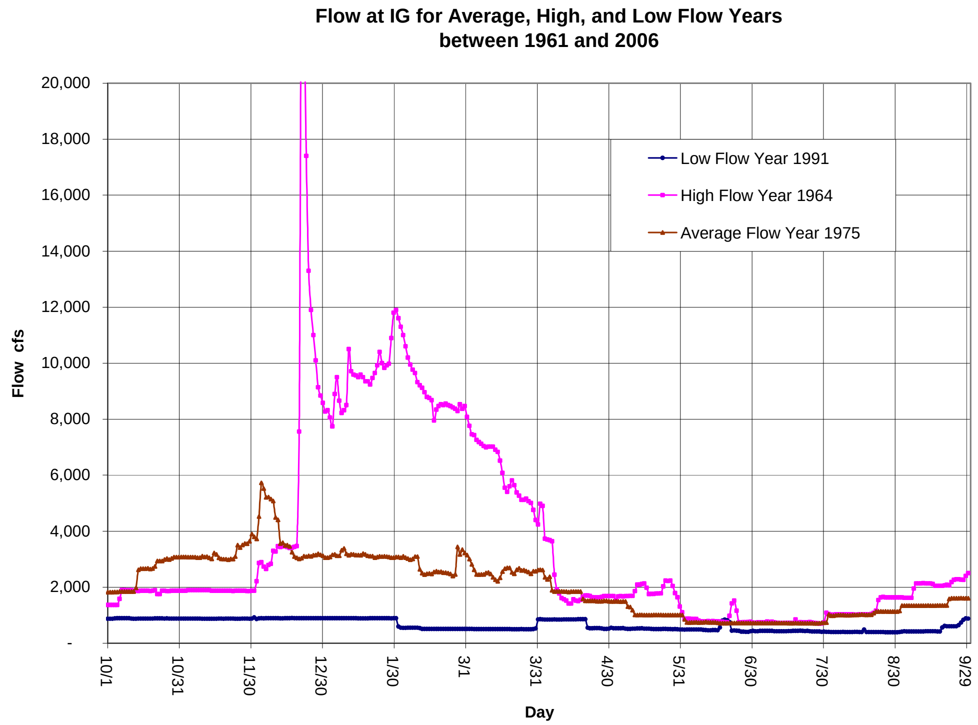

Figure 6 Daily Flows for Highest, Average, Lowest Flow Years at Iron Gate Dam

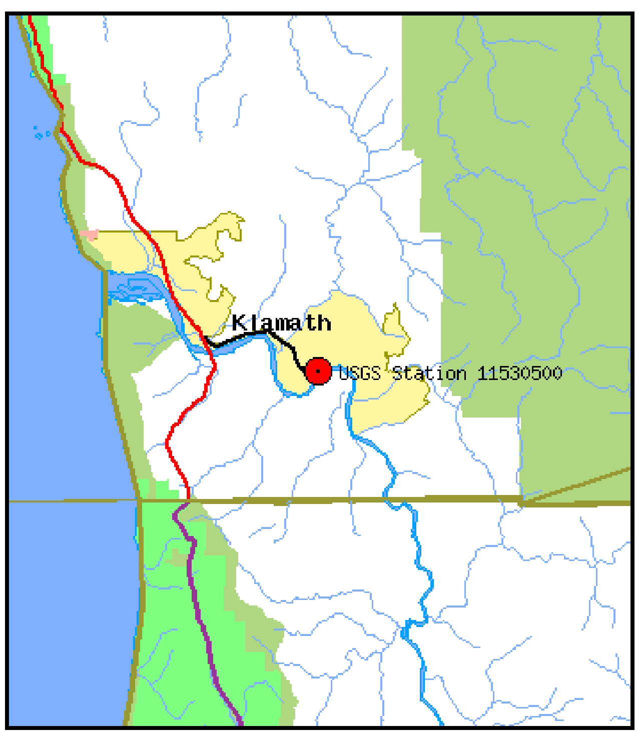

Figure 7 Gage Location near Klamath, CA

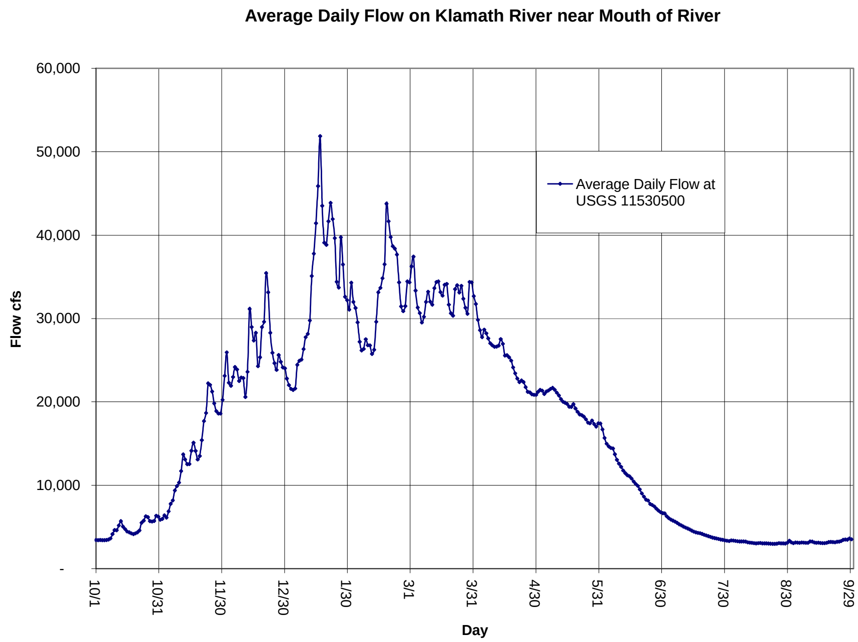

Figure 8 Average Daily Flow on Klamath River near Klamath, CA

4.1.1. Precipitation

Average monthly precipitation records at Copco 1 Dam are available from May 1959 to the present are contained in Table 3. Precipitation and ensuing erosion would play important role in developing sediment management techniques. Sections 5 and 6 discuss this further.

Table 3 Monthly Precipitation at Copco 1 Dam 1959 to 1989

Year	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Ann Total
1959					2.10	0.19	0.00	1.25	0.48	0.33	0.02	1.21	5.58
1960	1.49	4.83	3.22	0.85	1.51	0.00	0.07	0.01	0.00	1.02	5.09	3.22	21.31
1961	1.17	2.97	2.71	1.77	1.50	0.74	0.00	0.25	1.39	2.63	3.76	2.95	21.84
1962	1.94	1.41	1.22	0.58	1.51	0.08	0.03	0.50	0.56	0.85	2.49	2.84	13.16
1963	1.63	2.72	1.33	3.53	1.06	1.58	0.01	0.08	0.22	1.65	3.76	1.01	18.58
1964	5.42	0.41	1.58	0.69	0.71	1.80	0.29	0.22	0.08	0.21	2.27	10.71	24.39
1965	3.33	0.48	0.05	2.62	0.23	0.73	0.26	1.74	0.00	0.15	3.25	1.72	14.56
1966	3.67	0.57	1.60	0.46	0.39	0.33	0.09	0.65	0.50	0.26	4.02	4.35	16.89
1967	3.68	0.47	2.70	2.20	1.88	1.01	0.00	0.00	0.27	1.24	1.19	2.64	17.28
1968	1.93	2.07	1.43	0.50	0.82	0.35	0.00	1.17	0.17	1.29	3.52	2.72	15.97
1969	6.47	1.53	0.67	1.50	0.31	1.23	0.64	0.00	0.21	1.68	0.88	7.13	22.25
1970	6.46	1.52	1.69	0.43	0.41	1.75	0.01	0.00	0.02	1.81	7.70	3.77	25.57
1971	2.72	0.85	3.58	1.75	2.41	1.02	0.26	0.13	0.83	1.70	3.50	2.84	21.59
1972	4.71	2.35	3.69	1.34	0.81	1.46	0.00	0.25	0.59	1.00	1.01	3.24	20.45
1973	1.93	0.97	1.57	0.64	0.98	0.04	0.03	0.02	1.15	2.94	6.04	3.10	19.41
1974	4.07	2.40	2.82	2.56	0.08	0.00	0.33	0.20	0.00	0.61	1.21	3.01	17.29
1975	2.30	3.76	4.90	1.40	0.34	1.13	0.73	0.45	0.25	2.29	1.99	2.68	22.22
1976	1.24	3.32	1.19	0.72	0.34	0.26	0.39	3.57	0.57	0.36	1.08	0.27	13.31
1977	1.24	0.80	1.27	0.38	2.86	0.83	0.06	0.57	2.77	1.06	3.39	5.46	20.69
1978	2.14	1.54	2.41	2.27	0.82	1.99	0.17	2.08	1.68	0.03	1.32	0.91	17.36
1979	2.06	2.67	1.17	1.70	2.25	0.10	0.16	0.98	0.37	3.40	4.11	2.21	21.18
1980	3.51	2.96	1.53	1.27	0.80	1.23	0.05	0.00	0.50	0.89	1.57	2.86	17.17
1981	1.40	2.16	1.65	1.89	1.50	0.29	0.01	0.00	0.68	1.96	6.14	7.21	24.89
1982	1.73	4.75	2.49	0.73	0.17	1.33	0.43	0.33	0.69	2.50	2.81	5.64	23.60
1983	1.85	4.39	3.85	1.24	0.72	0.60	0.33	2.58	0.39	1.04	6.38	6.72	30.09
1984	0.27	2.72	2.49	1.79	0.46	0.77	0.03	0.96	0.23	2.45	6.22	2.00	20.39
1985	0.08	2.34	1.03	0.30	1.47	0.42	0.97	0.19	2.66	1.17	2.43	1.10	14.16
1986	2.37	6.07	2.01	0.82	1.23	0.96	0.00	0.02	2.49	1.00	2.37	1.03	20.37
1987	3.52	1.24	1.55	0.15	1.12	0.58	1.47	0.34	0.13	0.01	1.30	4.69	16.10
1988	3.24	0.12	0.87	1.12	2.70	2.02	0.00	0.29	0.21	0.00	5.88	1.79	18.24
1989	2.65	0.90	4.82	2.34	2.11	0.43	0.00	1.00	2.31	1.69	0.85	1.16	20.26
1990	4.82	1.49	2.59	1.48	3.56	0.13	0.98	0.40	0.69	0.86	2.18	0.90	20.08
1991	1.12	1.44	3.32	1.19	2.44	1.44	0.92	0.24	0.10	0.72	2.07	1.61	16.61
1992	1.16	1.57	1.41	1.18	0.37	1.40	0.88	0.01	0.41	1.56	1.65	4.05	15.65
1993	3.97	1.98	3.00	2.61	2.24	2.21	0.09	0.56	0.04	0.59	0.51	2.29	20.09
1994	1.35	1.28	0.64	0.53	3.07	0.20	0.07	0.00	0.39	0.26	4.68	1.62	14.09
1995	5.40	0.59	4.43	4.38	0.98	2.38	1.67	0.02	0.06	0.61	1.23	8.52	30.27
1996	6.68	1.99	1.80	1.72	2.07	1.21	0.45	0.11	0.91	1.75	3.86	8.02	30.57
1997	5.43	1.45	1.29	1.58	1.81	3.20	1.39	1.35	1.47	2.14	1.87	1.39	24.37
1998	6.83	3.60	2.97	1.87	3.23	0.87	0.35	0.00	0.49	1.07	7.55	2.44	31.27
1999	4.30	4.66	0.60	0.76	0.47	0.05	0.00	1.10	0.00	1.21	2.06	1.30	16.51
2000	6.22	3.36	1.08	2.23	0.93	0.17	0.05	0.32	0.31	1.69	0.82	1.84	19.02
2001	1.72	0.94	0.97	1.53	0.68	0.50	0.50	0.00	0.83	0.34	3.86	4.64	16.51
2002	1.97	1.56	1.12	2.95	0.60	0.40	0.01	0.01	0.03	0.02	1.81	7.14	17.62
2003	2.88	1.29	2.84	4.00	0.64	0.00	0.38	0.26	0.36	0.00	2.33	3.59	18.57
2004	2.72	3.75	1.67	1.04	1.53	0.07	0.78	0.26	0.05	3.61	1.52	3.38	20.12
2005	2.09	0.93	1.48	2.26	3.31	0.40	0.01	0.00	0.62	0.84	7.01	6.36	25.31
2006	5.76	2.48	1.67	1.63	0.47	1.02							

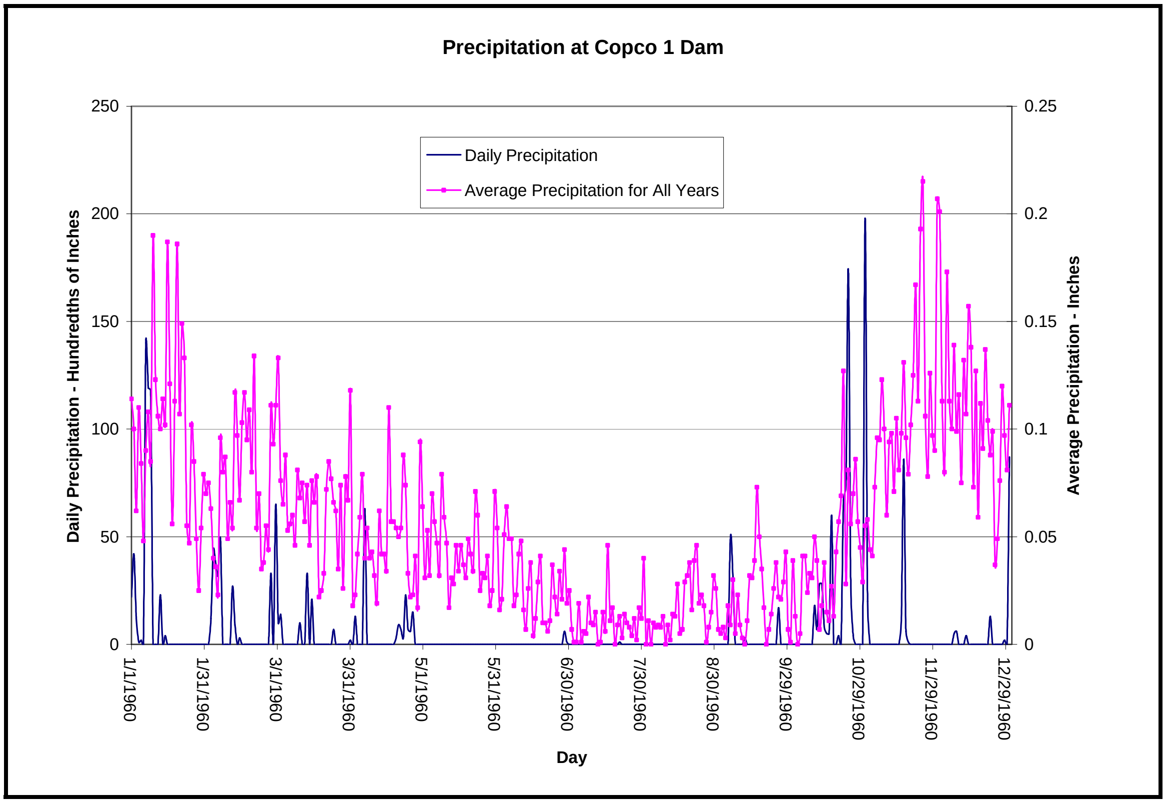

Figure 9 Precipitation for 1960 at Copco 1 Dam

4.2. Geology

The following description was excerpted from EXHIBIT E—ENVIRONMENTAL REPORT submitted by PacifiCorp to FERC as part of the relicensing process.

> Thick volcanic deposits underlie the Project area. Slopes are generally stable, except for talus slopes and landslide prone areas along steeper hillslopes and canyon walls. Three basic rock formations crop out in the Project area and consist predominantly of two volcanic rock types: andesitic tuff and basaltic lavas. Two main soil types occur in the Project area: a gravelly clay loam about 17-40 inches deep on steeper slopes and a well-drained colluvium gravelly loam about 15-60 inches deep on floodplain and terrace surfaces. Physiography in the Project area varies considerably.
>
> The Klamath Basin lies (from east to west and north to south) within the Modoc Plateau, Cascade Range, Klamath Mountains, and Northern Coast Range physiographic provinces. Most of the basin lies within the Klamath Mountains and the Southern Cascades provinces. The Klamath Hydroelectric Project area and its immediate vicinity lie within the Modoc Plateau and Southern Cascade provinces.
>
> Climatic changes, highly permeable rocks, regional faulting, and volcanism have disrupted drainage patterns in this province. The poorly developed modern drainage has resulted in the formation of lakes and large, closed, sediment-filled basins. Regional faulting is causing subsidence of the valley floor and perhaps influencing sediment transport characteristics of the rivers and streams in this area. These factors are currently causing subsidence of the valley floor that contains Upper Klamath Lake.
>
> Therefore, this area is sensitive to the effects of recent deformation on regional groundwater conditions, and on surface and subsurface flow. The Klamath River crosses several faults between the Upper Klamath Lake and Copco reservoir that were active during the last 10,000 years. Numerous earthquakes with magnitudes of greater than 4.0 have been recorded around the southern end of Upper Klamath Lake since 1964.
>
> The most recent significant event in the area had a magnitude of 5.9. It occurred in 1993 near Klamath Falls and was the largest felt in Oregon since 1872. The Klamath River has maintained its antecedent course across the rising Cascade chain and has cut a well-defined deep canyon through volcanic rocks from near Klamathon (RM 184) upstream to the California-Oregon border. The well-rounded topography of the region and the deeply incised canyons are indicative of the erodibility of the volcanic rocks associated with the Cascades.
>
> The presence of two Pleistocene cinder cones and associated lava flows at the downstream end of Copco reservoir, as well as extensive Holocene lake deposit along the margins of Copco reservoir suggest damming of the Klamath River at that site. The extensive valley-fill alluvium upstream of Copco reservoir probably is also a result of volcanic damming of the river that induced upstream backwater, and a subsequent reduction in channel slope. The Klamath River has incised through this lava dam and the upstream Holocene alluvial deposits over time.

4.2.1. Klamath Geomorphology

The following description was excerpted from EXHIBIT E—ENVIRONMENTAL REPORT submitted by PacifiCorp to FERC as part of the relicensing process.

> The Klamath River in the Project area has a bedrock (canyon) dominated channel composed predominantly of a step pool or riffle pool morphology, with minor alluvial reaches. The river is considered non-alluvial and sediment supply limited, with a steep, high-energy, coarse bedded channel that follows a course of convenience (Ayres Associates, 1999). The planform of the river has changed little over time. Pools, riffles, rapids, bars, flows, splits, and side channels have not changed location, nor significantly increased or decreased in size and shape (Ayres Associates, 1999). Most of the limited change that has occurred is attributed to localized sedimentation zones in proximity to tributary inflow points that provide a source of coarse sediment contribution.
>
> The Klamath River's channel shape and physical character is determined by local geologic characteristics and by infrequent, high magnitude flow events. The river has always undergone extreme droughts and floods. Changes in the river's flow regime resulting from basin-wide water projects have produced no significant channel geomorphic impacts (Ayres Associates 1999).

Further analysis will be required to determine effects of dam removal on downstream morphology.

5. Sediment Investigations

Construction of three of the four dams in this investigation created reservoirs large enough to capture significant volumes of sediment. To determine the feasibility of removing the dams, knowledge of the characteristics and volume of the sediment trapped by these reservoirs is required. To better understand the volume, grain size, and chemistry of that sediment a sediment investigation was conducted. The investigation included sampling and testing reservoir sediments. Sampling included taking 21 borings and 5 grab samples in the reservoirs.

The chemistry and grain size characteristics of the reservoir sediments were analyzed by a sediment testing laboratory. Sediment volume was based on information supplied by PacifiCorp from investigations they performed. Investigation of these characteristics was conducted to provide a basis for methods of dam removal and sediment management.

5.1. Sediment Sampling and Testing

Reservoir sediment samples were taken for testing from three of the four reservoirs; Iron Gate, Copco 1, and J.C. Boyle. Copco 2 did not have sufficient sediment to conduct testing. Investigation of the sediment chemistry involved two phases. The first phase, conducted by Shannon and Wilson, Incorporated of Seattle, Washington, involved a review of the potential upland sources of sediment contamination. This first phase, Phase 1, *Upland Contamination Source Study,* (Upland Study) are presented in Appendix A.

A review of reservoir sediment volume was conducted to determine the anticipated location of sediment in each reservoir. Reservoir sediment volume is discussed in Section 5.2. The results of the Upland Study and volume analysis were used to develop a plan, *Klamath Sediment Study: Sediment Sampling Plan,* (Sampling Plan) for locating borings and grab samples presented in Appendix B.

Based on the Sampling Plan, borings and grab samples were conducted by licensed drilling company Tabor Consultants. Shannon and Wilson supervised the borings. Details of drilling procedures, sample locations, grain size analysis results, a list of detected chemicals in the sediment, and results of Atterberg Limits testing can be found in *Summary Report, Sediment Sampling,* by S&W, Appendix D

5.1.1. Sediment Sampling and Testing Program

A Sampling Plan, Appendix B, was developed to guide sediment sampling and testing. In addition to the sampling locations described in the Sampling Plan one additional boring was conducted in Copco 1 reservoir, boring C12. Boring C1's location is exchanged with boring C7 as shown in the Sampling Plan.

The following sediment sampling activities were conducted.

- Sediment samples were taken at 26 locations in three reservoirs, including 22 borings and 4 grab samples. Borings were conducted at:

  - Nine locations on Iron Gate Reservoir
  - 12 locations at Copco 1 Reservoir
  - One location on J.C. Boyle Reservoir
  - Four additional samples were taken in J.C. Boyle Reservoir using a grab sampler.

- Sediment depth was measured at the 22 boring locations.

- Sediment grain size analysis was conducted on 45 sediment samples taken from the sediment borings and grab samples.

Sediment samples were shipped to ARI laboratories of Tukwila, Washington, where sediment chemistry and grain size analyses were performed. Chemical analysis procedures were based on protocols established for the Puget Sound Dredged Disposal Analysis (PSDDA) program. PSDDA has been used for nearly 20 years as a tool for establishing suitability of sediment for disposal of material into marine waters of Puget Sound. Analytes were chosen using PSDDA protocols. PSDDA was chosen as the most appropriate existing set of protocols because it was developed to address deposition of dredged spoils in marine. Since most of the sediment eroded from dam removal would be transported to the marine environment, PSDDA was deemed most suitable.

PSDDA testing criteria can be found in the Sampling Plan, Appendix B, the S&W Sediment Report, Appendix D, and results of ARI testing, Appendix E. Additional analytes were chosen based on the results of the Upland Study, Appendix A. Results of chemical tests are summarized in Appendix D. Full results of chemical and grain size analyses can be found in Appendix E.

In addition to tests conducted by ARI, S&W conducted a series of Atterberg[2] limits and in situ water contents. Atterberg limits test results are presented in Figure 5 of Appendix D. S&W also conducted five in situ water content tests shown in Table 4. These tests indicate that the sediment in the reservoir is a very low density, high water content, material that would easily erode when exposed to moving water.

Water content results also provide information used to analyze TSS levels. The results show that for most of the sediment, the in-situ dry unit weight is less than 40 pounds per cubic foot (pcf). Therefore, analyses of suspended sediment in the following sections of this report were conducted based on the assumption that the dry density of the eroded material that becomes suspended would be 40 pcf. Figure 10 shows the relationship between water content and dry density assuming of the dry material is 1.65. Further sediment testing may need to be conducted to provide a better spatial understanding of in-situ dry densities.

[2] Atterberg limits are a basic measure of the nature of a fine-grained soil. Soil may appear in one of four states, depending on the water content: solid, semi-solid, plastic, or liquid (suspension). The consistency and behavior of a soil is different in each state and thus so are its engineering properties. The boundary between each state can be defined based on a change in the soil's behavior. Atterberg limits provide indices that define the boundaries and the range of each state.

Table 4 In-Situ Water Content

Boring Location	Interval	Water Content
J1	S5	304.1%
IG9	S2	107.4%
C6	S5	330.3%
C2	S4	228.3%
C4	S6	283.4%

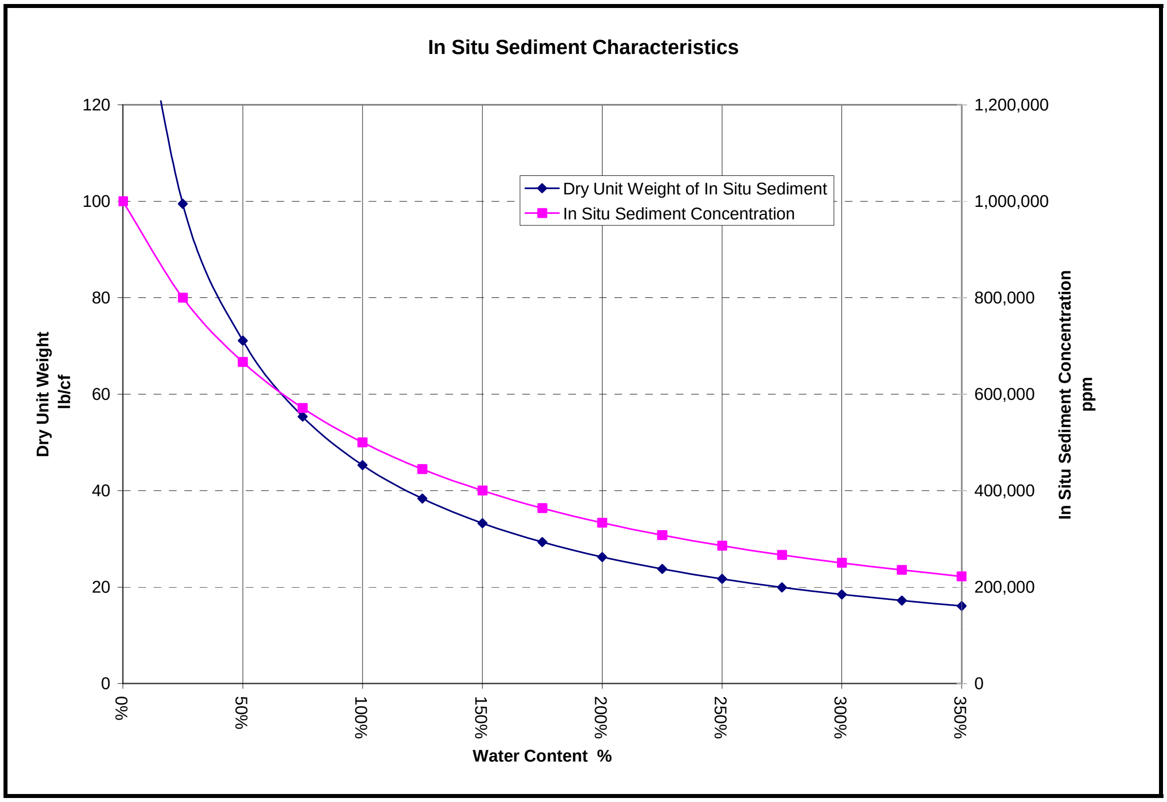

Figure 10 Water Content versus Dry Density

5.1.2. Grain Size Analysis

The size and location of sediment is an important aspect of determining how erosive forces would behave when reservoirs are drawdown. The JC Headwaters Report conducted for PacifiCorp in 2003, included an analysis of the sediment grain sizes and locations within the reservoirs. Hydroacoustic echo techniques were used to define bathymetry and grain size in that report. JC Headwaters' analysis of the sediment also included cores from the top four inches and visual observation of sediment using an under water camera.

Hydroacoustic and surface sampling techniques provide only limited, surficial, information regarding the grain size of reservoir sediments. Reservoir sediments tend to be layered with varying grain sizes. Analyzing sediment from only the top four inches does not provide a thorough analysis of sediment grain sizes and sediment size distribution. Accurate knowledge of grain size distribution is necessary to conduct analysis of sediment transport and erosion behavior.

Forty-five samples were taken for grain size analysis from the 26 sample locations described in Section 5.1. The grain size characteristics at sampling locations were used to extrapolate the material size distribution and location within each reservoir. Grain size distribution information was used to develop the analyses of eroded sediment.

Table 5 and Figure 12 present the grain size distribution analysis results. Results of grain size analysis for the Elwha River Ecosystem Restoration project and the Condit Dam Removal project are also shown for comparison purposes in Table 6.

Figure 12 shows the distribution the average grain size of particles in Copco 1 Reservoir as function of distance from the dam. As expected, average grain size becomes smaller closer to the dam because smaller particles entering the reservoir from the mainstem of the river fall to the bottom of the reservoir more slowly than larger particles. In Iron Gate Reservoir Copco 1 Dam traps sediment from the river mainstem before it can reach Iron Gate Reservoir. In Iron Gate Reservoir average particle size gets larger towards the tributaries but along not the river mainstem. For this reason Iron Gate and J. C. Boyle were not plotted in this fashion. Figure 11 shows the grain size classification used throughout this report.

Millimeters (mm)		Micrometers (µm)	Phi (ϕ)	Wentworth size class		Rock type
	4096		-12.0			
				Boulder	Gravel	Conglomerate/ Breccia
	256		-8.0			
				Cobble		
	64		-6.0			
				Pebble		
	4		-2.0			
				Granule		
	2.00		-1.0			
				Very coarse sand	Sand	Sandstone
	1.00		0.0			
				Coarse sand		
1/2	0.50	500	1.0			
				Medium sand		
1/4	0.25	250	2.0			
				Fine sand		
1/8	0.125	125	3.0			
				Very fine sand		
1/16	0.0625	63	4.0			
				Coarse silt	Silt	Siltstone
1/32	0.031	31	5.0			
				Medium silt		
1/64	0.0156	15.6	6.0			
				Fine silt		
1/128	0.0078	7.8	7.0			
				Very fine silt		
1/256	0.0039	3.9	8.0			
				Clay	Mud	Claystone
	0.00006	0.06	14.0			

Figure 11 Grain Size Classification by Size and Description

Table 5 Grain Size Distribution

Material Size Analysis Results Cubic Yards			
Reservoir	Iron Gate	Copco I	J.C, Boyle
Clay and Silt	7,288,388	8,614,839	125,292
Sand	1,092,064	2,090,359	509,436
Gravel	500,865	173,912	636

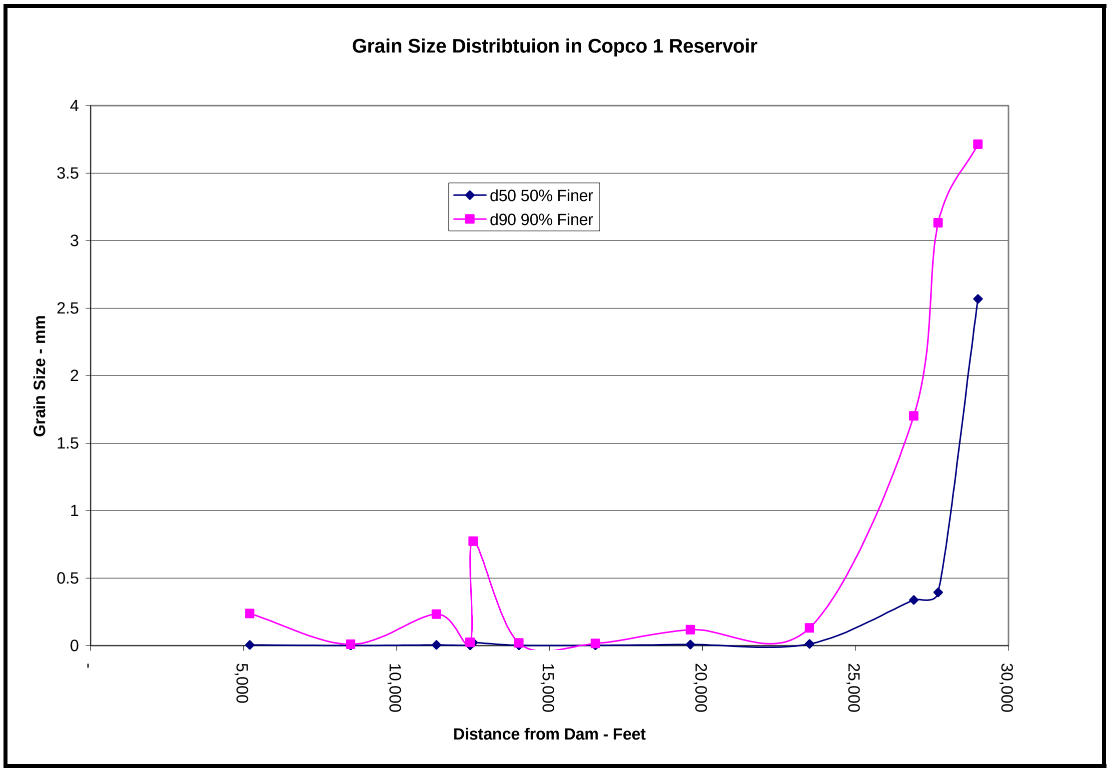

Figure 12 Grain Size Distribution in Copco 1 Reservoir

A comparison of the results of reservoir sediment grain size distribution in four other river systems where investigations of removal of large dams have been conducted is shown in Table 6. As shown in table, the Klamath River reservoirs have the highest proportion of fine sediment (silt and clay sized material) of any of the river systems under investigation.

The difference in relative distribution of sediment between the systems may be due to the larger size of the reservoirs on the Klamath River. Both Iron Gate and Copco 1 reservoirs are more than twice the size of the largest of the comparison group.

Table 6 Comparison of Sediment Distribution

Comparison of Material Size Distribution for Dam Decommissioning Projects				
Material Type	Klamath	Elwha	Condit	Matilija
Clay and Silt	79%	52%	36%	24%
Sand	18%	35%	60%	50%
Gravel or Larger	3%	12%	3%	26%

Table 7 Summary of Klamath River Sediment Distribution by Volume

Material Grain Sizes In Klamath River Reservoirs In Millions of Cubic Yards				
Material Type	J. C. Boyle	Copco 1	Iron Gate	Total
Clay	0.05	5.25	4.57	9.87
Silt	0.07	3.37	2.72	6.16
Sand	0.51	2.09	1.09	3.69
Gravel	0.00	0.17	0.50	0.68
Total	0.64	10.88	8.88	20.40

Table 8 Summary of Relative Distribution of Klamath River Sediment

Material Grain Sizes In Klamath River Reservoirs By Percentage				
Material Type	J. C. Boyle	Copco 1	Iron Gate	Total
Clay	9%	48%	51%	48%
Silt	11%	31%	31%	30%
Sand	80%	19%	12%	18%
Gravel	0%	2%	6%	3%

Table 9 Summary of Grain Size Distribution In Elwha River Dams

Material Grain Sizes In Elwha Reservoirs In Millions of Cubic Yards				
Material Type	Lake Mills	Lake Aldwell	Total	%
Clay and Silt	6.62	2.59	9.21	52%
Sand	5.16	1.08	6.24	35%
Gravel	1.85	0.16	2.01	11%
Cobbles	0.21	0.05	0.26	1%
Total	13.84	3.88	17.72	100%

Table 10 Material Grain Size Distributions at Condit Dam Reservoir

Material Grain Size Distribution in Condit Dam Reservoir		
Material Type	Volume CY	%
Clay	178,257	7.4%
Silt	697,783	28.8%
Sand	1,464,756	60.5%
Gravel	80,743	3.3%
Total	2,421,655	100%

Table 11 Material Grain Size Distribution at Matilija Dam Reservoir

Material Distribution behind Matilija Dam		
Material Type	Volume CY	%
Silt	880,000	24.0%
Sand	1,820,000	49.7%
Gravel	960,000	26.2%
Total	3,660,000	100%

Table 12 Klamath River Reservoirs Total Sediment Volume Size Distribution

Size Classification	Sieve Opening Microns	Volume in Size Class CY	Total Volume Smaller than Size Class CY	Total Volume Smaller than Size Class %
Fine Clay	1	5,766,530	5,766,530	28%
Medium Clay	2	1,907,834	7,674,364	38%
Coarse Clay	4	2,194,526	9,868,891	48%
Very Fine Silt	8	1,961,321	11,830,211	58%
Fine Silt	16	1,703,158	13,533,369	66%
Medium Silt	31	1,617,163	15,150,533	74%
Coarse Silt	63	877,986	16,028,519	78%
Very Fine Sand	125	1,183,414	17,211,933	84%
Fine Sand	250	1,318,252	18,530,185	91%
Medium Sand	500	646,804	19,176,989	94%
Coarse Sand	1000	344,795	19,521,783	96%
Very Coarse Sand	2000	198,594	19,720,377	97%
Gravel	4000	675,413	20,395,790	100%

Table 13 Iron Gate Sediment Size Distribution

Iron Gate Reservoir Sediment by Size Classification		
Description	Volume	Fraction of Total %
Fine Clay	2,851,578	32%
Medium Clay	837,812	9%
Coarse Clay	880,271	10%
Very Fine Silt	789,589	9%
Fine Silt	790,565	9%
Medium Silt	746,349	8%
Coarse Silt	392,223	4%
Very Fine Sand	432,540	5%
Fine Sand	294,119	3%
Medium Sand	162,390	2%
Coarse Sand	128,554	1%
Very Coarse Sand	74,461	1%
Gravel	500,865	6%
Total	8,881,316	100%

Table 14 Copco 1 Sediment Size Distribution

Copco 1 Reservoir Sediment by Size Classification		
Description	Volume CY	Fraction of Total %
Fine Clay	2,886,969	27%
Medium Clay	1,059,845	10%
Coarse Clay	1,298,356	12%
Very Fine Silt	1,154,559	11%
Fine Silt	896,693	8%
Medium Silt	849,826	8%
Coarse Silt	468,591	4%
Very Fine Sand	679,642	6%
Fine Sand	665,429	6%
Medium Sand	415,726	4%
Coarse Sand	206,065	2%
Very Coarse Sand	123,497	1%
Gravel	173,912	2%
Total	10,879,110	100%

Table 15 J.C. Boyle Sediment Size Distribution

J.C. Boyle Reservoir Sediment by Size Classification		
Description	Volume CY	Fraction of Total %
Fine Clay	27,984	4%
Medium Clay	10,176	2%
Coarse Clay	15,900	3%
Very Fine Silt	17,172	3%
Fine Silt	15,900	3%
Medium Silt	20,988	3%
Coarse Silt	17,172	3%
Very Fine Sand	71,232	11%
Fine Sand	358,704	56%
Medium Sand	68,688	11%
Coarse Sand	10,176	2%
Very Coarse Sand	636	0%
Gravel	636	0%
Total	635,364	100%

5.1.3. Sediment Chemistry

Sediment chemistry was analyzed to develop a basis for approaches to sediment management. Sediment management techniques generally require that sediments unsuitable for deposition in marine or fresh water environments be identified and removed to prevent exposure to river flow. Sediment identified as contaminated would be removed by dredging and taken to an appropriate disposal location or stabilized in place prior to lowering the reservoirs. Uncontaminated sediment would be either dredged prior to dam removal or eroded downstream as reservoirs were drawndown.

Sediment from 21 borings and 5 grab samples was tested for contamination. Puget Sound Dredged Disposal Analysis testing protocols and the Upland Study results were used to establish the list of analytes and acceptable concentration levels for conducting tests. Results of testing revealed no unacceptable sediment contamination that would require sediment to be removed prior to reservoir drawdown.

For most of the tests, none of the chemicals on the list of analytes were detected. PSDDA protocols provide a minimum detection limit for most analytes. ARI is a PSDDA certified laboratory, establishing that methods and equipment used are sensitive enough to detect chemicals at minimum PSDDA detection limits. A minority of the tests revealed the presence of chemicals of concern (COC) in concentrations above minimum detection levels by the laboratory testing.

Chemical concentrations detected above the minimum detection levels are compared to the maximum allowable concentration set by PSDDA screening level limits. PSDDA screening levels are the concentrations levels that initiate additional testing requirements for sediments. Screening levels and maximum levels were developed by PSDDA to set limits for concentrations of COC in dredged sediments. Most of the detected analytes were below PSDDA screening levels.

Two volatile COC were detected at one boring location in Copco 1 Reservoir. Due to the volatile nature of these chemicals, if eroded downstream they are expected to evaporate long before reaching marine waters. No other chemicals were discovered that might suggest that erosion of sediment would be infeasible or that pre dredging of sediments would be required. A complete discussion of the results can be found in Appendix D.

5.2. Sediment Volume Analysis

PacifiCorp's contractor, JC Headwaters, conducted a bathymetric survey of Iron Gate, J. C. Boyle, and Copco 1 reservoirs in 2001 and published the results in 2003. As part of their report, JC Headwaters also presented an analysis of the volume of sediment in each reservoir. PacifiCorp provided a digitized copy of pre dam and post dam surveys for this report. The post dam survey was assumed to be JC Headwaters bathymetry. Predam topographic surveys were conducted during dam construction. These digitized surveys were used to compute the volume of sediment in the reservoirs. Information regarding origins and development of the surveys was unavailable.

Results of the sediment volume analysis at Copco 1 Reservoir compared well with results of JC Headwaters volume computations. At both Iron Gate and J. C. Boyle computed sediment volume, discussed below and shown in

Table 16, were larger than JC Headwaters reported.

The Sampling Plan provided rough estimates of sediment depth at drilling locations in Tables 3, 4 and 5 of that report. Sediment depths were estimated by visually aligning the pre and post dam surveys and then, generally, rounding to a multiple of 5 feet. These estimates were intended to ensure that the driller provided sufficient pipe length and were not intended as an estimate of actual sediment depths.

Sediment thickness was measured at 21 sediment boring locations. A more accurate comparison of estimated thickness based on surveys and measured thickness based on boring is presented in Appendix D, where cross sections are cut at actual boring locations. The measured sediment depth at boring locations and depth based on surveys show good correlation in most locations.

As discussed further below, individual reservoir depth readings along cross section lines located at 50 meter intervals, were used to create the post dam survey contour lines. Because survey elevation information is extrapolated from point elevations on pre and post dam surveys, not all measured and estimated sediment depths would be expected to match perfectly.

Cross sections show that measured and estimated sediment depths matched as well as might be expected based on the accuracy and the level of detailed information taken to develop the post dam survey data. The level of detail used to develop the pre dam survey is unknown but may have been even less dense than post dam survey information. The process for creating predam survey data points is unknown.

Several additional sources of uncertainty are involved in the process of computing sediment volume that could account for the computed volume differences shown in

Table 16. None of the following issues could be investigated because others not involved in this report developed the original information.

- Differences in the vertical datum used. For instance, Iron Gate Reservoir covers about 950 acres. If the datum elevations were different for the pre and post dam surveys by 1 meter, the volume calculations would add or subtract, depending on the direction of the difference, approximately 5 million cubic yards of sediment.
- Data errors in the pre dam survey could come from any source that prepared the information before it was digitized. That would include everything from the original survey notes to the digitizing process.
- Alignment differences between the pre and post dam reservoir horizontal alignments could cause volume errors if Digital Terrain Models were used to compute volume. This report computed total water volume for the pre and post dam reservoirs. That approach allows computations to be independent of reservoir horizontal alignment. However, superimposing pre and post dam lake surface alignment from digitized surveys shows very good correlation. This may be due to very accurate surveys or adjustments to contour lines to force agreement between the two.

The discrepancies between measured and estimated sediment depths and the differences between computed sediment volumes in this report and the JC Headwaters report cannot be resolved with available information. Further investigation and analysis of sediment volume may be warranted if volume of sediment becomes an overriding consideration in dam removal activities.

However, sediment volume may not play a decisive role in dam removal and reservoir drawdown technique decision-making. TSS levels from sediment erosion will be high regardless of the amount of sediment in the reservoirs. Further, techniques used to stabilize exposed overbank sediments remaining after reservoir drawdown, will essentially be the same regardless of sediment volume.

5.2.1. Reservoir Bathymetry

JC Headwaters, Inc. issued a report in April 2003, conducted for PacifiCorp, investigating sediment characteristics in several reservoirs on the Klamath River. The report included results of bathymetric surveys conducted in 2001, analysis of trapped sediment volume in the reservoirs, and provided information on the nature and distribution of the sediments in the impoundments. Iron Gate, Copco I, and J.C. Boyle reservoirs were included in that investigation.

The report, entitled *Bathymetry and Sediment Classification of the Klamath Hydropower Project Impoundments*, J. M. Eilers and C.P Gubala, JC Headwaters, Inc., April 2003 (JC Headwaters), included figures showing bathymetric contour lines for the three reservoirs. To develop bathymetry the JC Headwaters investigation sampled water depths at cross section lines located at approximately 50-meter intervals. PacifiCorp presented the results of the bathymetric survey by JC Headwaters as part of the dam licensing proceedings. Bathymetric contour lines provided in electronic format were received from PacifiCorp for predam and post dam (JC Headwaters) surveys.

These digital files were used to compare the total water volume of the predam and current (2001) reservoirs. Contour lines, in a digital format compatible with AutoCAD software, were taken from the data provided by PacifiCorp. AutoCAD calculates the area contained inside a closed contour line. The volume of water contained in the reservoir, for both predam and the post dam surveys was determined by multiplying the average area inside adjacent contour lines by the difference in elevation between adjacent contour lines. The reservoir water volume was calculated as the sum of the volumes between all the contour lines in the reservoir.

The volume contained between two adjacent contour lines was based on the following formula, where $Elev_1$ indicates the contour line elevation associated with $Area_1$ and $Area_1$ indicates the area circumscribed by the first contour line.

$$\text{Volume between Contour Lines} = [Elev_1 - Elev_2] \times [Area_1 + (Area_1 \times Area_2)^{1/2} + Area_2]/3$$

Water surface area and elevations for the predam and post dam reservoirs were identical for pre and post dam calculations. The estimated volume of sediment contained in the reservoir was calculated as the difference between the water volume of the predam and post dam surveys. Appendix C shows the sediment volumes calculated using this approach.

Calculating pre and post dam water volumes independently in this manner eliminates the need for precise horizontal alignment of the two surveys. Methods that calculate volume of sediment by determining the direct volume of the sediment as the difference between the surfaces defined by the predam and post dam water/soil interfaces may require more precise alignment of the pre and post dam surveys. Misalignment could result in errors in the volume calculation.

Copco I predam survey was incomplete and not highly accurate. The survey was dated August 12, 1940; long after the dam was constructed. On the south side of the reservoir some contour lines were not shown at all. The survey drawing also does not align well with aerial photographs and the 2001 survey. The lack of accuracy and incomplete nature of the survey limits the accuracy of the computation of trapped sediment volume.

Both Iron Gate and J.C. Boyle predam surveys appear not to have been conducted before dam construction was underway. The predam surveys provide elevations only as low as the cofferdams, used to divert the river for dam construction. The lowest contour line for each was the elevation of the top of the cofferdam. Other drawings were used to determine lower river elevations in the vicinity of the dams. This lack of contour information inherently limited the accuracy of sediment volume calculations.

Using the techniques described above, both Iron Gate and J.C. Boyle reservoirs appear to have significantly more sediment in them than the JC Headwaters Report indicated. Without further investigation, such as multiple probe readings, to check the survey data no explanation for the large discrepancy in the volume of sediment in Iron Gate Reservoir is available.

However, analyzing sediment volume involves comparing two very large numbers to determine the remaining sediment volume. Small errors and extrapolations from point readings in the survey data can result in a large differences in the calculated volume of sediment and may be the reason for sediment volume differences at Iron Gate.

Comparison of bathymetry from the JC Headwaters Report to the predam survey at J.C. Boyle Reservoir clearly shows a large volume of sediment near the dam. This material may account for most of the larger volume calculation for the present analysis compared to the JC Headwaters Report shown in

Table 16

Table 16 Sediment Volumes

Comparison of Reservoir Sediment Volume Cubic Yards of Sediment				
	J.C. Boyle	Copco1	Copco 2	Iron Gate
AutoCAD	636,000	10,870,000	No sediment	8,767,000
JC Headwaters	22,222	9,629,00		4,818,000

6. Project Removal

The following sections describe removing the four downstream most dams and reservoirs on the Klamath River by demolishing the dam structures and most of the appurtenant structures excluding power lines. Sediment would be removed by allowing the river to erode a new channel through the reservoirs. Insufficient information was available regarding the power distribution system to determine the requirements for power line removal. Therefore, power line removal is not discussed in this report or included in cost estimates.

Removing the dams would involve demolishing most concrete structures at all four dams and excavating earth embankment structures at Iron Gate and J. C. Boyle dams. Drilling and blasting techniques are proposed for and are generally the most effective means of concrete removal. Material in embankment dams would be removed using large mechanical equipment. Lower portions of J. C. Boyle Dam would be removed by erosion of the dam material.

Drawing down the reservoirs and diverting river flow will be necessary at all four dams before dam removal activities begin. Iron Gate and J. C. Boyle dams have operable diversion passages used during dam construction that can be used to divert the river away from construction activities and lower the reservoirs. The power conduits can be used at all dams to partially lower the reservoir. Raising and lowering the Iron Gate and Copco 1 reservoirs to dry up the river at Copco 2 temporarily during initial demolition activities will allow demolition of Copco 2 Dam. No functional low level outlet facilities remain at Copco 1 Dam. The tunnel used to construct the dam is plugged with concrete and would be too small to completely lower the reservoir. A new low level opening constructed through the bottom of the dam is proposed at Copco 1 Dam.

Issues that effect removal activities and TSS levels, duration, and timing are discussed in the following sections. The major issues are; 1) the timing of the initiation of drawing down reservoirs, 2) the sequence of drawdown, and 3) the rate at which reservoirs are drawndown. Various approaches will result in significantly different outcomes. Further investigation of these issues will need to be conducted before a preferred approach can be determined. This report presents a range of options and results from the various approaches. For this report, one approach was chosen to illustrate that a feasible approach exists. Further study will be needed to refine options and alternatives.

The rate of lowering the reservoirs can affect the stability of inundated areas of the reservoirs. A variable flow control gate is proposed for the face of the downstream tunnel to control the rate of reservoir drawdown. The gate is included in the cost for both Iron Gate and Copco 1 reservoirs. A maximum drawdown rate of one foot per day was assumed to be adequately safe to ensure slope and dam stability. Further information gathering will be required to determine the need for controlled lowering and the maximum rate of lowering.

As the reservoirs are drawndown river, TSS levels will rise when sediment in the path of the river is eroded. Since high TSS levels in the river downstream of the dams may have unfavorable impacts other approaches to sediment were reviewed. Past studies including the Elwha River Ecosystem Restoration studies, Condit Dam Removal studies, and

Milltown Dam Removal studies have investigated mechanical approaches to removing sediment before the start of drawdown activities as a means of reducing TSS impacts. Those studies concluded that dredging would not provide sufficient benefit to warrant the cost. For this reason sediment erosion was chosen for this investigation as the means of removing sediment from the river channel.

The sequence of reservoir lowering, rate of drawdown, and river flow at the time of drawdown will affect the TSS concentration levels and duration in the downstream river. Past studies on the Elwha, White Salmon (Condit Dam), and Clark Fork (Milltown Dam) have indicated that duration of elevated TSS may be a more important consideration than level of TSS concentrations. Therefore, lowering the reservoirs in a manner that reduced the duration to the extent possible was chosen as one of the primary criteria for project decommissioning.

6.1. Sediment Management

A review of methods to control the movement of sediment resulting from reservoir drawdown was conducted to determine the optimum approach to sediment management. The objective of sediment management activities is to control, to the extent feasible, the affects of reservoir sediment in the downstream reaches. Methods that could be used to control sediment include removing sediment in advance of reservoir drawdown by dredging or allowing sediment to naturally erode as the reservoir elevation drops.

Sediment quality investigations showed that reservoir sediments pose no contamination risk if eroded downstream. Therefore, dredging would not be required for removal of contaminated sediment. Pre dredging the reservoirs to remove sediment prior to reservoir drawdown was studied extensively on the Elwha and Milltown dam removal investigations but rejected.

Pre dredging a channel would remove much but not all of the sediment in the river channel. Even the best dredging procedures would still leave some sediment in the river channel and possibly create elevated suspended sediment levels as a result of the dredging. Reservoir drawdown would still erode sediment from the banks and exposed adjacent surfaces. The Elwha EIS concluded that even the best dredging technology would not eliminate suspended sediment impacts from dam removal but would add expense and risk without eliminating negative impacts. Complicating issues associated with dredging also involve finding a storage and consolidation site for dredged spoils, limitations to dredging depth, and the extremely fine sediment trapped in Iron Gate and Copco 1 reservoirs.

Spoils sites for the dry Iron Gate Dam material are limited. Finding a suitable disposal site for semi liquid hydraulically dredged sediments within a reasonable distance may not be feasible. Dredges can economically operate in a range from about 0 to 25 feet of water. Accessing deep sediments would require that the reservoirs be drawndown as dredging progresses towards the dams. Drawdown would introduce sediment from dredging activities into the water column over the length of time required to dredge the reservoirs. Finally, because of extremely fine reservoir sediments, the overbank areas will erode surfaces of exposed sediment immediately after drawdown occurs before vegetation is established that will also continue for the period of dredging.

For these reasons dredging was not fully investigated. However, further consideration of the effects of TSS may indicate a need to investigate feasibility, costs, and impacts of full or partial dredging of the sediments in future studies.

The current investigation assumes that reservoir sediment would be allowed to naturally erode as the reservoirs are drawdown. Eroding the sediment will cause downstream water quality to be affected by high total suspended sediment (TSS) concentrations.

Dam removal will require lowering each reservoir water elevation sufficiently to access the dam in the dry to remove the structure. The means of breaching the dams, sequence of breaching, rate of lowering, and river flow at the time of lowering will influence the width of the eroded river channel and therefore the amount of sediment eroded. Steep riverbank slopes, apparent in recent reservoir bathymetry, would cause the new river channel to conform to the predam river channel alignment. Not all sediment trapped in the reservoirs will erode. Most of the sediment outside of the river channels in Copco 1 and Iron Gate reservoirs will remain in place.

6.1.1. Sediment Erosion Process

Generally, three independent sediment erosion processes involving three separate time periods will erode sediment from the reservoir after the dam is breached. More detailed analysis of the sequence of reservoir drawdown, timing of the initiation of drawdown, the rate of drawdown, and the physical limitations imposed by predam river channel configurations will be required to provide detailed estimates of the volume of sediment eroded from the reservoirs and resulting suspended sediment concentrations downstream of Iron Gate Dam.

The analysis and associated figures showing sediment concentrations are on based preliminary analysis and are not intended to provide an exact analysis of TSS levels resulting from river channel formation. All TSS levels shown in the following discussions are values immediately downstream of Iron Gate Dam.

Average daily river flows based on the record Iron Gate were used to develop the following preliminary information. Higher or lower flows will decrease or increase suspended sediment levels respectively due to dilution or concentration. However, variations in river flow would not be expected to greatly change the volume of eroded sediment because of the low density and high water content of the reservoir sediments.

The time of year of initiation of the drawdown will determine the range of river flows that erode sediment in the river channel. However, average suspended sediment levels based on river flow variation from a wet year to an average year or from a wet year to a dry year would not be expected to vary by more than approximately a factor of 2 from the levels shown in the following discussion.

The three general sediment erosion processes are:

1) ***River Channel Formation*** - This process involves erosion of clay, silt, sand, and gravel above the pre-dam river channel. This erosion process will form the new river channel and will occur immediately after drawdown begins. The process is discussed in Section 6.2. In addition to sediment in the predam river channel, bank failures caused by water seeping out of the sediments will introduce additional material into the river water column as bank sediments consolidate. Further analysis of the sediment will be required to determine the rate and time period of sediment consolidation and bank slumping. Sediment consolidation rates will be affected by possible reinundation after initial drawdown. Limits to existing diversion tunnel outlet flow capacity may cause partial refilling of the reservoirs during the first winter/spring high flow season after reservoir drawdown. Raising and lowering the reservoir during this period will also induce further episodic erosion from channel widening.

2) ***Surface Erosion –*** After reservoir drawdown is complete sediment not in the river channel alignment will be exposed to erosion precipitation. Surface erosion of overbank areas above and to the side of the river channel would form gullies and rills in these overbank areas. Surface erosion will continue after river channel formation and begin as soon as the overbanks are exposed. Erosion will continue with decreasing intensity over time as vegetation develops and sediments consolidate. The extent of erosion will depend on revegetation and bank stabilization measures undertaken after drawdown. Vegetation growth on banks will inhibit surface erosion and help form minor conveyances. Stabilization techniques can increase the rate of sediment dewatering and decrease the time and extent of sediment erosion. Rising and falling reservoir elevations during the winter/spring after drawdown due to Iron Gate tunnel flow restrictions could cause additional surface erosion as sediment is reinundated.

3) ***Flood Plain Formation –*** Over a period of years after reservoir drawdown, riverbank failures and erosion during high flow events subsequent to dam removal will continue to erode sediment. Progressively higher river flows would be required to access sediment elevations above those already exposed to river flow and cause this type of failure to occur less frequently with time. This process will occur only when a new post dam removal high flow event occurs. Bank failures will last for a short duration (i.e., hours or days during the highest flows) over many years. Intensity and frequency would decrease with time after dam removal. Similar processes, not associated with dam removal, occur in other reaches of the river.

Figure 13 illustrates the *concept* of intensity and frequency of TSS concentrations, from the processes described above, downstream of Iron Gate Dam. Levels of TSS shown are intended to represent order of magnitude. More detailed analysis of the removal approach will be required to determine the concentrations and duration of elevated TSS. Surface erosion in particular will be dependent on the actions taken immediately after drawdown. Future flood plain formation will depend on the approach to reservoir vegetation and bank stabilization undertaken after dam removal. Concepts for reducing overbank erosion immediately after the reservoirs are drawdown would include revegetation by hydroseeding and tree planting.

Immediately after the reservoirs are completely drawndown the sediment not remaining will be too soft to walk on or place any type of vehicle on. If future river flows were not expected to refill the reservoirs before the dams are completely removed, revegetation could proceed as the reservoirs are drawdown. If reservoirs refill no actions to stabilize the remaining sediment would be effective.

Whether and to what extent the reservoirs refill after initial drawdown will depend on the time of the year that drawdown is initiated. Initiating drawdown in the autumn of the year will most likely not provide time enough for complete dam removal before high winter/spring flows begin. Winter/spring flows would, for average flows, slightly exceed Iron Gate tunnel capacity and cause partial re-elevation of the reservoir. Higher than average flows would significantly temporarily re-elevate the reservoirs. Only the highest flow of record brought Iron Gate and Copco 1 reservoirs to full elevations.

Initiating drawdown in late spring would allow sufficient time to remove the dams prior to higher winter flows and would eliminate the potential re-inundation of uneroded sediments. Revegetation and dewatering techniques that would aid in reducing erosion could be employed to stabilize the bank and overbank sediments. Bank stabilization would only be appropriate if sediment were eroded to predam riverbanks. Stabilizing a river cross section smaller than predam conditions would not be expected to be effective.

Dewatering techniques could be employed to allow quicker access for vehicles and pedestrians on the remaining sediments. Initially this sediment will have a water content too high to support loads. As the water content decreases load-bearing capacity of the material will increase. Dewatering techniques could decrease the time required between final drawdown and access to the top of the sediment. Dewatering techniques could include well points, preloading, wick drains, or drainage ditches. Using dewatering techniques, access to previously inundated fine sediment would be expected to be accomplished in less than 6 months.

Surface erosion shown in the second year after drawdown in Figure 13 may be significantly reduced beyond levels shown in the figure if a program for stabilizing the remaining sediment is developed and conducted. Cost for this activity is not included in the cost estimates in Section 6.7. Further analysis will be required to develop surface and bank stabilization approaches for sediment remaining in the reservoir after drawdown.

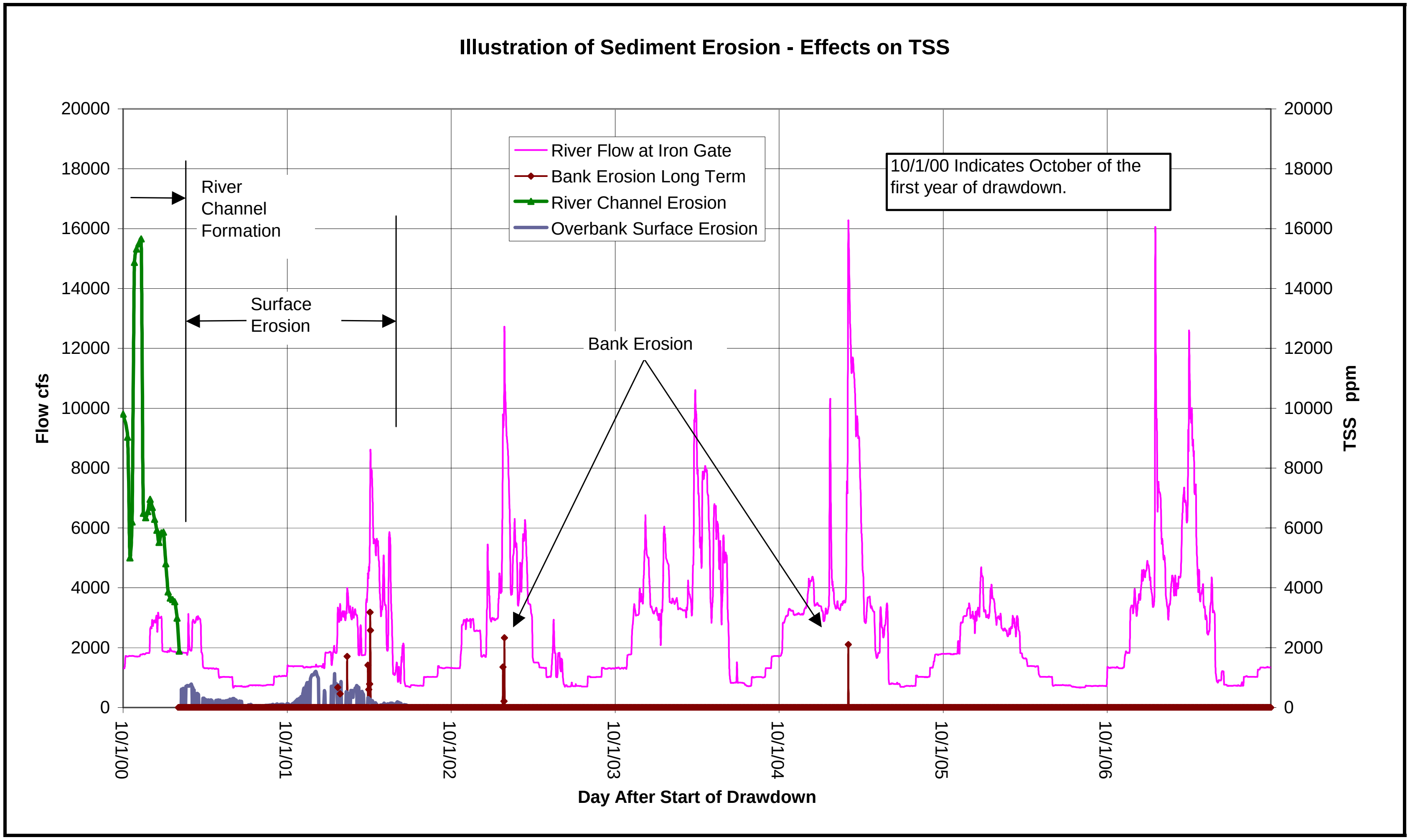

Figure 13 Illustration of TSS from Drawdown and Long Term Channel Formation

6.2. Reservoir Drawdown Approaches

A number of different approaches to lowering the reservoirs, including different rates of lowering, methods of breaching, and sequence of breaching the dams are possible. For a given volume of eroded sediment and river flow, the concentration of suspended sediment will be nearly directly proportional to the rate of erosion.

Lowering the reservoirs slowly will extend the duration of high TSS levels downstream of Iron Gate Dam. Faster drawdown rates increase the concentrations of TSS but decrease duration. Outlet tunnel capacity, river canyon wall slope stability, and embankment dam structure stability may limit the rate of reservoir drawdown and the extent to which the duration of the elevated TSS can be reduced.

The time of the year and associated river flows will influence the width of the river section initially eroded through the sediment. Higher river flows during lowering will erode a wider river path causing more sediment to erode. If drawdown is initiated in late spring summer flows will erode a smaller section that will be widened by successive high winter/spring flows following drawdown.

A rapid drawdown rate may induce more slope failures in sediment on steep surfaces and increase the overall volume of sediment eroded during the drawdown period. From a sediment management perspective, it may be desirable to have a more rapid drawdown rate that would induce more sediment initially rather than a lower drawdown rate that leaves more sediment behind to be eroded later.

Finally, the duration of high TSS in the river is most significantly affected by the *sequence* of lowering the reservoirs. Lowering the reservoirs concurrently will allow for the shortest duration of high TSS while producing the highest concentrations. Concurrent drawdown was chosen as the optimum approach to reduce the duration of the downstream impacts to water quality from removal of the projects.

6.2.1. Effects of Drawdown on Bedload and Suspended Sediment

The rate of sediment movement downstream due to erosive forces will depend on the sediment grain size. Very fine sand, silt, and clay particles will travel downstream at nearly the stream flow velocity, from approximately 2 to over 5 feet per second depending on flow and river geomorphic conditions. Eroded silt and clay particles that are not subjected to slack water conditions will reach the mouth of the river in approximately 3 to 4 days.

Sand and larger particles will move more slowly. Most of the larger particles may not reach the mouth of the river. Riverbed aggradation may result from erosion of the reservoir larger sediments in reaches near the dams. However, as discussed in Section 5.1.2, the reservoirs contain relatively small amounts of larger sized materials. In 2003 Stillwater Sciences investigated the downstream effects of lowering the reservoirs and eroding the sediment based on volume and grain size information available in the JC Headwaters Report. Stillwater Sciences reviewed results of the volume and grain size analyses conducted for this report. They were asked to comment on the implications of the revised information on their analysis. They conclude:

> To briefly summarize, the volume of sediment release assumed in Stillwater Sciences (2004) modeling is almost identical to Mr. Gathard's estimated sediment release for the period of Iron Gate Dam removal and immediately following the removal of the Iron Gate coffer dam; and the Stillwater Sciences (2004) modeling assumed a coarser sediment release during this period, further ensuring the conservativeness of that modeling. With that, we conclude that the Stillwater Sciences (2004) modeling results can still be viewed as worst-case-scenario results in terms of downstream sediment deposition. The above conclusion is made independent of several other worst-case-scenario assumptions made for the Stillwater Sciences (2004) modeling, which further ensure that the Stillwater Sciences (2004) results remain to be worst-case scenario estimate. It can be expected that some or all of the worst-case-scenario assumptions can potentially be reexamined if new information that favors downstream sediment deposition is discovered.

Appendix H contains their review of the results of sediment volume and size analysis relative to their previous assumptions.

6.2.2. Reservoir Drawdown Initiation Timing

Primary considerations for timing of reservoir drawdown include; 1) concentrations and duration of elevated TSS, 2) dam low level outlet flow capacity to drawdown the reservoir for the flows at the time of the year, 3) ability of structure demolition and removal activities to accomplish the required work before high flows refilled reservoirs, and 4) effects of subsequent high flows on water quality.

Seasonal flows on the Klamath River vary widely as illustrated in Figure 14. Lowering the reservoirs elevations at times of highest flows would lower the TSS levels relative to summer flows due to dilution by the larger water volume. A larger opening and more costly control device would be required at Copco 1 to lower the reservoir during the spring high flows. Iron Gate Dam's low level outlet is an existing tunnel over 900 feet long. As illustrated in Figure 21, the flow capacity of the tunnel is between approximately 3,000 and 8,000 cfs as currently configured.

Initiating drawdown during mid summer low flows would allow for a smaller outlet and control at Copco 1 Dam and more demolition flexibility to remove Iron Gate Dam. Review of the timing of fish runs in the river suggests that optimum timing to avoid fish impacts would be sometime starting in October. As Appendix F illustrates, the Klamath River is utilized by aquatic life every month of the year. Starting the drawdown in October would provide reliable higher flows to erode sediments and avoid impacts to many of the species.

Starting drawdown in late spring of the year would allow more construction flexibility. If drawdown were to begin before June, Iron Gate Dam could be removed before winter high flow events occur. Overbank revegetation could also proceed without concern over loss of efforts due to reinundation of the sediment. However, the following winter flows could be expected to erode a wider channel and cause intermittent pulses of elevated sediment as banks eroded.

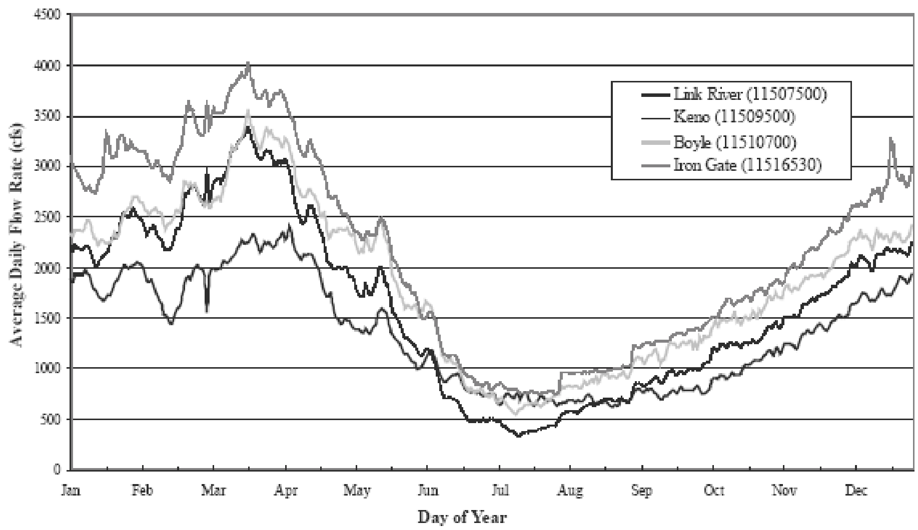

Figure B4.2-1. Annual hydrographs of average daily flows (cfs) for the period 1967-2001 at four gauging stations on the Klamath River in the Klamath Hydroelectric Project area.

Figure 14 Average Daily Flow at Several Locations on the Klamath River

6.2.3. Rate of Drawdown versus TSS Duration

The duration of the highest TSS levels will coincide with reservoir drawdown as a new river channel is eroded. Extending the duration of the drawdown will reduce the intensity of TSS but extend the duration of effects of TSS over a longer time period. It was assumed for development of this investigation that the optimum approach from a water quality perspective would compress the duration of the TSS spike in the river to the shortest possible time period. However, downstream of Iron Gate Dam significant dilution of the suspended sediment will occur. Further investigation will ultimately be required to assess the relative merit of suspended sediment duration versus concentration. Many variations on the proposed approach are conceivable and may prove feasible with further analysis.

The FERC provides guidelines for evaluating the limits on rate of reservoir drawdown in *Engineering Guidelines for the Evaluation of Hydropower Projects*. Chapter 4, Embankment Dams, Sections 4.5 and 4.6 specifically discuss analysis requirements that would be required as part of the determination of maximum drawdown rates for Iron Gate and J. C. Boyle dams. Access to prior analysis of maximum drawdown rates at the two embankment dams was not available for this report. Personal communications with John Mudre, PhD at FERC indicated that some embankment dam projects are restricted to a maximum drawdown rate of ½ foot per day.

A preliminary analysis of Iron Gate Dam only was conducted by PanGeo, Incorporated, geotechnical engineering consultants located in Seattle, Washington. This analysis presented in Appendix K, indicates that a drawdown rate of 3 feet per day would be safe for Iron Gate Reservoir. In addition to dam safety considerations, riverbank and canyon wall stability issues would need to be investigated. This would be the case especially at Copco 1 reservoir to ensure stability of banks supporting structures around the reservoir.

For a particular volume of sediment, such as the sediment that will erode from formation of a new river channel in the reservoirs, the concentration of TSS immediately downstream of the dams and the duration of the elevated TSS are nearly directly inversely proportional. A shorter duration of elevated TSS will correspond with a higher concentration of suspended sediment and vice versa.

Copco 1 reservoir has infrastructure around the margins of the reservoirs. Structures, such as homes, bridges, and roads could be damaged if saturated slopes fail due to rapid lowering of the reservoir water levels. Lowering the reservoirs at a rate of one foot per day was assumed to be acceptable to preserve riverside slope stability and protect infrastructure. However, reviews of the geology of the region and dam construction techniques suggest that further analysis may show that a more rapid rate of drawdown could safely occur. Details of more rapid drawdown rates have been included in this document. Further study will be needed to determine limiting rates of drawdown at each reservoir.

All four reservoirs can be and have been lowered, to some extent, through penstocks used for power generation for maintenance. Copco 2 can be completely drained but has no significant reservoir. Draining Copco 2 will, therefore, have no significant influence on the timing, methods, or sequence of removing the dams.

For analysis purposes the initiation of drawdown activities begins at the lowest water elevation achievable using existing penstocks. It was assumed that reservoirs would have been drawndown over a considerable length of time, prior to initiation of use of low level outlet, through penstocks. Because previous reservoir drawdowns have occurred for maintenance reasons it was assumed that using penstocks to drawdown the reservoir would not create significant TSS considerations. Figure 17 through Figure 18 show the range of resultant downstream TSS levels resulting from concurrent reservoir drawdown at Iron Gate and Copco 1 for the most rapid through the proposed rates of drawdown. Sequential drawdown of the reservoirs, discussed in Section 6.2.4, would result in greater duration of elevated TSS.

6.2.4. Sequence of Reservoir Drawdown

Approaches to reservoir drawdown include several variations of sequentially removing the reservoirs over time or concurrently removing the reservoirs. Sequentially removing the reservoirs would inherently involve longer durations of elevated TSS in the river downstream of Iron Gate Dam. Using Iron Gate Reservoir to trap some of the suspended sediment as upstream reservoirs are drawndown would reduce the TSS levels downstream. However, due to the large volume of very fine material about 40% of the suspended sediment would not be trapped by Iron Gate Reservoir.

Lowering all the reservoirs concurrently would require that construction activities be conducted at three locations simultaneously and would possibly require a larger construction company than sequential removal. Simultaneously drawing down all three major reservoirs would create the shortest duration of water quality disturbance when compared to other approaches. The major impacts would be confined to one year, mostly to one season. Downstream TSS levels would be higher than other approaches but water quality protection measures may need to be provided regardless of TSS concentrations.

6.2.4.1. Sequential Removal

Sequential removal, for the purposes of this report, refers to the sequential breaching of the dams and creation of a free flowing river past the dams. Comparison of effects of the breaching sequences is primarily for the purpose of examining water quality. Time required to remove the structures was not included. The season in which initiation of drawdown occurred was also not included. If some form of sequential removal was chosen as the preferred approach, further examination of effects of structure removal and drawdown initiation timing would be required.

Several approaches are possible to removing the dams sequentially. Removing the dams from either an upstream to downstream or downstream to upstream direction would have little effect on dam removal costs. The effects on water quality downstream of Iron Gate Dam will be decreased if upstream dams are breached before downstream due to the ability of the lower dams to act as sediment traps while upstream dams are removed. However, the trapping efficiency of Iron Gate Reservoir may not be sufficient to eliminate potential water quality protection requirements associated with removing the upstream dams.

6.2.4.1.1. Upstream to Downstream

Removing the upstream dams while the more downstream dams are in place would allow some trapping of the suspended sediment. It would not, however, completely eliminate elevated TSS levels downstream of the dams. Most of the sediment in J.C. Boyle Reservoir is sand and would be trapped in Copco 1 Reservoir. Copco 1 Reservoir sediment is mostly silt and clay. Approximately, 40% of the material eroded from Copco 1 would pass through Iron Gate Reservoir. TSS levels downstream of Iron Gate Dam would remain above 1,000 ppm for over 120 days during Copco 1 Reservoir drawdown. Removing J. C. Boyle Dam before Copco 1 would result in little or no significant rise in TSS levels downstream of Iron Gate Dam due to the trapping capacity of the Iron Gate and Copco 1 reservoirs. Figure 15 show approximate TSS levels versus time to drawdown reservoirs at one foot per day resulting from this approach.

This approach involves the following sequence:

- Remove Copco 2
- Construct river diversion at J. C. Boyle
- Remove J. C. Boyle
- Lower Copco 1 Reservoir approximately 20 feet through penstocks
- Open river diversion at Copco 1 Dam
- Remove Copco 1 Dam while reservoir is drawndown
- Remove power generating equipment at Iron Gate before Copco 1 is drawndown
- Open river diversion tunnel at Iron Gate Dam
- Remove Iron Gate Dam

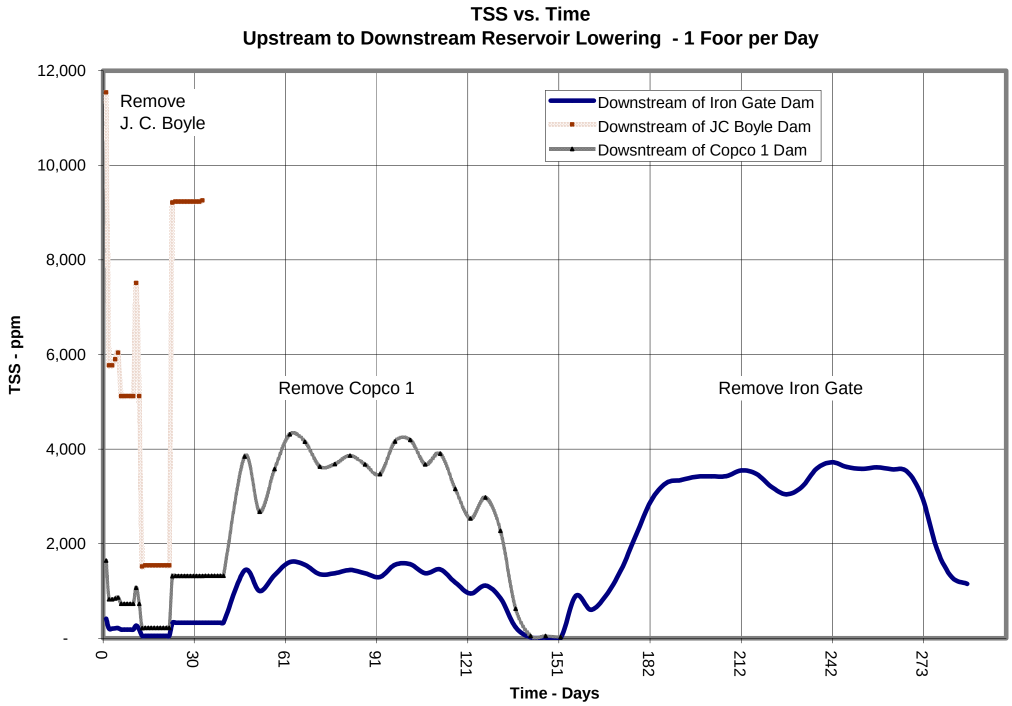

Figure 15 TSS Resulting from Upstream to Downstream Removal

6.2.4.1.2. Downstream to Upstream

In this approach dam breaching would begin at Iron Gate Dam and proceed upstream. As discussed elsewhere, the removal of Copco 2 could occur at any time in the process without significant impact on results. Removing the downstream dams first would eliminate the advantages of having the lower dams in place to reduce TSS. Lowering each reservoir would create high concentrations of TSS.

This approach involves the following actions:

- Remove power generating equipment at Iron Gate.
- Remove Copco 2 Dam by raising and lowering up and down stream dams.
- Construct downstream diversion tunnel control gate at Iron Gate Dam.
- Open diversion tunnel at Iron Gate and lower reservoir by 1 foot per day.
- Begin removing Iron Gate Dam when tunnel is opened if initiated in late spring. Wait until late spring if initiated in autumn.
- Construct Copco 1 low level outlet.
- Lower Copco 1 reservoir approximately 20 feet through penstocks.
- Open low level outlet at Copco 1 and drain reservoir at 1 foot per day.
- Remove Copco 1 Dam.
- Lower J. C. Boyle Reservoir to approximately 3780 through spillway.
- Open culverts and lower reservoir to approximately 3758.
- Remove J. C. Boyle Dam to 3760.

- Erode section through dam.
- Remove remaining J. C. Boyle structure.

Figure 16 shows anticipated TSS levels in the Klamath River that would occur if dams and reservoirs were removed in a sequential fashion beginning downstream with Iron Gate and moving upstream to J. C. Boyle with the exception of Copco 2. Copco 2 would be removed first by taking advantage of the ability to raise and lower upstream and downstream reservoirs to dry up the river while the dam was demolished. As shown, the next upstream dam would be breached immediately following the complete draining of the lower reservoir. However, the time between breaching each reservoir could be extended. Timing of the initiation of drawdown would also affect the time between finishing Iron Gate and beginning Copco 1 Reservoir drawdown. Late winter flows could exceed the low level outlet flow capacity at Copco 1.

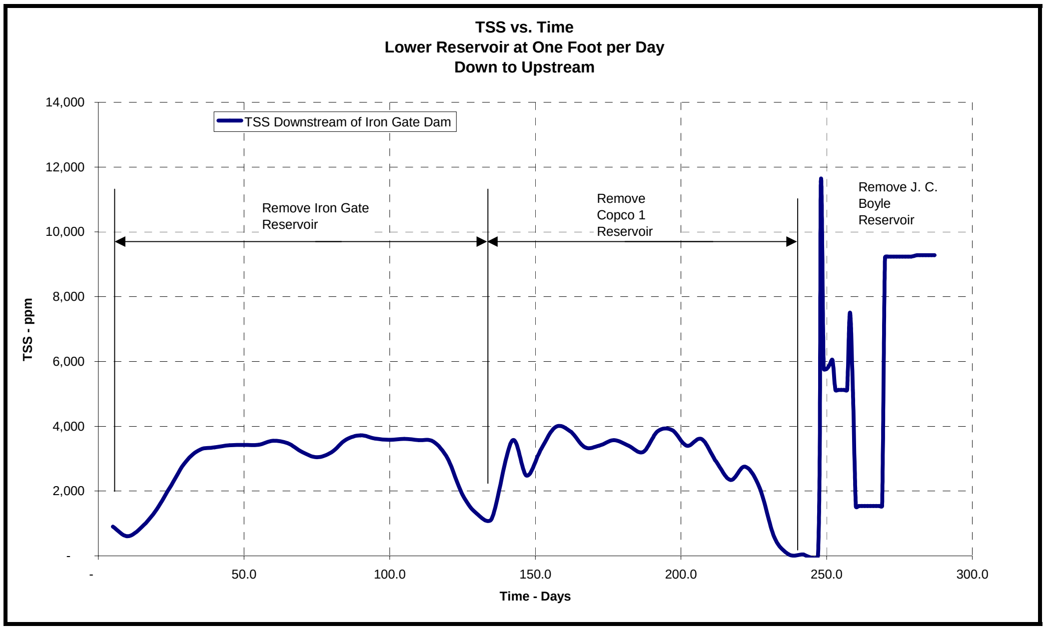

Figure 16 Downstream to Upstream Removal

6.2.4.2. Concurrent Reservoir Drawdown

As discussed in section 6.2.4.1 TSS levels will remain very high for approximately 9 months if sequential methods for removing the dams and reservoirs are used. Drawing down the two larger reservoirs simultaneously could significantly reduce this duration of elevated TSS. Concurrent drawdown of the reservoirs will reduce the duration of the very high TSS levels while increasing the concentrations of TSS. Because duration is generally the more significant variable when considering the impacts to water use, concurrent drawdown of the reservoirs was chosen as the approach developed for developing schedules and cost estimates.

Figure 20 describes the proposed sequence of activities that would be conducted for concurrent drawdown. These activities are based on the assumptions that 1) mid October would be the optimum start time and 2) reservoirs can only be lowered at the rate of approximately one foot per day. Both of these assumptions are preliminary. Further study of the reservoir drawdown rate on slope and embankment dam stability will be required.

A more rapid drawdown would result in a shorter duration of high TSS. However, the duration would ultimately depend on the river flow conditions and tunnel capacity. For a controlled drawdown rate of one foot per day, as proposed below, both Iron Gate and Copco 1 outlet diversion would require new gate controls on the downstream face of the outlet. If studies indicate a more rapid drawdown is safe several options would be possible depending on the rate as discussed below.

Starting drawdown in mid October allows the existing diversion structure at Iron Gate to pass average flows plus additional flow of about 500 cfs required to drawdown the upstream reservoirs. Iron Gate reservoir could only be partially drawndown in spring months due to tunnel capacity restrictions. Conversely, starting the drawdown in late spring would allow the diversion tunnel to pass all incoming flow and allow sufficient time for Iron Gate Dam to be removed concurrently with the drawdown. Figure 14 and Figure 21 show the seasonal flows and completely open Iron Gate tunnel capacity respectively.

6.2.4.2.1. Maximum Drawdown Rate

The maximum drawdown rate possible is controlled by the capacity of the Iron Gate diversion tunnel fully open[3]. Fully opening the tunnel would involve removing both the upper and lower concrete gate in the Iron Gate diversion tunnel. Currently only the upper gate can be raised. Removing the concrete gate plug would involve raising the upper plug and demolishing the lower gate. Construction of a new, approximately 120 square foot, outlet tunnel near the bottom of Copco 1 Dam would be required to drain Copco 1 Reservoir at the same rate as Iron Gate Reservoir.

Assuming a river flow of 2000 cfs, both Iron Gate and Copco 1 reservoirs could be drained in approximately 10 to 12 days if no other issues limited the rate of drawdown. The rate of drawdown at Copco 1 Reservoir would most likely control the maximum rate because of concern for safety of structures along the rim of the lake. The maximum rate for Iron Gate would be limited by tunnel capacity. The maximum drawdown rate is limited to about 11 feet per day for an inflow of 2,000 cfs to Copco 1 Reservoir.

Higher inflows would decrease the maximum drawdown rate and lower inflows would increase it. This rapid rate could easily cause slope failures around the rim of the reservoir or structural issues at Iron Gate Dam. It would most likely increase the total volume of sediment eroded by encouraging loose sediment to flow into the declining reservoir water.

Figure 17 shows TSS levels downstream if no slope failures and sediment sliding occurred. Levels could be three to four times higher in this scenario if, as likely, significant slope failures were to occur. Some rate of drawdown faster than one foot per day but slower than

[3] PacifiCorp proposes to modify the existing tunnel concrete gate. Proposed modifications may reduce tunnel capacity and may add further constraints to drawdown rates.

the maximum illustrated in Figure 17 could produce the optimum results of minimum slope failures at maximum drawdown rate. Sliding of sediment into the river for erosion could slightly reduce longer term elevated TSS occurrence and may be desirable. Massive slope failures in sediments would potentially produce a wider river channel that would have less sediment available for erosion during subsequent high flow events.

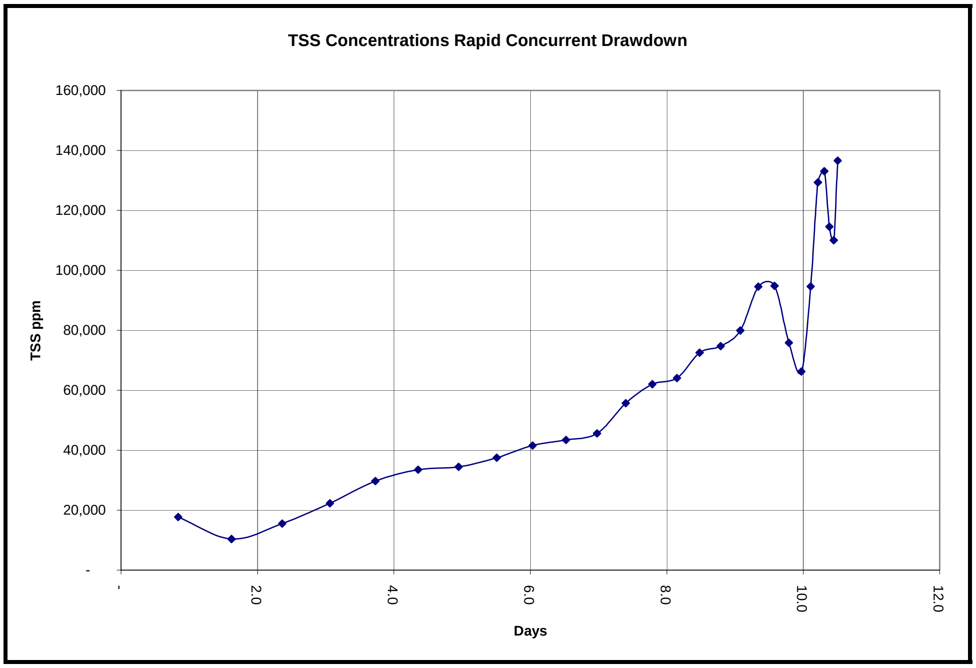

Figure 17 TSS Downstream of Iron Gate for Concurrent Rapid Drawdown

6.2.4.2.2. Drawdown Rate Limitations

The rate of reservoir drawdown will be limited by; 1) slope stability concerns, 2) dam safety considerations, and 3) the capacity of low level outlets to pass flows sufficiently large to drain the reservoirs. Slope stability was not evaluated for this investigation. A conservative rate of drawdown of one foot per day was used for construction cost and schedule analysis purposes for the concurrent drawdown approach after discussion with S&W geotechnical engineers and reviewing rates of drawdown at other projects. This rate is similar to rates used for other reservoir drawdown actions.

However, a higher rate may prove to be feasible upon further analysis of structural and slope stability issues. A higher rate of drawdown would reduce the duration of the highest TSS levels. A preliminary analysis of dam safety limitations at Iron Gate Dam, Appendix K, indicates that 3 feet per day drawdown would be safe and feasible. Figure 18 shows the approximate TSS resulting from drawing down all three reservoirs simultaneously at a rate of three feet per day. Higher rates of drawdown may prove to be more feasible at times of the year when adjacent slopes are drier and will remain dry for sometime.

Starting drawdown activities in the summer months would provide the longest dry slope period. Starting later in the year could potentially resaturate marginally stable slopes above the reservoir. Drawdown rate restriction may be greater starting earlier in the year due to already saturated upper slopes. More analysis will be required to determine drawdown rate limitations.

As discussed in Section 6.2.4.2.1, the maximum drawdown rate for average autumn flows is greater than current state of knowledge of slope stability would recommend. Future analysis may show that more rapid drawdown is possible. Drawdown rates for the three reservoirs may ultimately be different from each other allowing more complex concurrent drawdown scenarios. For this investigation it was assumed that the primary erosion process caused by lowering reservoir water surface elevations occurred within a 120 day period as illustrated in Figure 20. Figures Figure 19 and Figure 18 represents the erosion from channel formation only. Figure 13 includes effects from surface erosion and long term flood plain formation.

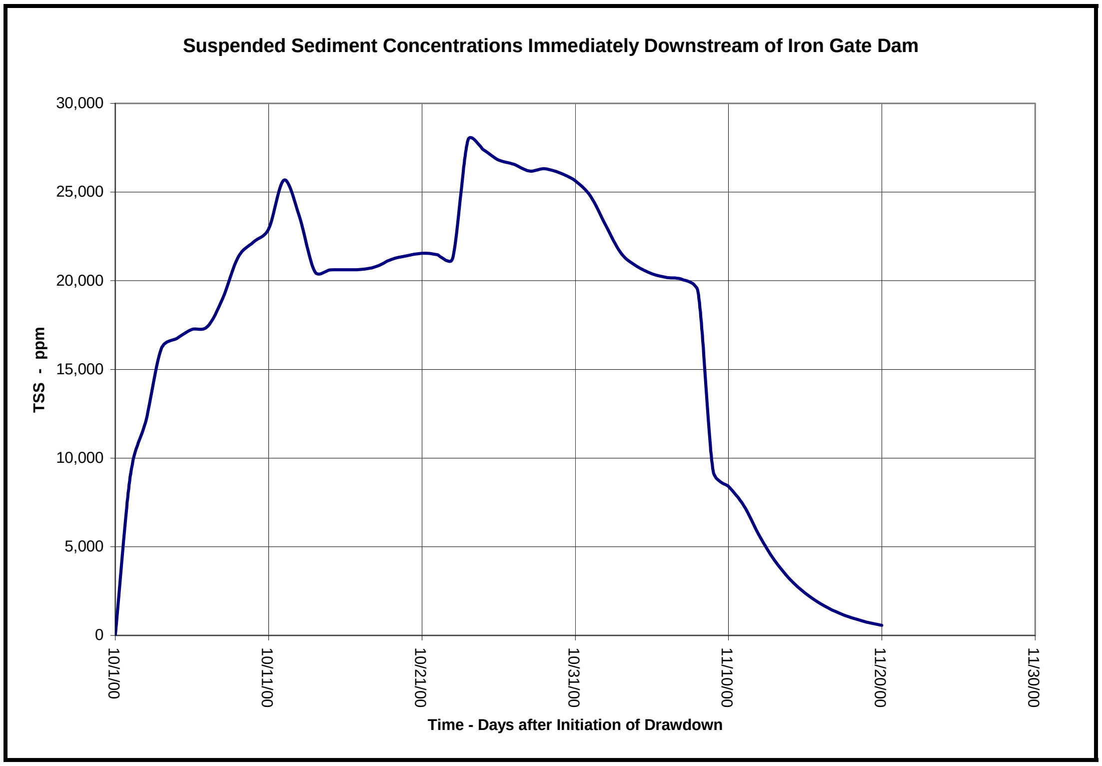

Figure 18 TSS Resulting from Concurrent 3 Feet per Day Reservoir Drawdown

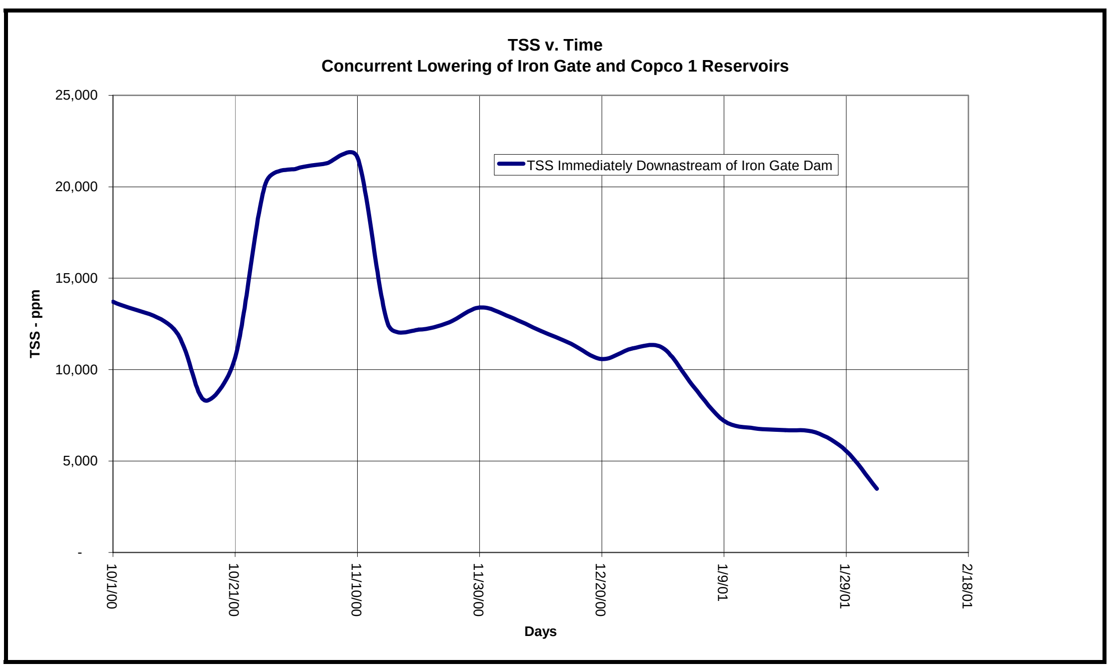

Figure 19 TSS Resulting from Concurrent 1 Foot per Day Reservoir Drawdown

6.3. *Proposed Approach to Project Decommissioning*

The many combinations of dam removal and reservoir drawdown options result in a variety of levels and duration of suspended and bedload sediment movement down the river due to project removal. For the current investigation, the assumption was made that an approach resulting in the least *duration* of impacts to aquatic life and water users would be the optimum. As discussed elsewhere, the limitations on least duration of sediment effects are closely related to the rate of reservoir drawdown. The major issues are low level outlet capacity, embankment dam safety at Iron Gate, and slope stability in Copco 1 reservoirs. The following approach assumes the sequence of reservoir drawndown and dam removal events shown in Figure 20, or that the reservoirs will be drawdown concurrently.

In general, removal of the earthen dam embankment structures would be accomplished using heavy earthmoving equipment. Concrete building structures, such as powerhouses and fish facilities, would be demolished using impact devices such as wrecking balls, backhoes, and jackhammers. Massive concrete structures such as Copco 1 and Copco 2 dam structures would be demolished using drilling and blasting techniques. Material from demolition would be removed from the river and permanently stabilized in a nearby upland location.

The current analysis indicates that approximately 20.4 million cubic yards (mcy) of sediment were trapped in the reservoirs when J.C. Headwaters performed their testing in 2001 (2003 report). Removal of the dams will erode a new channel through the reservoir sediments. Approximately 4 million cubic yards will move downstream as the new river channel is eroded.

This analysis is based on the assumption that the river will form a river channel between 150 and 200 feet wide bankfull with average side slopes of 1 foot vertical to 10 feet horizontal. Total suspended sediment (TSS) levels downstream of Iron Gate dam may temporarily exceed 50,000 parts per million (ppm) and average above 20,000 ppm for days during the reservoir drawdown period.

The start time for reservoir drawdown shown in Figure 20 is approximately mid October of the year. This time was chosen based on recommendations by fisheries agencies to avoid peak run times. As discussed in Section 4.1, Hydrology, river flow begins to increase in the fall of the year. During a high flow year the downstream most diversion tunnel at Iron Gate Dam would not have sufficient capacity to pass winter flows and would re-inundate upstream sediments during high flows. Re-inundation of sediments would cause additional TSS from bank failures and surface erosion as the reservoir drops again.

The schedule shown in Figure 20 removes the three reservoirs containing sediment essentially concurrently so that the effects of sediment erosion are concentrated into the smallest feasible duration. Within this approach there may be numerous ways to vary the particular rate of drawdown. For instance, the reservoir at Copco 1 may be drawndown slowly during the initial portion of the drawdown but more rapidly at lower water elevations. If dam safety allows, it may be possible to drawdown Iron Gate reservoir at a higher rate. This would have the effect of allowing the temporary use of Iron Gate Reservoir as a sediment trapping facility for the initial portion of the drawdown.

Analysis of various rates and methods that may be able to further compress the duration of the worst aspects of elevated TSS are beyond the scope of this study. Further investigation of the limits of the rate of reservoir drawdown will be conducted in future investigations.

Klamath RiverReservoir and Dam Removal Schedule

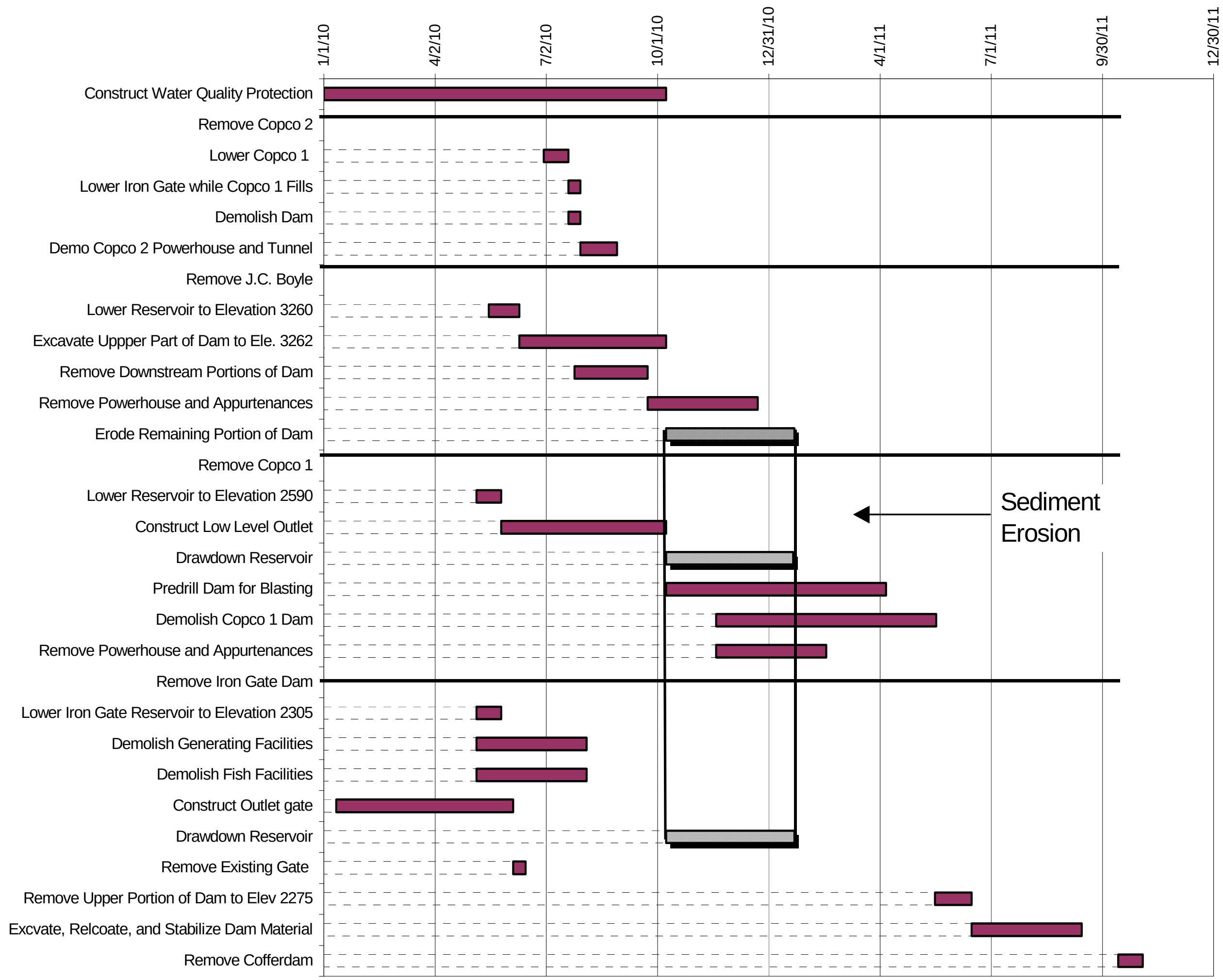

Figure 20 Schedule for Concurrent Reservoir Drawdown Approach

6.3.1. Iron Gate Project Removal

Iron Gate Dam is the most downstream dam on the Klamath River. The earth embankment dam structure contains over 1 mcy of material. The method, timing, and rate of drawing down the reservoir will greatly influence the water quality and safety down stream of the project. River diversion would be accomplished using a modified existing diversion tunnel constructed for diverting the river during dam construction.

Removing the dam material will require a significant work effort. The time required to remove the structure will depend on the amount of construction equipment employed. Before dam excavation is undertaken the reservoir would be first drawndown. Removal of the embankment structure and other downstream structures must be accomplished in a manner that assures the safety of downstream structures. If high river flows exceed the capacity of the diversion facility to pass flows, the reservoir may partially refill and could possibly overtop a partially demolished dam. Consideration of methods to keep the reservoir elevation below the elevation of the excavation until embankment material and the downstream fish facilities are completely removed from the river will be required.

Reservoir drawdown can be accomplished by diverting river flow through an existing low level tunnel used during the dam construction. Dam excavation can be accomplished using mechanical excavating, hauling, and compaction equipment similar to that used to construct the dam. The issues involved with decisions regarding demolition and diversion methods, sequence of dam removal, demolition construction time, and the timing of the beginning and rate of reservoir drawdown are discussed throughout this document. The scope of this study does not allow the ability to completely address all conceivable alternatives. The removal approach analyzed was chosen to address the objective of least duration of elevated TSS levels in the downstream river while removing the dam structure in a manner that assured safety against dam failure.

The proposed approach would drawdown Iron Gate and Copco 1 dams concurrently at the highest feasible rate by lowering the reservoirs some time from late spring to autumn, when river flows are relatively low and predictable, by diverting flow through the existing tunnel. New downstream gate facilities would be installed to ensure control over the rate of reservoir elevation drop.

Dam demolition activities, described below, assume the demolition would begin as early as possible in the spring of the year when river flows begin to decline and assurances that the reservoir would not refill and overtop construction can be made. To accomplish complete removal before high winter flows begin will require a large amount of construction activity. To assess feasibility, the method described below completes all excavation work in approximately 4 months. Further investigation will be required to determine whether some of the activity could begin earlier or that safety concerns could be met if excavation and demolition began with reservoir drawdown.

6.3.1.1.1. Facilities

Figure 26 shows a plan view of the structures located at the Iron Gate Dam site. Facilities at Iron Gate Dam site that would be removed include; 1) earth embankment dam, 2) concrete fish facilities on the downstream base of the dam, 3) power generation facilities, and 4) the diversion tunnel facilities would be demolished and would be plugged at the end of construction.

Analysis of original topography at the dam site compared to existing dam topography indicates that approximately 1.1 mcy of material was placed to construct Iron Gate Dam. Figure 30 is a copy of original California Department of Water Resources Division of Safety of Dams (DSOD) documentation that also indicates that approximately 1.13 mcy of embankment material was placed to construct the dam. The concrete lined spillway would remain and be filled with embankment material.

Standard large scale mechanical excavating and hauling equipment would be required to remove Iron Gate Dam. Investigation showed that some of the embankment material could also be safely removed by erosion. However, that option was not developed here due to concerns regarding TSS effects resulting from the erosion after the initial drawdown. Eroding the dam material would elevate TSS levels downstream and might cause a longer duration of elevated levels than removing the structure using mechanical equipment. It was assumed, for this investigation, that all material in the dam is removed, transported to an upland spoils site, and compacted for permanent placement using mechanical equipment.

Structures not involved with dam structural capacity could be demolished before reservoir drawdown during or immediately after reservoir drawdown begins. This would include fisheries facilities at the downstream base of the dam, all power production facilities, and concrete appurtenances on the dam structure. Concrete would either be salvaged or placed in the spillway section. Generating equipment and structural steel would be salvaged. Spillway concrete would only be removed in accessible areas not essential to the dam structural stability prior to drawdown.

Surface riprap comprises approximately 175,000 cubic yards of the material in the dam. Riprap on the up and down stream faces of the dam would be removed and temporarily stock piled downstream of the dam on the right bank. This material has significant economic value and would either be used to stabilize other dam material or sold. Further structural analysis of the dam will be required to determine if this material can be safely removed prior to the beginning of structural excavation. For this analysis it has been assumed that most of the downstream riprap would be removed before the start of demolition. Removing the riprap surface material would allow more rapid excavation of embankment material. Upstream riprap removal could also begin as early as mid April and directly precede embankment excavation.

Most of the concrete spillway liner would not be removed and would remain in place to stabilize dam embankment material permanently placed in the spillway during demolition. This location can permanently hold as much as 300,000 cubic yards of material or about 1/3 of total volume of material in the dam.

Project information indicates that material used to construct the dam was most likely excavated from sites near the dam along the riverbank. One material site on the left bank approximately a mile and quarter upstream of the dam has the capacity to store the remaining approximately 650,000 cubic yards of dam material. However, that site may be buried beneath the sand and silt that erodes and settles near the dam during any future reservoir drawdown process. Further analysis will be required to determine the suitability of any in reservoir site. Bank stabilization in the upstream reservoir may also be desirable.

Material from the dam may be useful for bank stabilization. Further analysis will be required to determine stabilization approaches and suitability of embankment materials.

Several upland disposal sites appear to have the capacity to store the remaining dam material and remain in a long term stabile configuration. Further site analysis will be required to confirm the final location for storage of embankment materials. The site nearest the dam, which appears to have sufficient capacity to store all the embankment material, is shown in Figure 29. An existing road to the site would need to be upgraded to handle heavy equipment. Further geotechnical analysis will be necessary to confirm the acceptability of this site. Several other potential sites are shown in Figure 31.

6.3.1.1.2. River Diversion

Iron Gate reservoir can be lowered from normal water elevation of 2325 mean sea level (msl) to approximately elevation 2200 msl through the existing river diversion tunnel. This tunnel was used to divert the river while the dam was constructed. The mouth of the tunnel is plugged by a two-piece concrete gate, shown in Figure 23, that can be raised in extreme flood conditions to help pass high flows. The downstream portion of the tunnel is unlined and in a poor state of repair. It may be possible to control reservoir water elevations using the existing gate without performing extensive upgrades to the tunnel. Insufficient information regarding gate operation was available for this report to assure that the gate could be successfully used to control the rate of reservoir drawdown. Therefore, the proposed approach would use a new downstream gate control valve, shown in Figure 22.

Installing a new controllable gate valve on the downstream face of the existing Iron Gate diversion tunnel would ensure that the drawdown rate is controlled and reservoir lowering can proceed safely. Further study will be needed to determine the feasibility of using the existing concrete gate and unlined tunnel for water level control.

To lower the reservoir the tunnel must pass the incoming river flow upstream of Copco 1 plus additional flow to lower Copco 1 and Iron Gate reservoirs. Lowering the reservoirs at one foot per day would require that the tunnel pass approximately 500 cfs in addition to the incoming flow to completely lower the reservoir to elevation 2200 msl.

As Figure 14 illustrates, incoming flow in late winter through mid April will on average be greater than 3,000 cfs the tunnel capacity at water elevation 2200 msl. This will cause reservoir elevation just upstream of Iron Gate Dam to rise temporarily. Further analysis of flow conditions and sediment conditions immediately adjacent to the dam will be required to determine whether dam removal activities can begin immediately after drawdown or would need to be postponed until spring high flows are complete. Analysis of construction time and cost has assumed that demolition would begin in June of the year following reservoir drawdown. Activities would be conducted to excavate to near riverbed elevations by October. River flow will be below maximum tunnel capacity when the bottom portions of the dam are being removed.

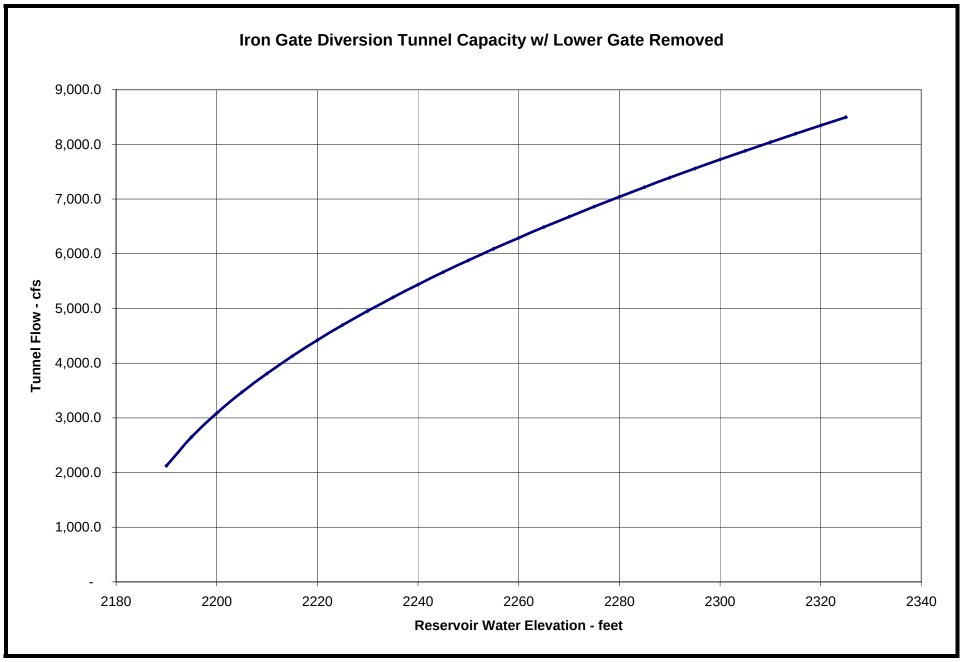

Figure 21 Iron Gate Tunnel Capacity Fully Open

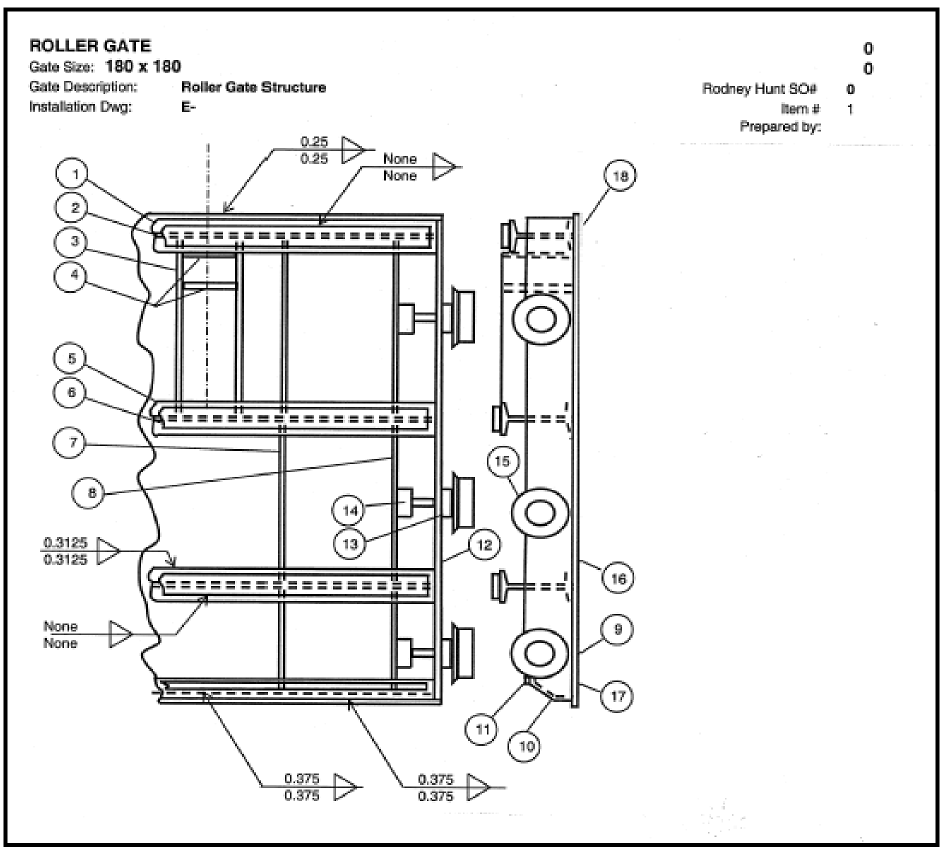

Figure 22 Partial Elevation and Section of Downstream Control Gate

GEC
40031st Ave NW
Seattle, WA

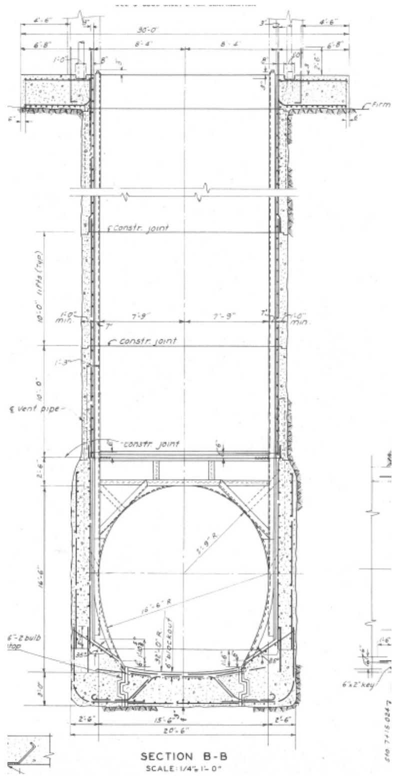

Figure 23 Section through Diversion Tunnel at Upstream Gate

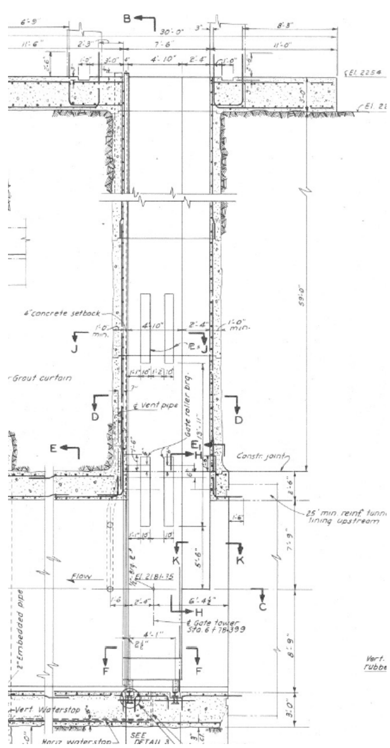

Figure 24 Section through Upstream Gate

6.3.1.1.3. Demolition Approach

Removal of the earthen embankment dam would be accomplished using large earth excavating and hauling equipment. The timing of the start of excavation of the embankment dam will determine the work force size and number of pieces of earth moving equipment required. If excavation can be started immediately after the beginning of drawdown activities time available for removing the embankment structure would extend from October to September of the next year allowing an entire year for excavation.

Starting excavation of the dam immediately after drawdown begins, however, involves some risk that both Iron Gate and Copco 1 reservoirs would refill during the winter and overtop the partially demolished Iron Gate Dam. While Starting excavation in the autumn would provide more flexibility, it also involves some risk. As Figure 6 shows, some year's flows have been extremely high. More analysis of hydrology, construction approaches, and downstream impacts from erosion of the structure would be required to determine the feasibility of this approach.

Starting excavation in spring of the year after drawdown when river high flow events are unlikely to occur could reduce the risk of overtopping significantly. Review of flow records at Iron Gate gage shows that removal of the embankment structure could safely begin in late spring. Determining the optimum start date would require agreement on acceptable risk levels, which is beyond the scope of this document. Starting on June 1 would allow 3 to 4 months to remove the embankment portions of the structure. This constricted window of time for excavation may require longer work days and weeks, which may result in associated additional costs. Table 17 shows equipment and work time anticipated to be necessary to complete the excavation. The number of pieces of equipment required for this effort would cause onsite construction congestion and could reduce efficiency. The work could also be accomplished in the same over all time period working longer hours with less equipment causing less local congestion. All information shown in Table 17 was taken from *Heavy Construction Cost Data*, 20th Annual Edition (2006) by RS Means.

Large mass excavators would continuously excavate the embankment material and place it into large off road trucks. Trucks would continuously haul material to the deposition site, back dump the material and return to the dam site to be loaded. To excavate the entire embankment in the time shown in Table 17, the 12 cubic yard trucks on the road would be spaced at approximately 250 foot intervals. The road from the site to the deposition location would have an average grade of about 6% requiring heavy duty trucks to travel in low gear when fully loaded. The roadway would be required to be widened to accommodate the heavy loads and two lane traffic with shoulders wide enough to accommodate breakdowns. Trucks would end dump their loads and return to be reloaded.

At the deposition site material would be continuously graded and compacted. Grading would be accomplished using large dozers. Dumped material would be compacted using vibratory rollers in 1 to 2 foot lifts. The location and design of the configuration for the deposition site will require additional geotechnical analysis to ensure safety of the site.

Embankment material can be excavated to approximately elevation 2220, the elevation of the dam construction cofferdam. By October of the year following drawdown most of the earth embankment material will be removed. Concrete cutoff walls shown in Figure 27 will be removed down to the predam streambed.

Cofferdam removal will occur near summer low flow conditions to allow maximum safety of removal. Sheet piles will be used to create cells. Material in the cells will be excavated and lateral sheet piles removed to create a diversion for the river while the remaining elements of the cofferdam are excavated in the dry. Figure 28 shows the cofferdam and river flow.

Table 17 Excavating Equipment to Remove Iron Gate Dam

Item/ Equipment	Capacity	Rate CY/hour	Number of Units	Total Hours per Unit	Time Required Weeks
Mass Excavator	5 CY	185	6	901	15
Truck	12 CY	23.2	54	901	15
Dozer	300 H.P.		4	901	15
Compactor	Vibratory Roller	3000	4	901	15

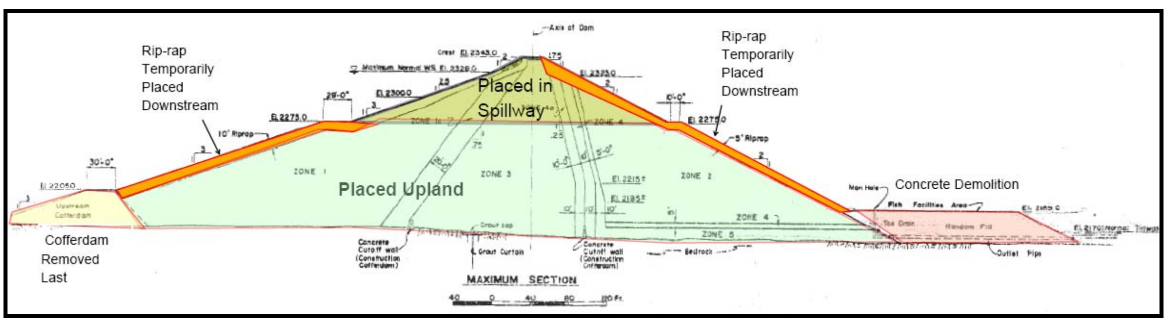

Figure 25 Section Through Iron Gate Dam Showing Excavated Material Site Placement

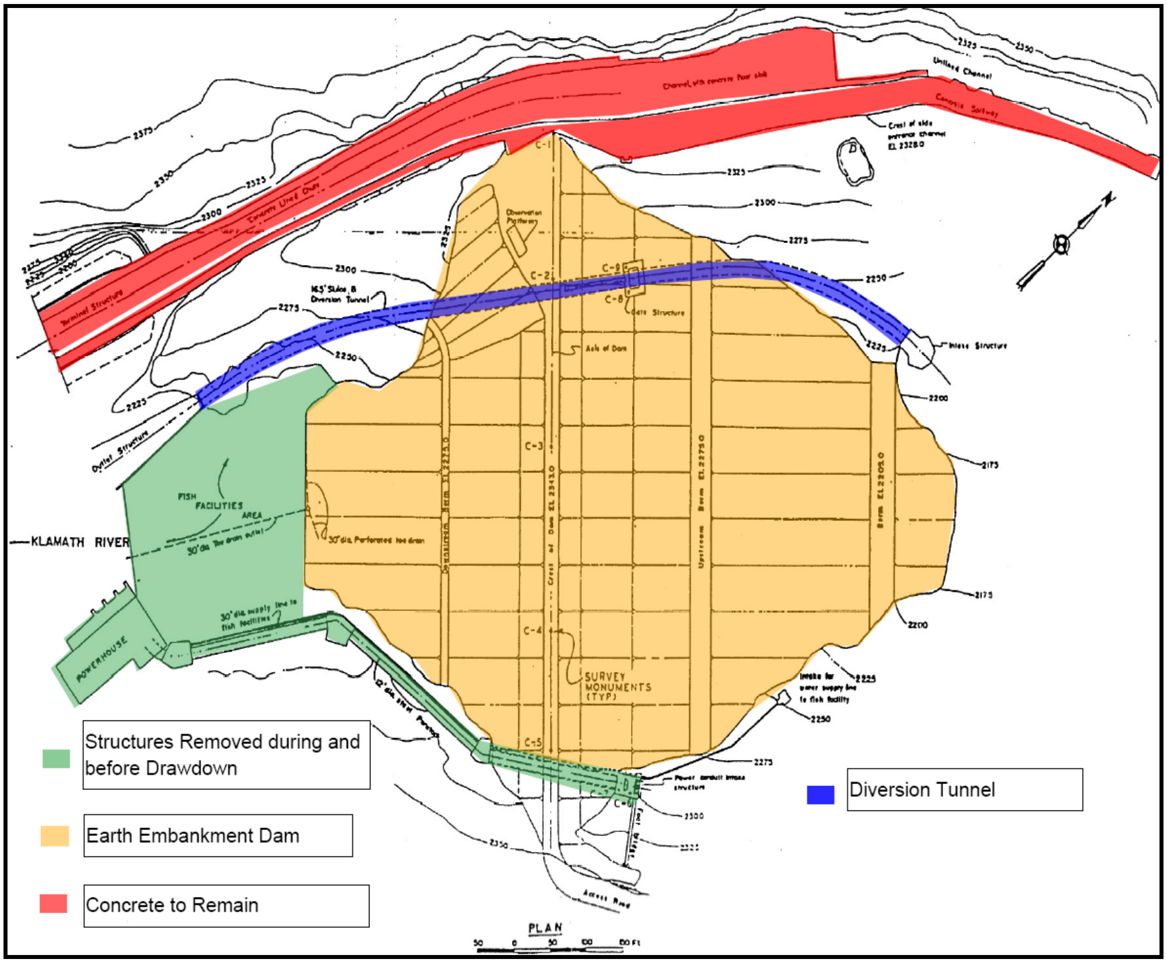

Figure 26 Iron Gate Dam Structural Component Removed

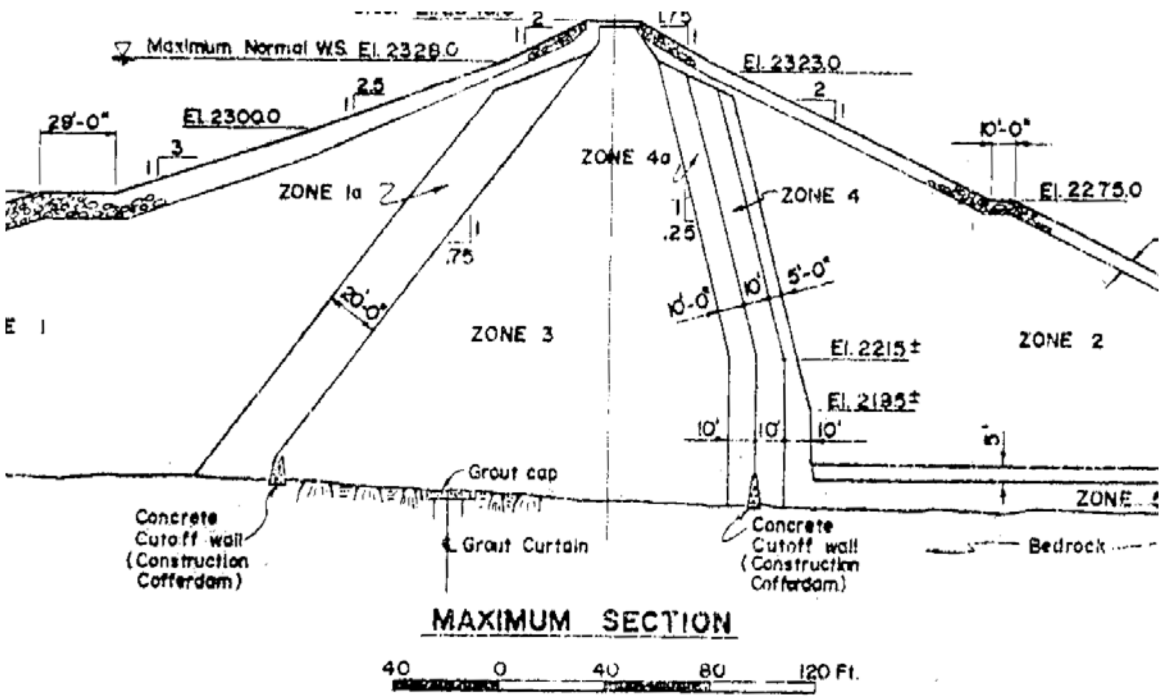

Figure 27 Section through Iron Gate Dam

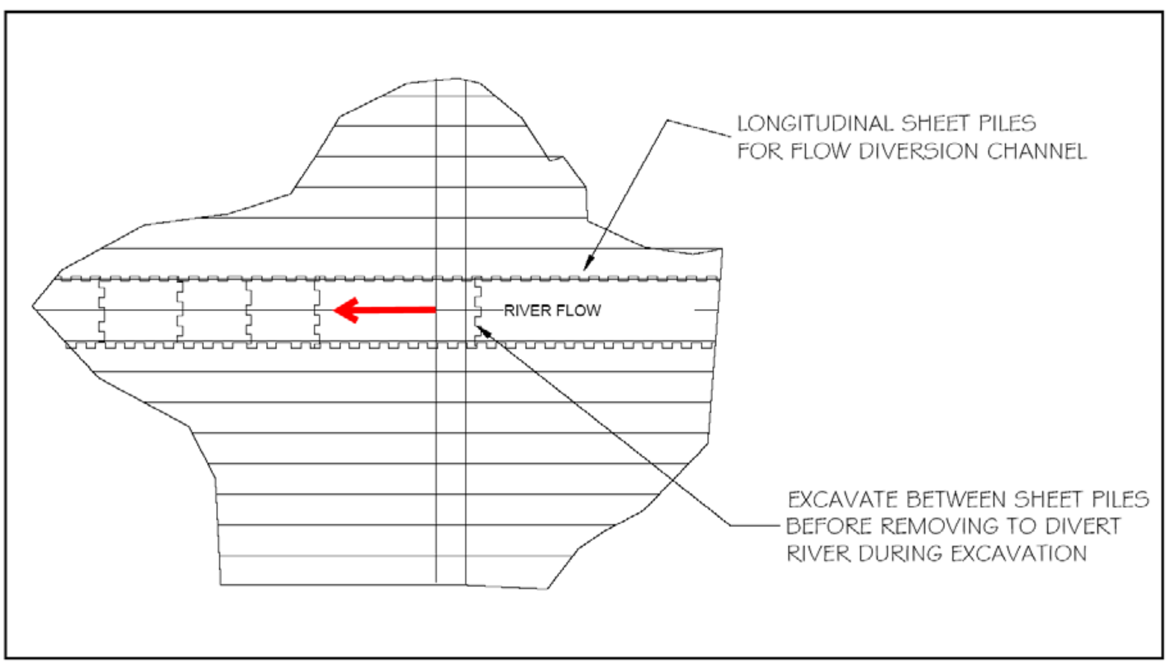

Figure 28 Iron Gate Cofferdam Removal

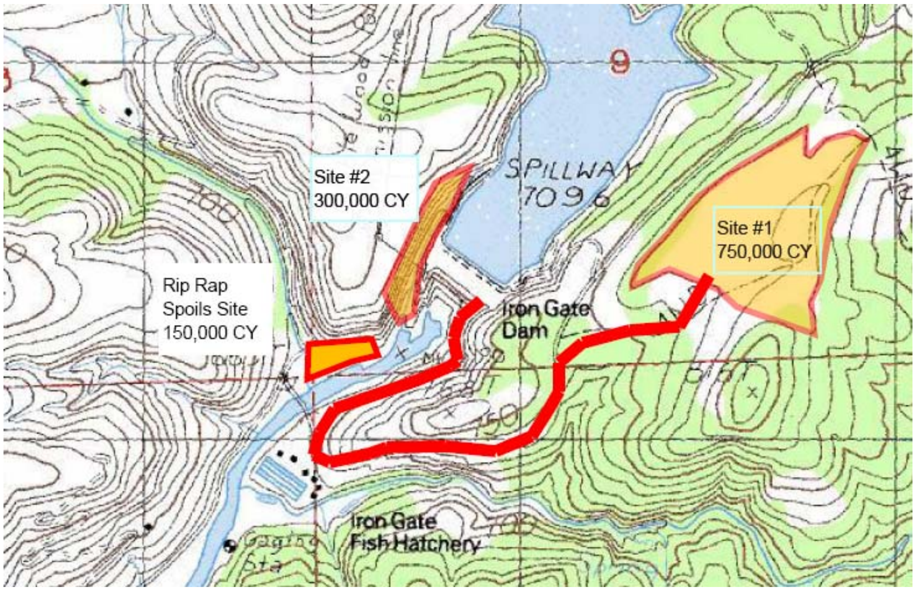

Figure 29 Iron Gate Material Spoils Sites

Quantities at end of shift on July 24,

Item	Production For Day	Total
Pervious, Zone 1	4135	192,400
Pervious, Zone 2	1950	107,720
Clay Core, Zone 3	3550	136,350
Side Filter, Zone [illegible]	750	16,390
Filter, Zone 4	280	17,710
Bottom Filter, Zone [illegible]	360	11,890
Drain, Zone 5	155	21,710
Fish Facilities Berm	—	16,000
COFFERDAM	—	35,000
TOTAL	11,180	555,170

Received in the field 7-25-61 ALC

TOTAL EMBANKMENT - 1,133,000 C.Y.

Figure 30 Copy of DSOD Document Showing Embankment Total Volume

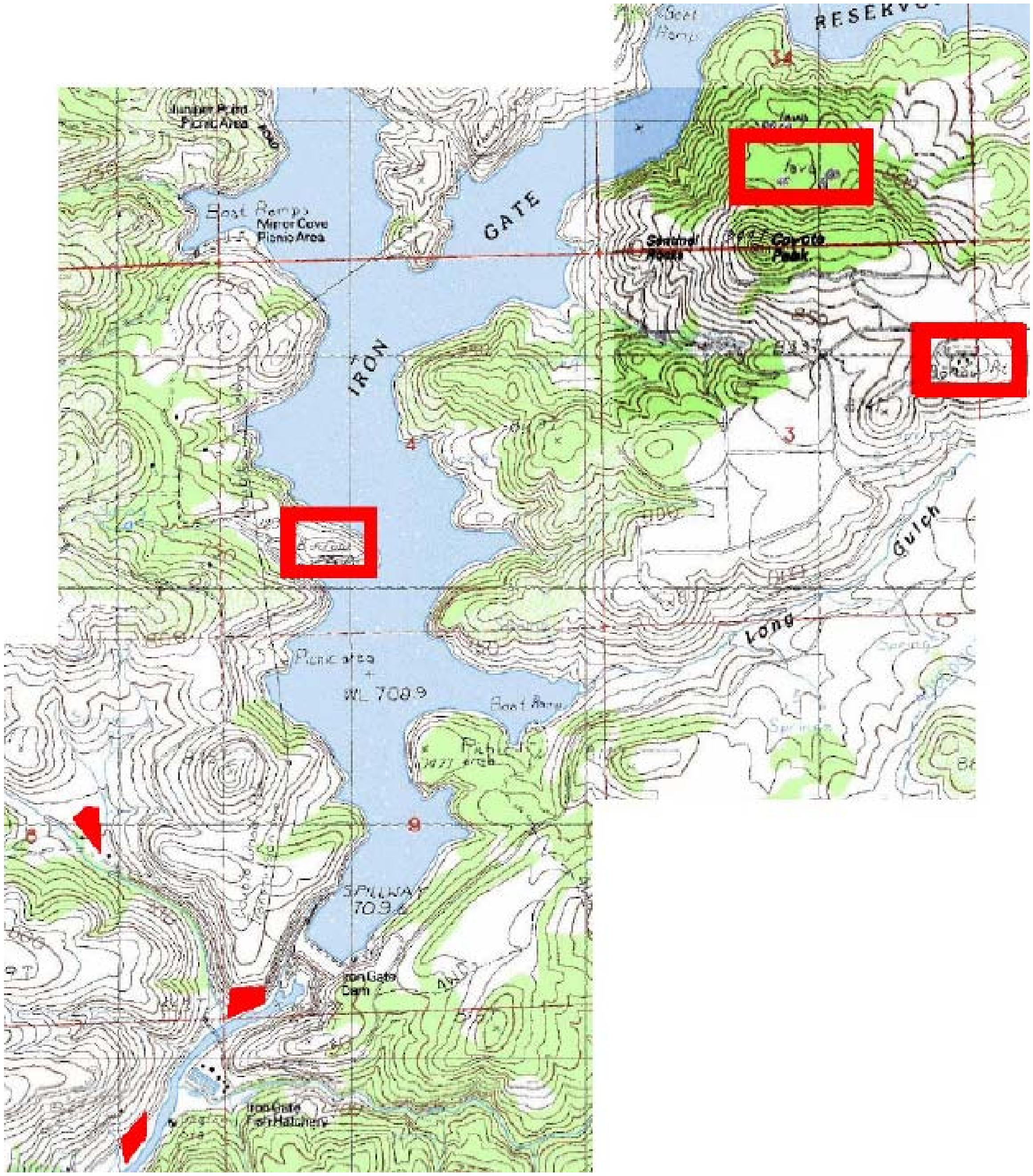

Figure 31 Potential Spoils Sites for Iron Gate Dam Embankment Material

6.3.2. Copco 1

The arched concrete Copco 1 structure varies in thickness. Figure 35 shows the dimensions of the dam at the base to be approximately 94 feet tapering in stair step fashion to approximately 31 feet at the top of the structure. The approach to removing the dam would involve drilling and blasting concrete into rubble and relocating the concrete for permanent storage adjacent to the site. Access to the dam will require that the river flow be diverted and the reservoir drawndown either during or before the demolition of the concrete structure.

Copco 1 reservoir can currently be lowered no further than the limits imposed by the elevations of the penstock supplying the power generating units, approximately elevation 2585 msl. To drawdown the reservoir either a new low-level outlet will need to be constructed or notches will need to be constructed in advance of the demolition to allow water elevations to remain below demolition activities.

The rate of reservoir drawdown will affect the duration of elevated TSS levels in the river downstream of Iron Gate Dam. Numerous structures are located around the edge of Copco 1 reservoir. Drawing down the reservoir too rapidly could negatively affect the stability of the inundated slopes around the reservoir edges. Slope stability and embankment dam safety considerations will need to be further investigated to determine the maximum rate of drawdown and therefore the minimum duration of the elevated TSS.

6.3.2.1.1. Facilities

The following description of Copco 1 Dam is excerpted from FERC license application documents submitted by PacifiCorp.

> Copco No. 1 dam is a concrete gravity arch structure with a 462-foot radius at the crest. As originally designed, the spillway crest was approximately 115 feet above the original riverbed. After construction began, the river gravel was found to be over 100 feet deep at the dam site; this material was excavated and then backfilled with concrete, making the total height of the dam 230 feet, measured from the lowest depth of excavation to the spillway crest, and 250 feet to the top of the spillway deck.
>
> The crest length between the rock abutments is approximately 410 feet. The upstream face of the dam is vertical at the top, then battered at 1 horizontal to 15 vertical. The downstream face is stepped, with risers generally about 6.0 feet in height. The ogee-type spillway is located on the crest of the dam. It is divided into 13 bays controlled by 14-foot by 14-foot Tainter gates. The spillway crest is located at El. 2,593.5 feet msl. The normal operating reservoir water level is 1.5 feet below the top of the gates at El. 2,606.0 feet msl. The estimated spillway capacity at water surface El. 2,607.5 feet msl with all 13 gates open is 36,764 cfs. Two intake structures are located at approximately invert El. 2,575.0 feet msl in the dam near the right abutment. The left intake houses four vertical lift gates. Two 10-foot-diameter (reducing to 8-foot-diameter) steel penstocks feed Unit No. 1 in the powerhouse. The right intake houses four vertical-lift gates.
>
> A single, 14-foot-diameter (reducing to two 8-foot-diameter) steel penstock feeds Unit No. 2. There are two side-by-side trash racks, which measure 44 feet wide, 12.5 feet

high, and have bar spacings of 3 inches, in front of each intake. The low-level sluice outlet has been abandoned.

The Copco No. 1 powerhouse is a reinforced-concrete substructure with a concrete and steel superstructure enclosed by metal siding located at the base of Copco No. 1 dam on the right bank. The two turbines are double-runner, horizontal-Francis units, each with a rated discharge of 1,180 cfs, and rated at 18,600 hp at a net head of 125 feet. The generators are rated at 12,500 kVA at 0.8 power factor (10 MW). There are no turbine bypass valves. Unit 1 has three single-phase, 5,000-kVA, 2,300/72,000-V transformers to step-up the generator voltage for transmission interconnection. Unit 2 has three single-phase, 4,165-kVA, 2,300/72,000-V transformers to step up the generator voltage for transmission interconnection.

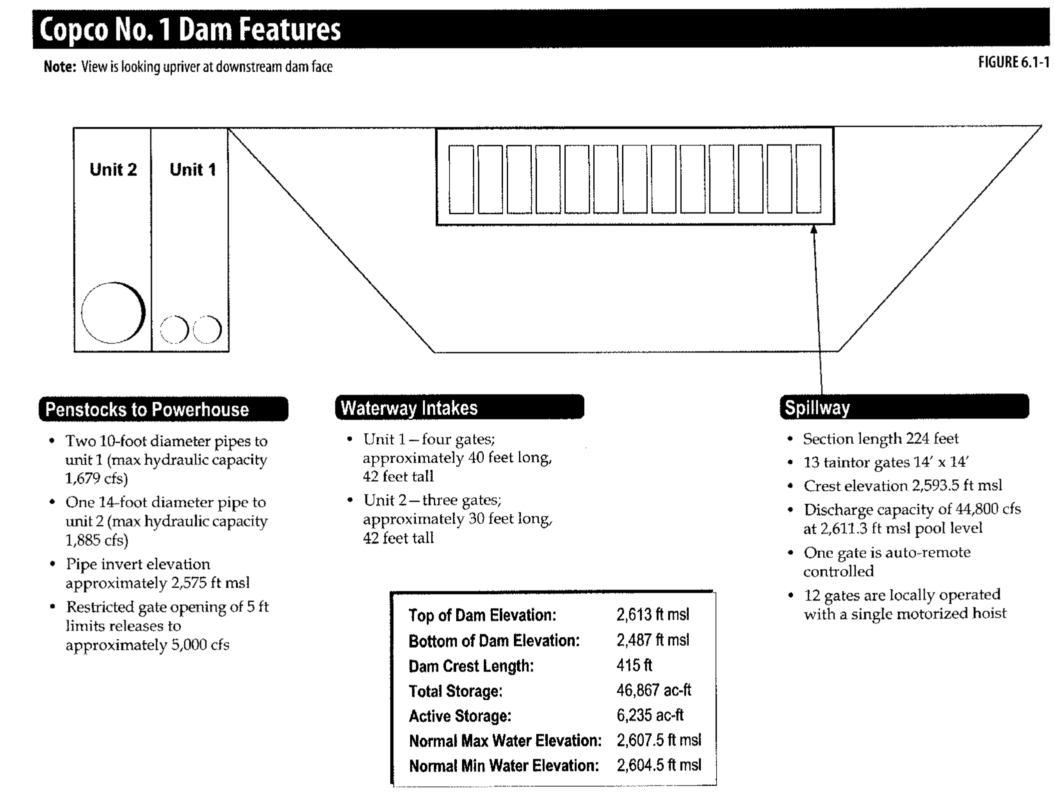

Figure 32 Copco 1 Dam Features

6.3.2.1.2. River Diversion

Copco 1 reservoir has no working low-level outlet. A six-foot diameter tunnel in the left abutment of the dam was used to divert flow for dam construction but was filled with concrete after completing dam construction. It may be possible to reopen that diversion tunnel for reservoir drawdown using explosives. However the tunnel size is not large enough to allow sufficient flow to lower the reservoir for average late fall early winter flows plus the additional flow needed to drawdown the reservoir.

Three approaches were investigated to ensure that the reservoir could be drawndown at a rate that ensures bank stability.

1. Rapid notching of the central portion of the dam would allow the river to flow through a notch at a lower elevation than adjacent concrete demolition activities. Notches would be constructed at a lower elevation than surrounding demolition work to ensure reservoir elevations were below construction activities. Notches would be constructed at sequentially lower elevations as demolition progressed. Reservoir elevations would drop in increments, determined by notch depth, of approximately 12 feet each. This approach would have two disadvantages for this project.
    a. If rapid reservoir dropping from the construction of a single notch exceeded slope stability guidelines increments would may need to be very small raising costs. Further, if high winter flows re-elevated the reservoir, no control over the subsequent rate of lowering of reservoir elevations would be possible.
    b. High flows during the lowest portion of the demolition might impair construction activities.
2. Construct a large diameter gated tunnel through the base of the dam. Drilling and blasting methods would be used to complete the tunnel. A new, gated, outlet would be added to the downstream face of the tunnel to allow flow control. The gate would be anchored to the face of the dam with high strength rods grouted into the concrete. The tunnel capacity would depend on flow passage requirements at the lowest elevations and during the highest flow periods. Final removal of the last elements of the structure would most likely not occur until after spring high flows.
3. Construct a series of smaller diameter ungated tunnels, located vertically up the face of the dam. These tunnels would be blasted open in a sequence that controls the flow to ensure safe drawdown rates. This approach would require thorough understanding of the limits of reservoir drawdown rates.

Further exploration of drawdown timing will be needed to determine the optimum diversion control methodology. For the scheduling and cost estimates, the low level gated tunnel approach has been assumed. This approach would provide the most safety and control of lowering rates.

Regardless of the method and timing of reservoir and dam removal, suspended sediment concentrations (TSS) in the downstream river due to the erosion of reservoir sediment will cause elevated TSS downstream of Iron Gate Dam. The proposed approach to removing the reservoirs would involve lowering Iron Gate and Copco 1 reservoirs concurrently at the maximum rate that is compatible with slope stability and embankment dam safety in the inundated reservoir. Lowering the reservoirs as rapidly as possible reduces the time span of water quality impacts downstream. While the maximum rate of drawdown compatible with slope stability is under investigation, a rate of 1 foot per day has been assumed to prepare cost and schedules.

For both Copco 1 and Iron Gate the upper portion of the reservoirs can be lowered in a controlled fashion using the existing penstocks. The lowest elevation attainable at Copco 1 by diverting flow through the penstocks is approximately 2585 msl. This elevation could be achieved over several weeks or months without substantially affecting TSS levels due to the trapping of both Iron Gate and Copco 1 reservoirs simultaneously. The starting elevation for the more rapid rate of drawdown was assumed to be the lowest elevation possible using penstocks only. Drawdown subsequent to that elevation would be achieved using newly constructed diversion facilities such as a gated tunnel.

The lowest reservoir elevation attainable through a low level tunnel would be approximately 2480 msl. Lowering the reservoir below the penstock elevations at 1 foot per will require approximately 105 days. During this period TSS downstream of Iron Gate Dam will be significantly elevated as the sediment in the path of the river is eroded and carried in suspension downstream.

6.3.2.1.3. Demolition Approach

Removal of Copco 1 Dam would be conducted using drilling and blasting techniques. Concrete would be predrilled before beginning demolition to allow placement of explosives. Demolition of the concrete dam structure could occur concurrently with the reservoir drawdown. Timing of concrete demolition would depend on whether Copco 1 Reservoir were needed to help control reservoir elevations in Iron Gate during the high flow season subsequent to drawdown.

Removal of all concrete could be accomplished in approximately 4 months. If control of Iron Gate Reservoir were not required, demolition of Copco 1 Dam would begin immediately upon beginning reservoir drawdown. Demolition would proceed through the winter months and be completed before the start of excavation activities at Iron Gate Dam.

Approximately 35,000 cubic yards of concrete would be blasted into pieces small enough to be removed with an adjacent tower crane. Reinforcing steel would be removed and recycled. The structure would be demolished to approximately 5 feet below the predam riverbed. Final demolition activities in the below riverbed area would not occur until low flows in August or September. Low flows would allow river diversion from side to side while riverbed concrete was demolished.

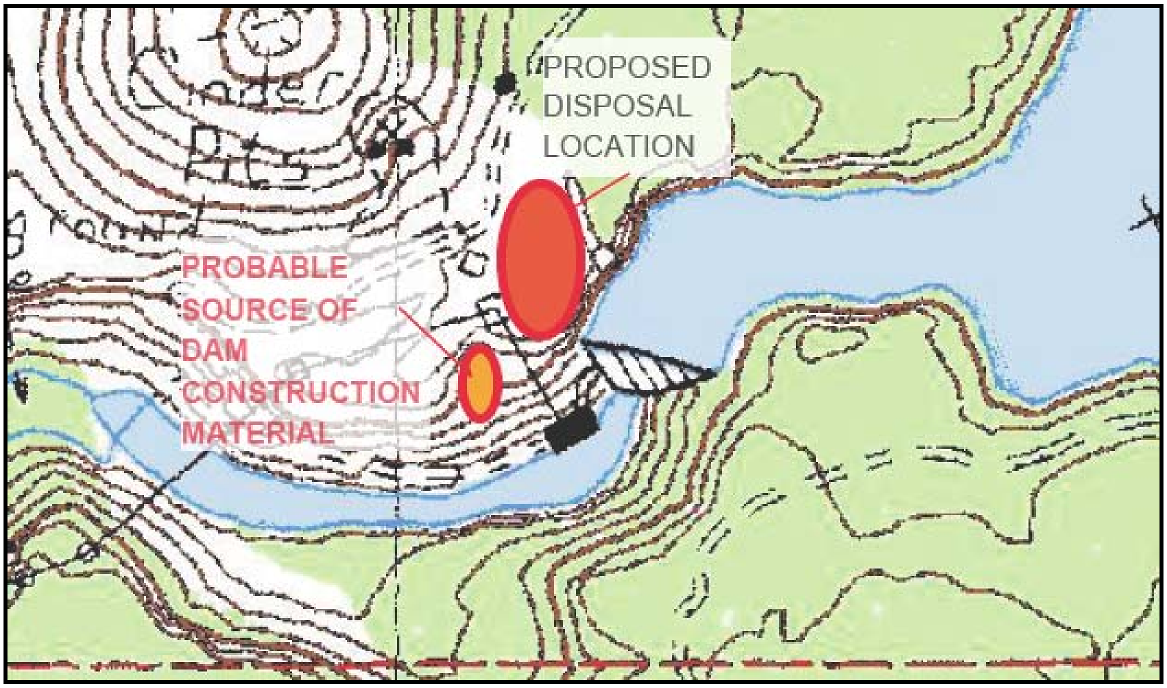

Figure 33 Plan View of Copco 1 Dam and Proposed Spoils Site

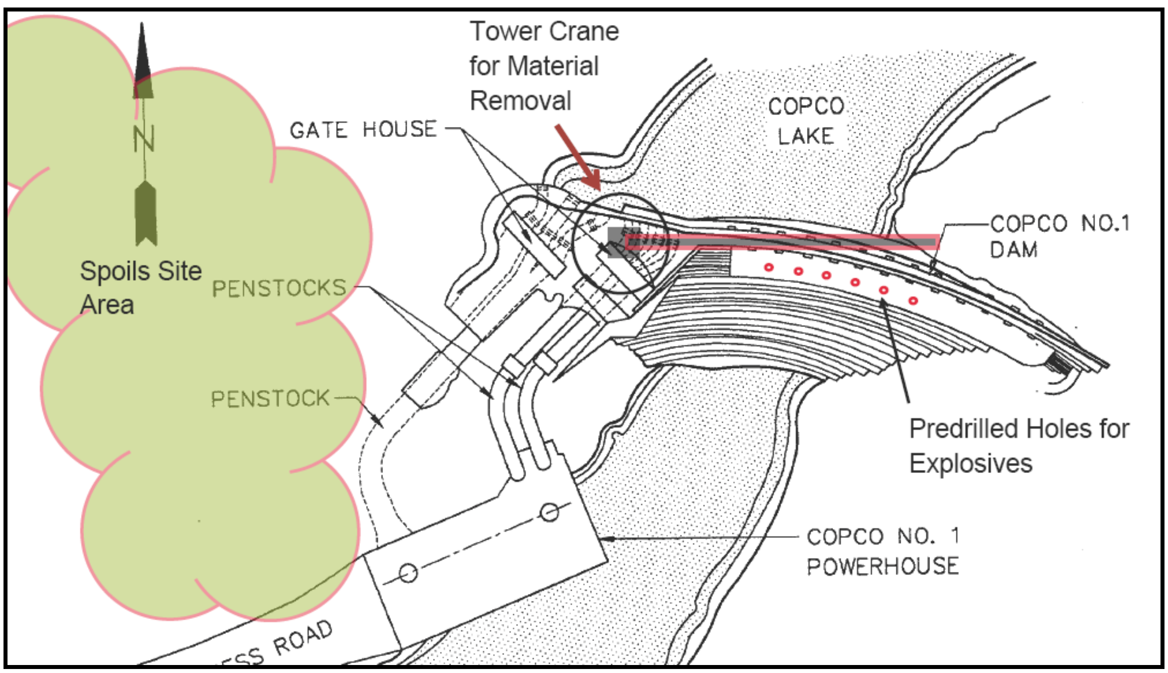

Figure 34 Copco 1 Dam Demolition Approach

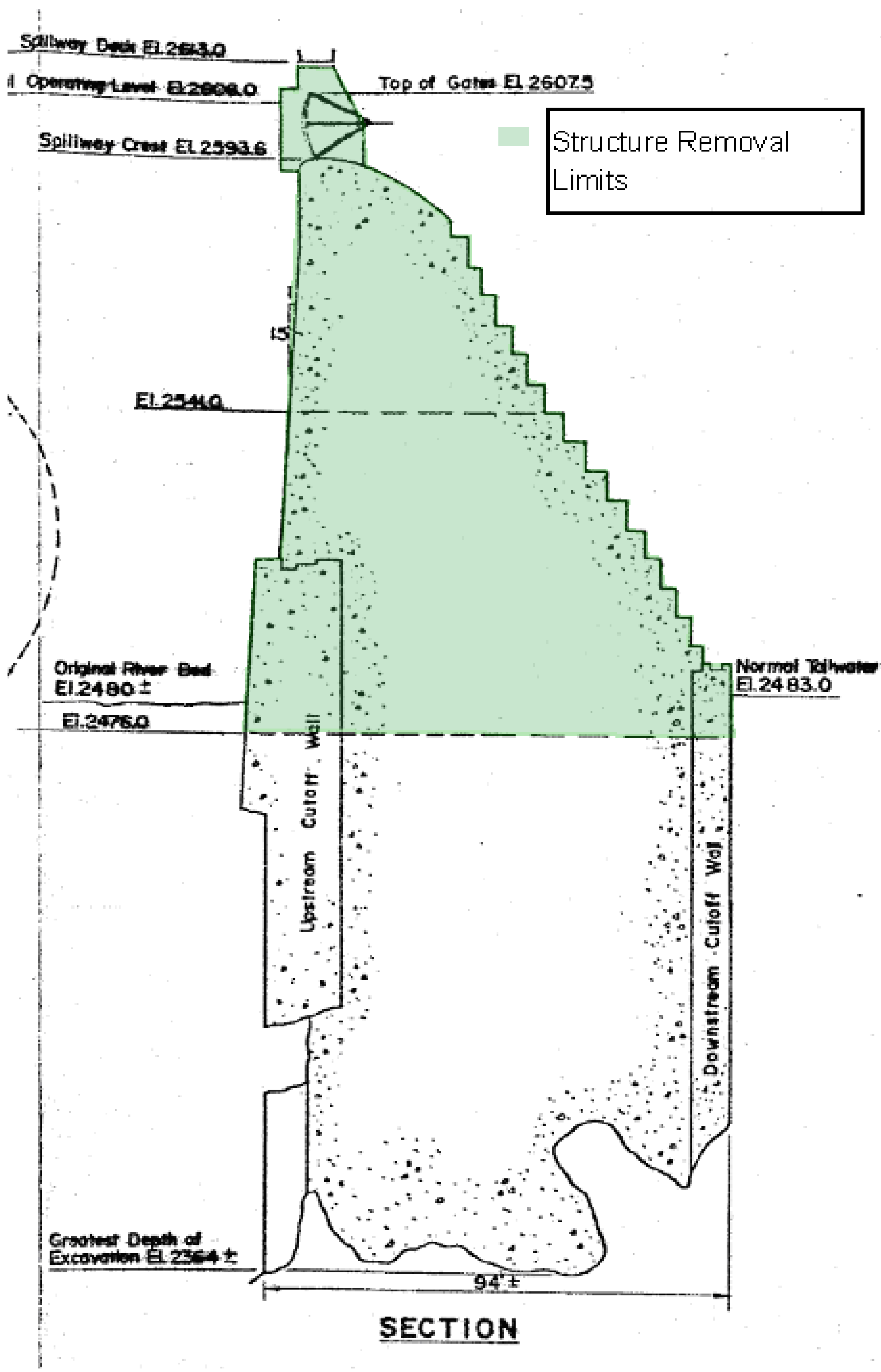

Figure 35 Original Drawing of Section through Copco 1 Dam

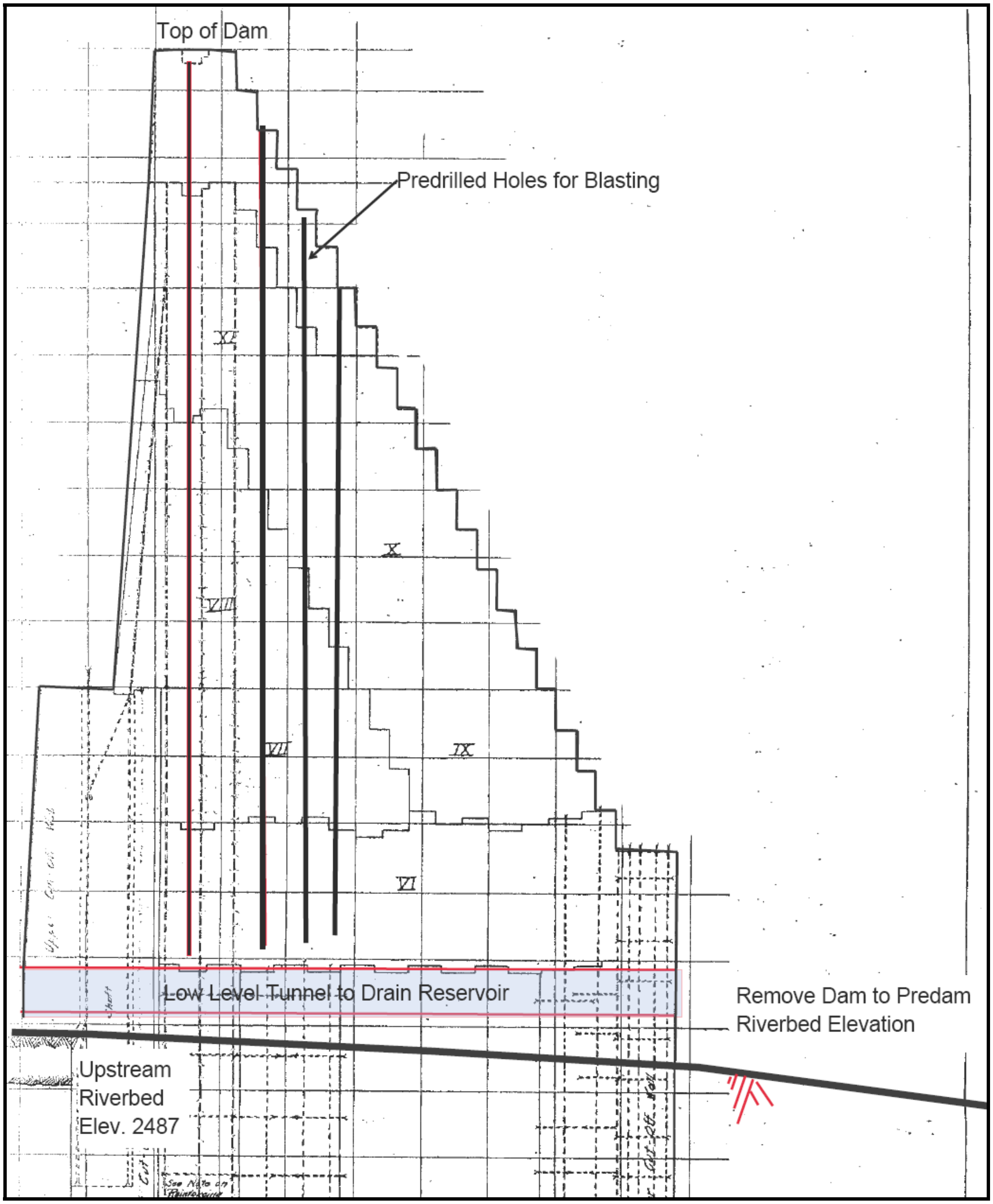

Figure 36 Section Through Dam Showing Removal Approach

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Seattle, WA

6.3.3. Copco 2

Copco 2 is a relatively small dam concrete gravity dam located immediately downstream of Copco 1 Dam. Removal of the dam would involve drilling and blasting spillway concrete. Access to the dam could be accomplished in dry conditions by filling and drawing down Iron Gate and Copco 1 reservoirs to temporarily dry up the reach between them while maintaining flow downstream of Iron Gate Dam.

6.3.3.1.1. Facilities

The following description of Copco 2 Dam is excerpted from FERC license application documents submitted by PacifiCorp.

> The Copco No. 2 Development consists of a diversion dam, a small impoundment, and powerhouse located just downstream of Copco No. 1 dam between approximately RM 198.3 and RM 196.8. The reservoir created by the 38-foot-high dam has minimal storage capacity (73 acre-feet). Copco No. 2 is entirely dependent upon Copco No. 1 releases for water and as a result functions as a "slave" to the Copco No. 1.
>
> The Copco No. 2 dam is a concrete gravity structure with an intake to the flowline on the left abutment and a 145-foot-long spillway section with five Tainter gates. The dam is 33 feet high, has an overall crest length of 335 feet and a crest width of 9 feet. The crest elevation is El. 2,493 feet msl.
>
> The dam has a 132-foot-long earthen embankment with a gunite cutoff wall. The dam has a manual gate controlling a sluiceway adjacent to the intake. The concrete gravity spillway section crest elevation is 2,473 feet msl. The intake structure incorporates trash racks and a roller-mounted (caterpillar) bulkhead gate. The trash rack is 36.5 feet by 48 feet and has 2-inch bar spacing.
>
> Copco No. 2 dam has five spill gates and a manual gate valve that can control a small amount of water into the bypass reach. The flowline to the powerhouse consists of portions of wood-stave pipe, rock tunnel, and steel penstock. At the entrance to the flowline is a 36.5-foot by 48-foot trash rack. There are two 13.5 MW units with a combined hydraulic capacity of 3,200 cfs in the powerhouse.
>
> The flow line to the powerhouse consists of portions of 2,440 feet of concrete-lined tunnel, 1,313 feet of wood-stave pipeline, an additional 1,110 feet of concrete-lined tunnel, a surge tank, and two steel penstocks. The diameter of the tunnel and wood stave pipeline sections is a constant 16 feet. The two penstocks, one 405.5 feet long and one 410.6 feet long, range from 16 feet in diameter at the inlet to 8 feet in diameter at the turbine spiral cases.
>
> The powerhouse is a reinforced concrete structure that houses two vertical-Francis turbines. Each turbine has a rated discharge of 1,338 cfs and a rated capacity of 20,000 hp at 140 feet of net head. The synchronous generators are rated 15,000 kVA at 0.9 power factor (13.5 MW). There are three single-phase, 10/20-megavolt ampere (MVA), 6,600/72,000-V transformers for each generator to step up the voltage. There are also three single-phase, 10/20-MVA, 73,800/230,00-V step-up transformers for interconnection to the transmission system.

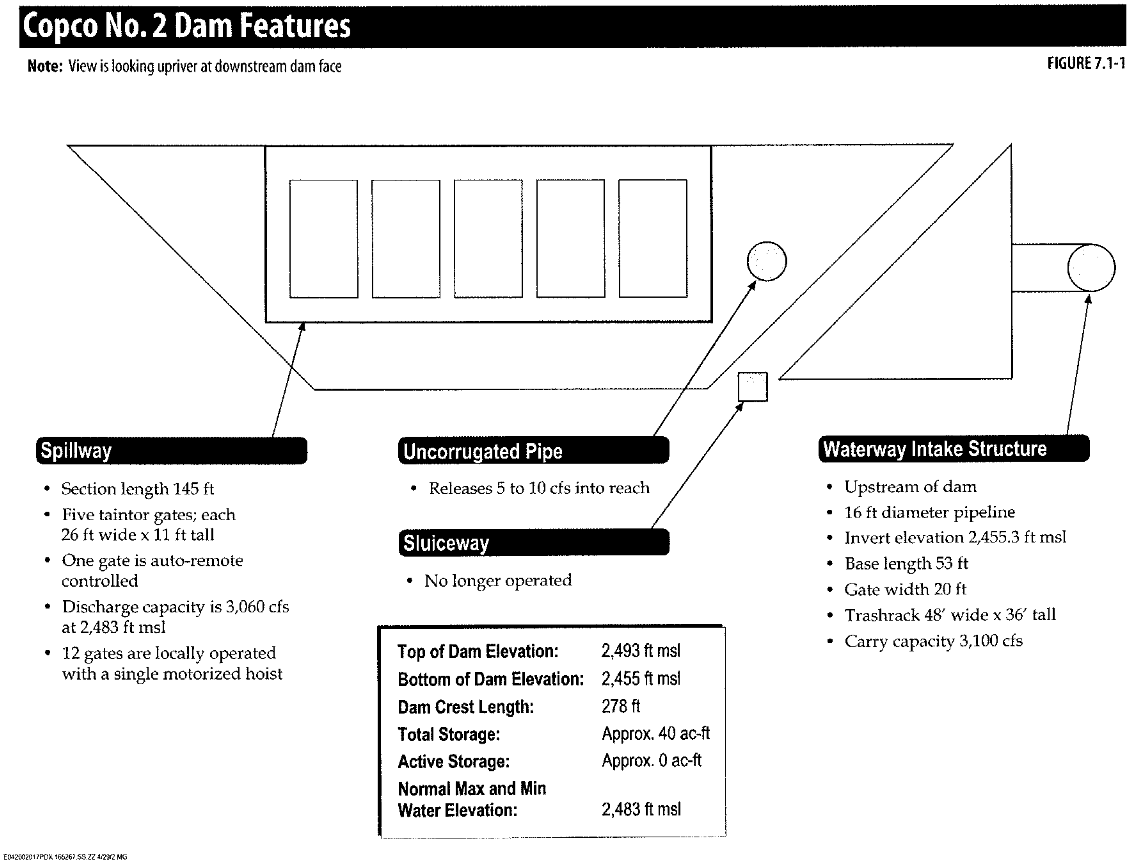

Figure 37 Copco 2 dam Features

6.3.3.1.2. Dam Removal

Copco 2 would be removed in the first year of construction activities. Demolition would begin in the summer low flow periods prior to drawing down Iron Gate and Copco 1 reservoirs. The spillway would be removed first to allow a free flowing river between Iron Gate and Copco 1 reservoirs while tunnels were plugged and powerhouse, penstocks, and intake were demolished. During summer flows, even in the highest flow year of record, the entire flow in the river can be diverted through the power canal. This would allow the downstream stilling basin portion of the spillway structure to be demolished in the dry.

Raising and lowering Iron Gate and Copco 1 dams would be used to temporarily dry up the section of river between the dams. During summer low flows when no water passes over the spillway, the main spillway structure would be drilled and packed with explosives. Copco 1 reservoir would be slowly drawndown approximately 10 feet prior to the completion of drilling activities. Drawdown would occur during summer low flows to limit TSS downstream of Iron Gate Dam. By limiting the drawdown to only the upper 10 feet little or no sediment would be eroded and suspended.

Flow at Copco 1 would then be stopped causing the reservoir was raised over the next 5 to 7 days. River flow downstream of Iron Gate Dam would be maintained by lowering Iron Gate Reservoir. During this time, the section of river between Copco 1 and Iron Gate would have no flow. While the river was dry the spillway section would be removed by blasting.

An alternate approach would use a temporary cofferdam constructed from concrete blocks or Jersey barriers placed diagonally across the stream, as shown in Figure 41, to divert flow into the tunnel. The spillway section would be removed while flow was diverted through a partially full power tunnel. This approach could be used in lower flow years. Higher flow years may require a higher pool and therefore excessively high cofferdam to divert the flow during spillway demolition. A cofferdam may also be used after removing the initial section of spillway to divert flow around the undemolished section to divert flow instead of lowering the reservoirs to dry up the stream.

To demolish the structure, Copco 2 Dam would be drilled and packed with explosives prior to drying up the river channel between Copco 1 and Iron Gate. Records obtained from DSOD and calculations based on dam drawings indicate that the spillway section contains approximately 6500 cubic yards of concrete. A crane located on the right bank would lift demolished material out of the spillway area. Trucks would transport the demolished concrete to the spoils site. Demolition would begin at the left bank of the spillway structure. Approximately 1/3 of the length of the spillway could be demolished while river flow was shut off during the 5 to 7 day period. The remaining sections would either be removed by again raising and lowering reservoir levels or using a cofferdam to divert flow. The tunnel and powerhouse would be removed after flow returned to the river.

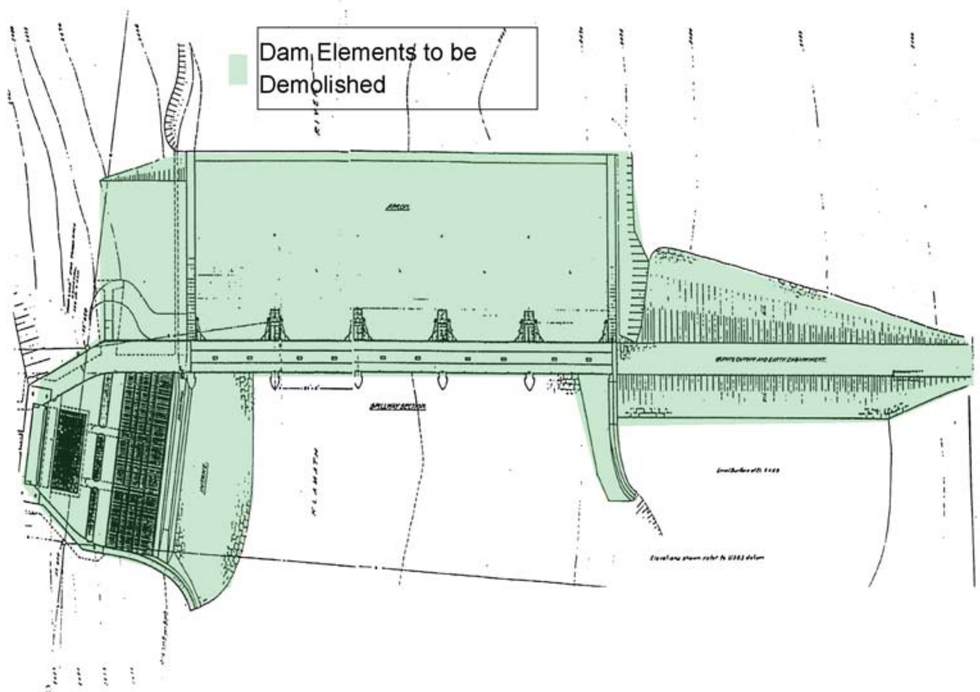

Figure 38 Plan View of Copco 2 Dam

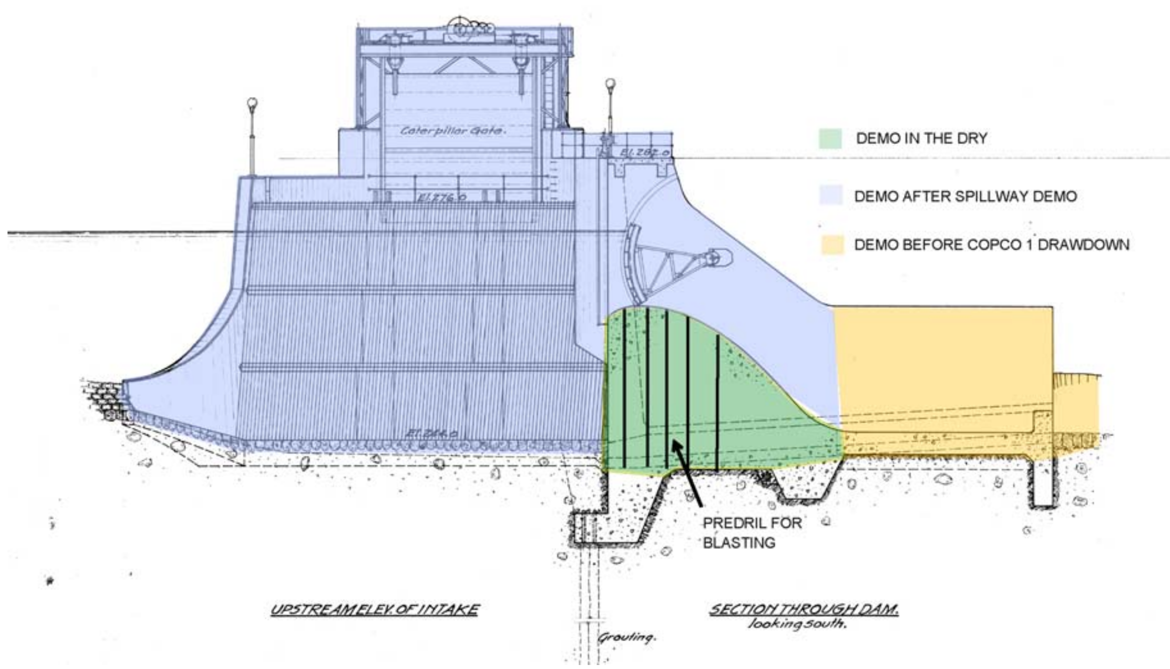

Figure 39 Copco 2 Spillway Removal Sequence

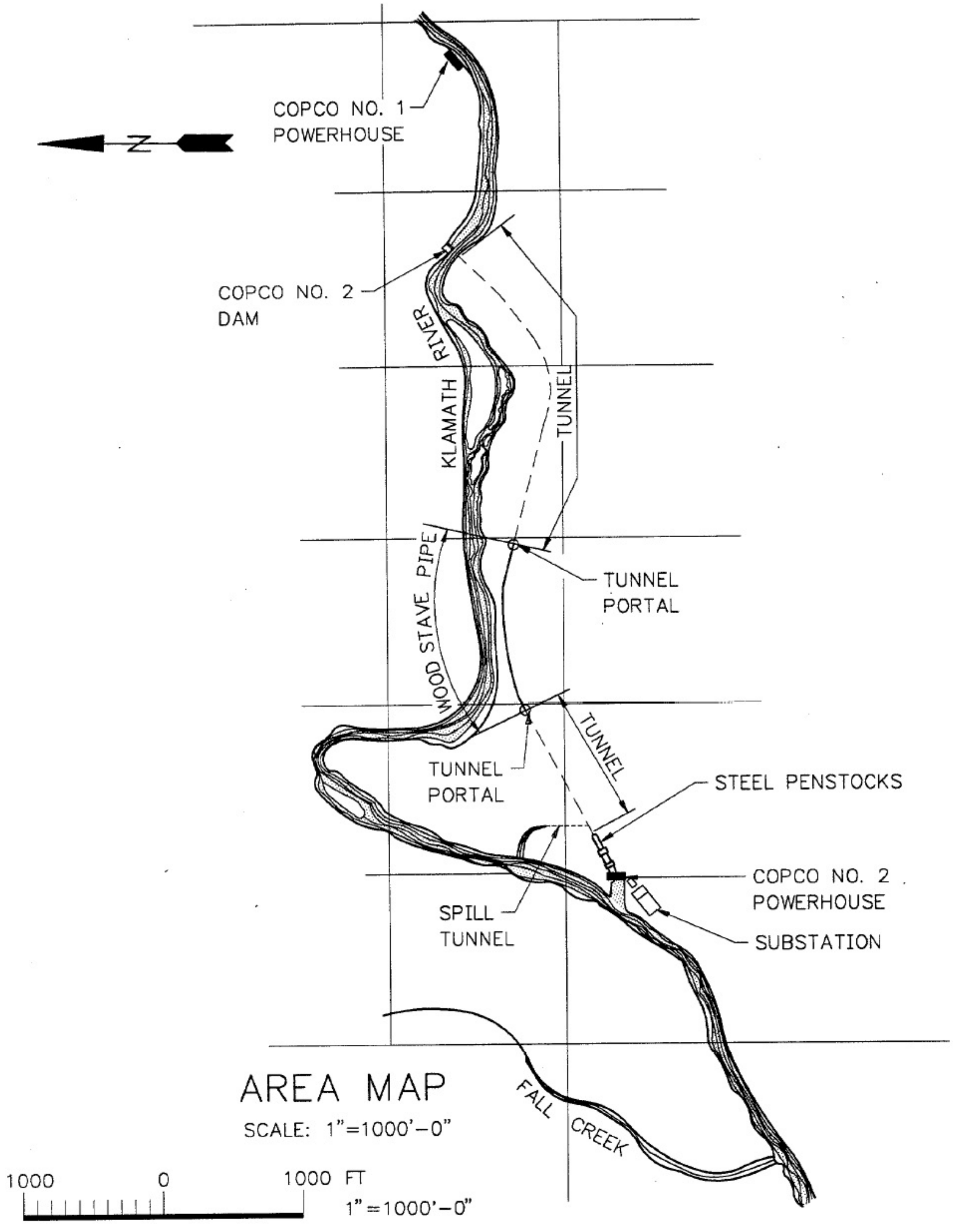

Figure 40 Location of Copco 2 Project Elements

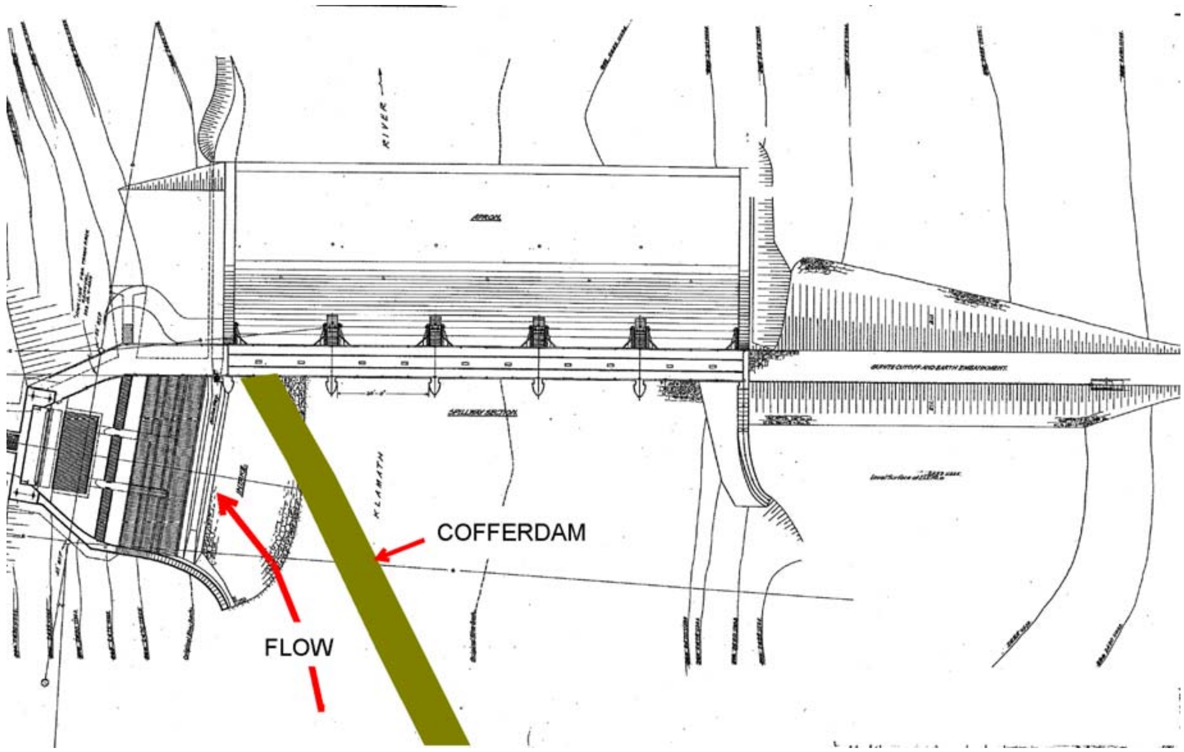

Figure 41 Cofferdam Diversion at Copco 2

6.3.4. J.C. Boyle

J.C. Boyle is an embankment dam constructed in 1958 containing approximately 125,000 cubic yards of material. The reservoir is also a relatively small reservoir with approximately 630,000 cubic yards of sediment, mostly sand. Most of the sediment is located adjacent to the upstream face of the reservoir. The sediment apparently came from a tributary on the left bank entering just upstream of the dam.

The dam would be removed using large excavating equipment after allowing the reservoir to drain and erode much of the sediment. Material from the dam would be relocated above the left bank in the location of the borrow pit used for construction of the dam. The reservoir would be drawndown using two culverts used to divert river flow during dam construction.

6.3.4.1.1. Features

The J.C. Boyle Development, located on the Klamath River between approximately river mile (RM) 228 and 220, consists of the J.C. Boyle dam, powerhouse, fish ladder, and other appurtenant facilities. Originally named the Big Bend dam, the J.C. Boyle dam was constructed in 1958. It is an earth embankment structure composed of compacted earth on either side of a clay core. The dam has a concrete gravity spilling section that is 68 feet high and 693 feet wide. The reservoir is a narrow impoundment of 420 surface acres (J.C. Boyle reservoir). The reservoir supplies water to a free surface canal, which provides flow to two 40-MW turbines located in a single powerhouse, located approximately 4.3 river miles downstream of the dam.

Placed in service on October 1, 1958, the J. C. Boyle powerhouse is the single largest generating facility of the Project. The plant has two exposed generating units with a steel gantry crane system for repair and maintenance. A substation and small metal maintenance building are also located at the site.

The impoundment formed upstream of the dam contains approximately 3,495 acre-feet of total storage capacity. The dam has a spillway with three spill gates. The rated hydraulic capacity of the powerhouse is 2,850 cfs. A fish ladder at the dam provides for upstream fish passage. Water diverted at the dam enters a 617-foot-long steel flowline that empties into a canal. The canal extends just over 2 miles along the river canyon. At the downstream end of the canal is a small forebay where two automated spill gates direct overflows to a short spillway and into the bypass reach. Water flowing to the powerhouse goes through a trash rack before entering a tunnel. The water then flows into two steel penstocks, each serving a separate 40-MW unit. Features of the dam structure are shown in Figure 42, excerpted from PacifiCorp licensing documents provided to FERC.

No information regarding the construction details of the concrete water supply canal were available. Estimates of the length, width, depth, and concrete thickness were developed using known J. C. Boyle Reservoir water elevations, elevations at the downstream end of the canal shown on USGS maps, canal flow requirements. For volume calculations the canal was assumed to be 17 feet wide by 12 feet tall. Concrete walls were assumed to be 12 inches thick.

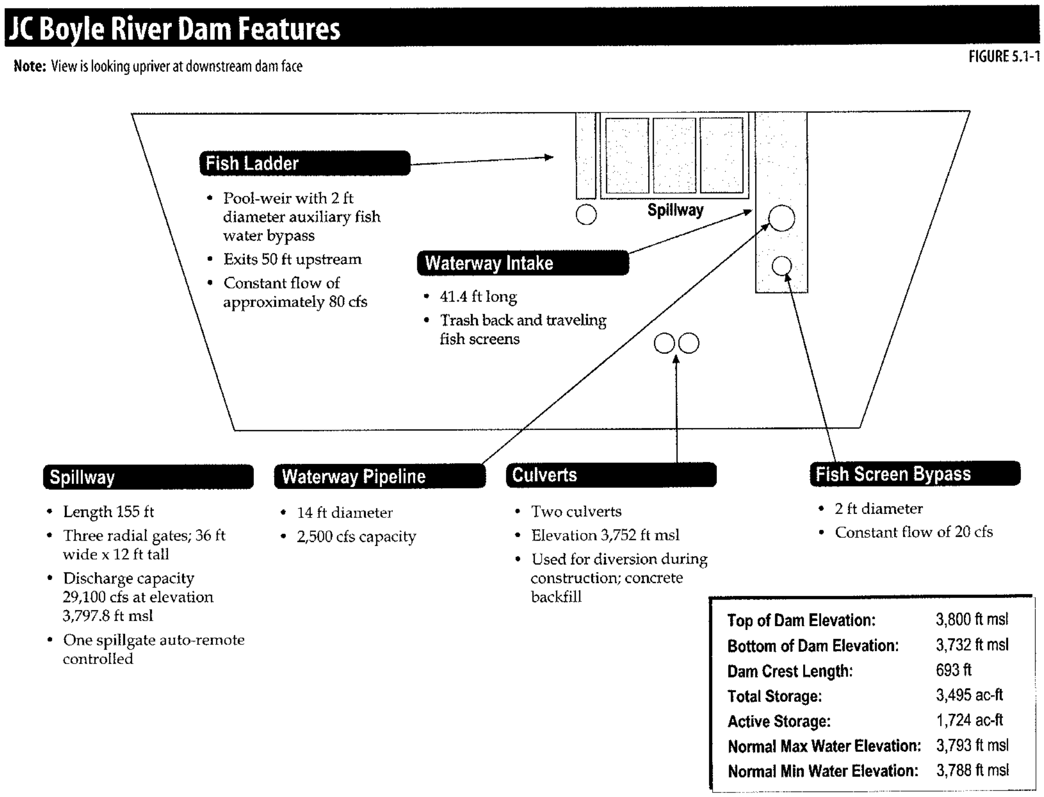

Figure 42 J. C. Boyle Dam Features

6.3.4.1.2. River Diversion

The original dam construction diversion would be used to lower J. C. Boyle Reservoir. Two “culverts”, approximately 10 feet by 9.5 feet each, were used to divert flow during the construction according to plans. The culverts do not allow the reservoir to completely drain. The normal operating water surface elevation for J.C. Boyle is 3793. The reservoir can be drawndown to approximately elevation 3780 through the existing penstock. Below that are two culverts through the left abutment that were used for river diversion during dam construction. According to drawings of the facility, the culverts have concrete stop logs that can be removed to lower the reservoir to approximately elevation 3762. Riverbed elevations immediately downstream of the dam are approximately 3730.

J.C. Boyle reservoir contains a relatively small volume of sediment, located primarily immediately upstream of the dam structure. Except for a bridge crossing the reservoir on State Highway 66, no structures other than those associated with dam operations are in the immediate vicinity. Drawing the reservoir down to elevation 3780 could occur at anytime with only minor effects on the TSS levels downstream of Iron Gate Dam. The rate of reservoir drawdown to from 3780 to 3760 could be controlled partially by removal of the two concrete stop logs sequentially.

However, because of the lack of upstream structures drawdown rate would be controlled by limitations on dam structure safety. TSS effects of eroding material in the upper section of the reservoir would be small and trapping of suspended material in Copco 1 and Iron Gate reservoirs would essentially eliminate TSS from J.C. Boyle downstream of Iron Gate Dam.

The upper portion of the dam would be removed while the river is diverted through the culverts with a reservoir elevation near elevation 3760. After excavation of the upper portion of the dam, the lower section of the dam and most of the trapped sediment immediately upstream of the dam would be eroded by the river simultaneously with the drawdown of Copco 2 and Iron Gate reservoirs.

The lower section of the dam includes approximately 50,000 cubic yards of material. Because of the narrowness of the river channel most the sediment upstream of the dam is located in the river path and will be eroded as the lower part of the dam is removed by river erosion. Figure 44 shows the profile of the predam and current thalweg. As illustrated by this figure, most of the erodible sediment is location adjacent to the dam.

6.3.4.1.3. Dam Demolition

J.C. Boyle embankment dam contains approximately 125,000 cubic yards of material. Drawings indicate the material was taken from a borrow pit adjacent to the dam. This site would be used as the spoils site, the site to which all excavated and demolished material from the dam structures would be taken. To excavate the dam material the reservoir surface would be lowered to approximately elevation 3260. Approximately 75,000 cubic yards of dam material would be excavated using heavy construction equipment and removed to the dam material spoils site. The remaining dam structure would be eroded downstream along with the approximately 500,000 cubic yards of material behind the dam.

This event would be coordinated to take place simultaneously with the sediment erosion in Iron Gate and Copco 1 dams. Figure 43 shows the dam and the location of the borrow pit used for construction. Review of contemporary aerial photographs indicates that the borrow area is currently open space within the project boundaries.

Rate of removal of the embankment material would depend on the type and number of pieces of equipment used. The upper portion of the dam could be removed in 2 to 3 months using two large backhoes and approximately 20 trucks to excavate and haul the material.

Excavation could start any time after the reservoir was drawndown. If started in the autumn it could be completed before winter high flows began. To complete excavation and erosion of the lower portion of the dam within the duration of time for drawing down the two lower reservoirs at 1 foot per day, the upper portion would need to be excavated within 2 months of start of drawdown. During the remaining one month the lower portion of the reservoir and most of the sediment immediately upstream of the dam face would be eroded. Because of the relatively small volume of material in the dam overtopping the partially excavated dam caused by high river flows would not have severe consequences downstream.

Table 18 Excavating Equipment to Remove J. C. Boyle Dam

Item/ Equipment	Capacity	Rate CY/hour	Number of Units	Total Hours per Unit	Time Required Weeks
Mass Excavator	5 CY	185	2	340	8
Truck	12 CY	23.2	16	340	8
Dozer	300 H.P.		2	340	8
Compactor	Vibratory Roller	3000	2	340	8

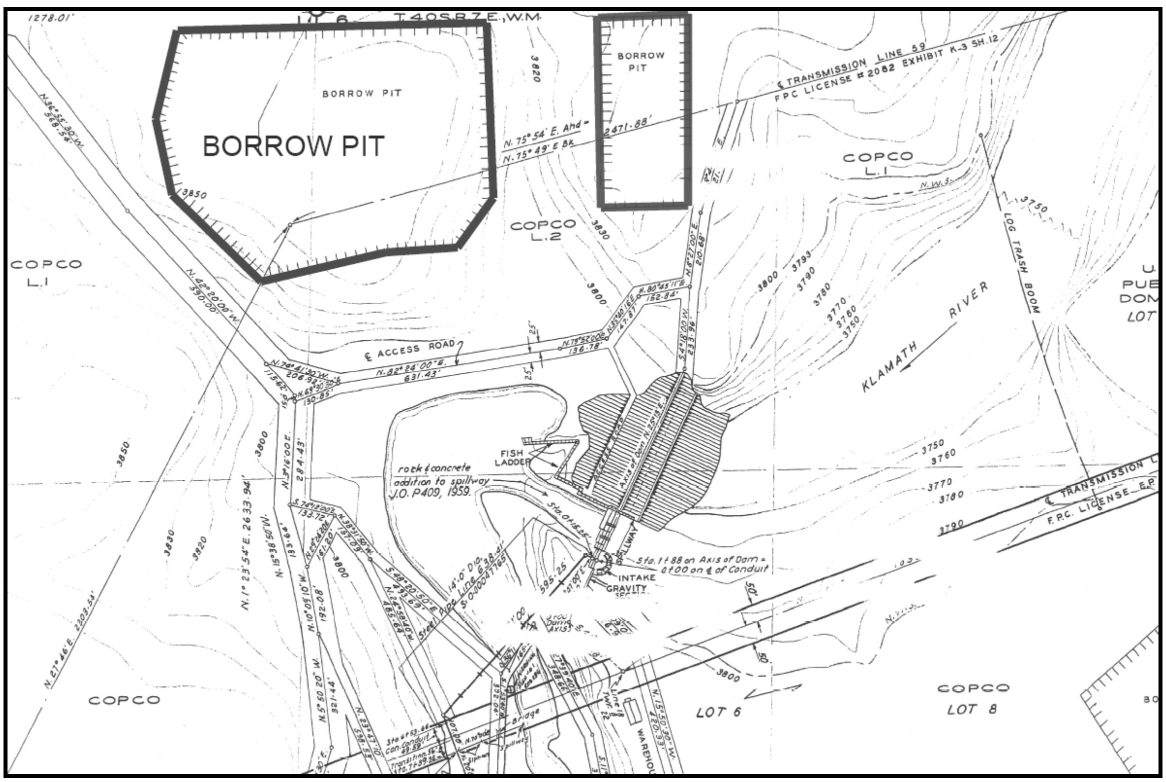

Figure 43 Plan of J.C. Boyle Dam and Borrow Pit

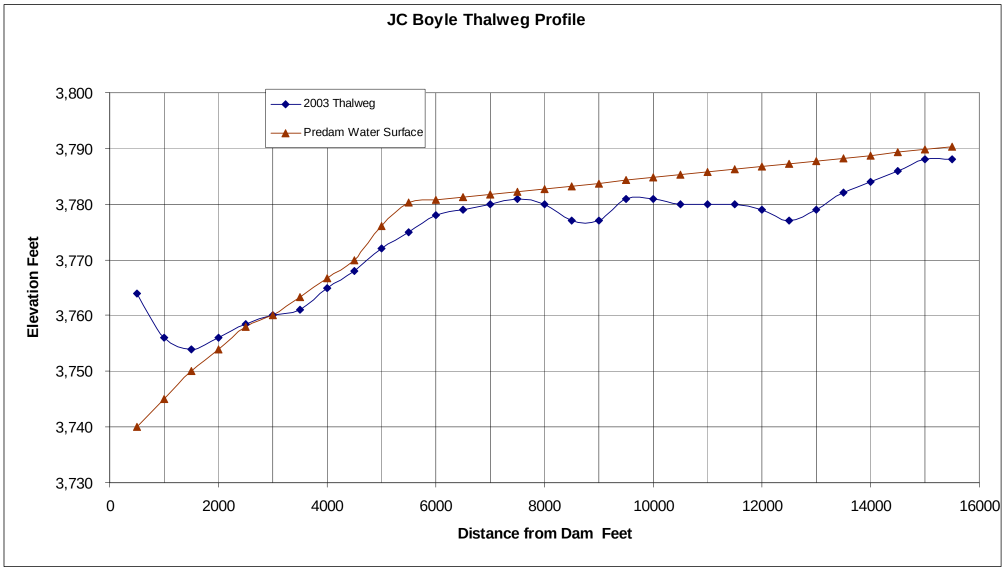

Figure 44 Profile of Sediment in J. C. Boyle Reservoir

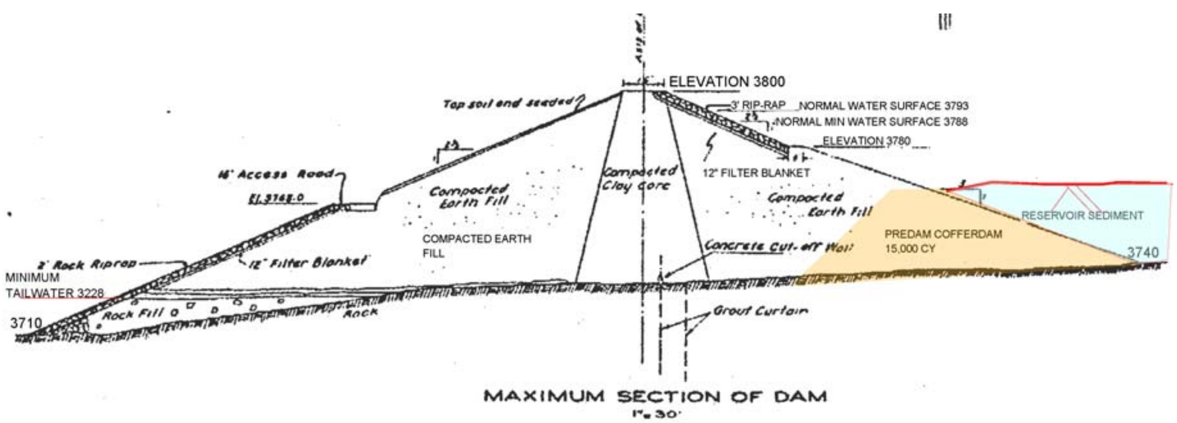

Figure 45 Section through J. C. Boyle Dam

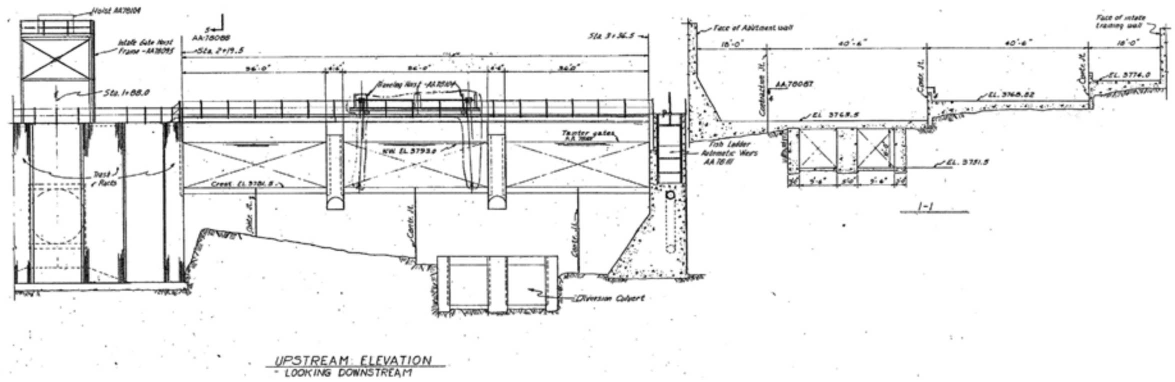

Figure 46 Section of J. C. Boyle Dam Looking Upstream

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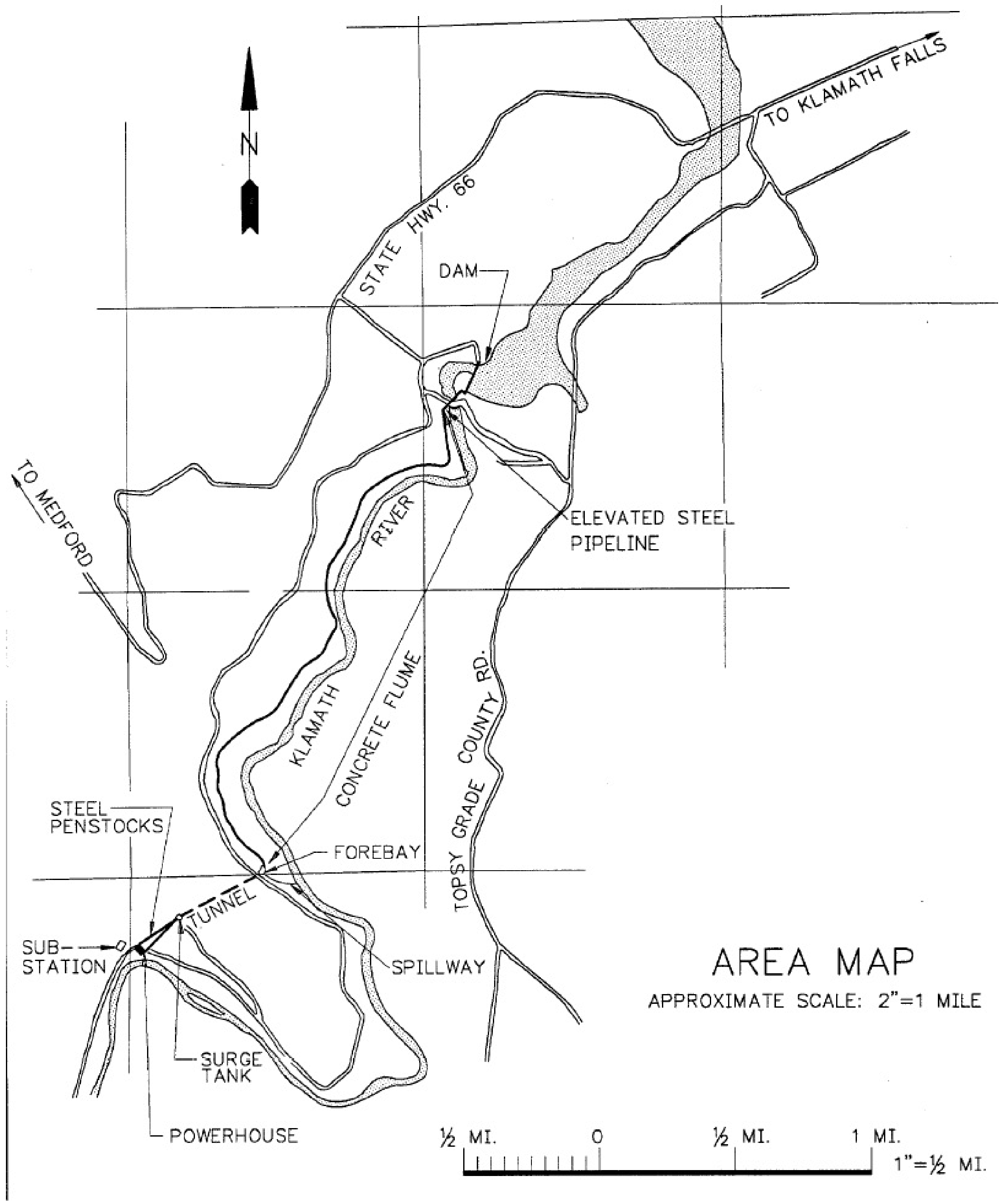

Figure 47 J. C. Boyle Facilities Locations

6.4. Water Quality

Water quality will be affected by the removal of the dams for all approaches to removal. Erosion of trapped sediment will greatly increase suspended sediment concentrations downstream of IG dam. The length of time and level of suspended sediment concentration will depend on the Klamath River flow and sequence of removal. Section 6.1.1 describes the effects of sediment erosion from reservoir drawdown in more detail. Other water quality issues such as dissolved oxygen and nutrients are beyond the scope of this investigation.

6.5. Water Use Downstream of Iron Gate Dam

Ninety-one water rights holders were identified. The largest two of these rights were held by PacifiCorp. Eight of the water rights were held by the California State Water Resources Control Board. Klamath River Country Estates Owners Association Inc. holds two water rights that use pumps to remove water between March 1st and October 1st.

The remaining water rights holders are either unidentified or private non corporate landowners. All but 16 of the 91 water rights are listed as pumped diversions. Of these non-pumped diversions 10 are either PC or SWRCB rights. The remaining 6 private were non-corporate holders. They have rights to divert between 8.91 and .11 cfs between the months of April and October.

No use for any of the rights was listed. Figure 48 shows the location of the water rights.

6.6. Affects on Users

None of the water rights found show surface water diversion for domestic water supplies or industrial processes. These two uses would be the highest quality water. Even with dams in place suspended sediment concentration from natural process downstream of the dam would tend to be relatively high and would discourage surface water use for these categories.

Much of the use immediately downstream of the dams is for irrigation. Irrigation use withdrawals would not be likely if periods of high TSS from dam removal were to occur after the growing season. The timing and sequence of the breach of the dams will determine whether and how temporary water quality changes affect downstream users.

6.6.1. Water Quality Protection

Protection of water uses downstream may be required. It is beyond the scope of this investigation to determine exact protection measures. No specific use information was developed for this report. However, based on number, type, and location of users feasibility level costs were developed based on water quality measures typically proposed for other similar projects.

- Domestic water supplies including affected wells
    - New well away from river
    - Filtration system
    - Flocculation, Chlorination, and or Ozination
    - Bottled water for short term low volume use
- Fisheries
    - New hatchery or off river rearing
    - Reintroduction programs
    - Side channel development
- Irrigation
    - Filtration, flocculation
    - Well
    - Winter reservoir removal
- Fire protection
    - Fund for equipment replacement as required
- Live stock watering –same as irrigation

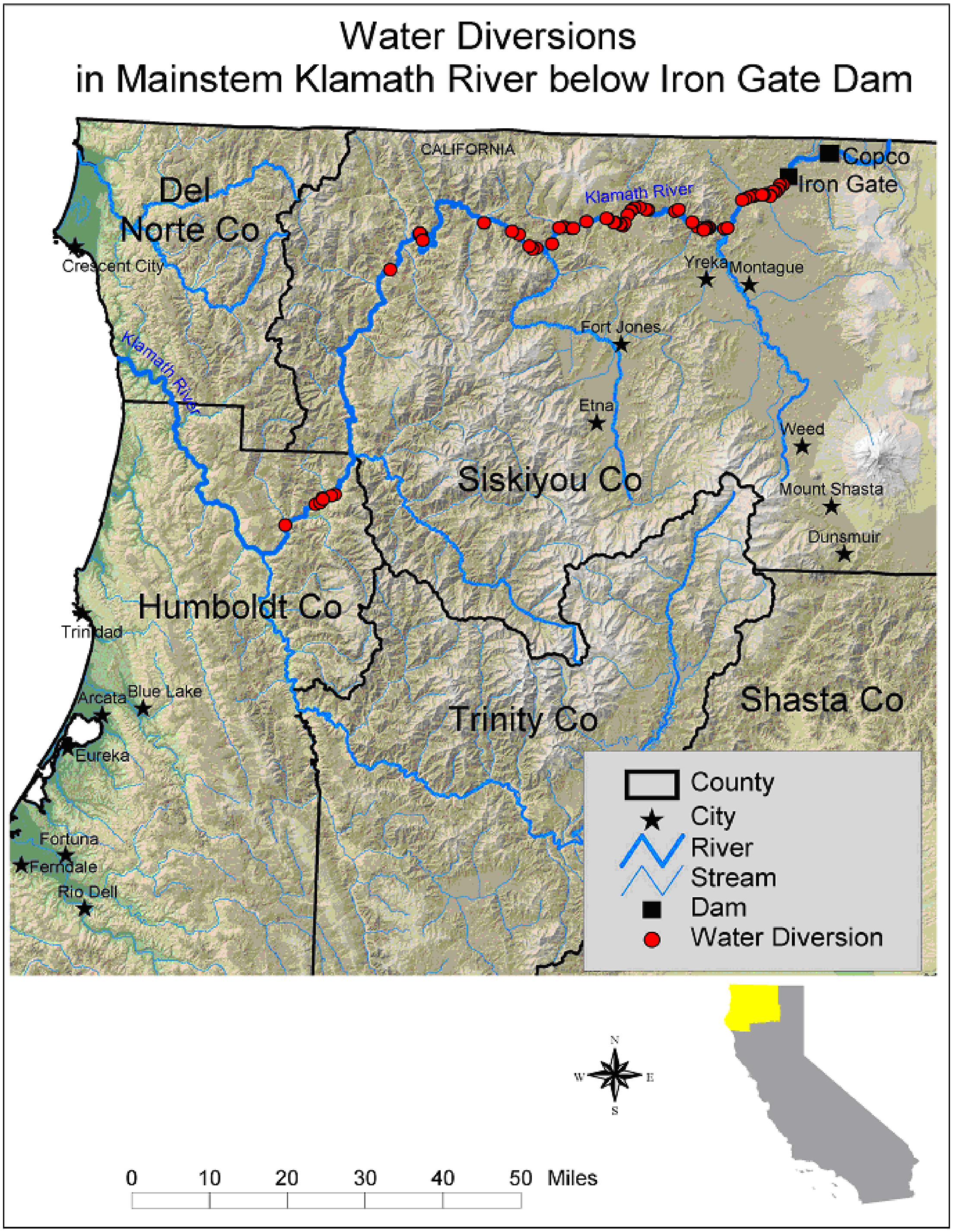

Figure 48 Locations of Water Diversions on the Klamath River

6.7. Cost Estimates

Cost estimates were developed for the cost of demolishing, removing, and stabilizing the elements of the dam projects that affect the free flow of the Klamath River. Assumptions made for the following cost estimates were that earthen embankment dams would be removed down to the predam riverbed surface. Concrete structures that may deteriorate and present the possibility of a future safety hazard would be demolished, removed to a stable storage location for recycling or to a permanent disposal location.

Steel structures would be demolished and recycled. Reinforcing steel would be recycled. No cost benefit was taken for recycled products and none of the costs for recycling, such as crushing concrete or hauling steel were included.

Most of the unit costs and production capabilities for equipment included in the estimate were taken from RS Means *Heavy Construction Cost Data*, 20th Annual Edition, 2006 (Means). Unit costs for specialty items that Means either does not list or has a very small data base for were derived from work done at other dam removal projects including the Elwha River Ecosystem Restoration Project and the Condit Dam Removal Project. This includes the unit costs for concrete demolition using drill and blast techniques, which Means lists at a much lower cost than other more specific sources, and revegetation work for exposed sediment, which has few specific precedents.

Access to construction plans was not available for much of the generating and transmitting equipment. Costs for substation removal are included in each cost estimate. A cost for environmental clean up around the power house and generating facilities is also included though no knowledge is available and no investigation of the facilities has been conducted[4]. Past dam removal investigations have discovered small areas associated generally with transformers that have required environmental clean up. Further cost analysis will be required when all project documents are available for inspection.

[4] The Upland Study revealed one location where contamination from powerhouse activities exists. No further study was conducted. Costs were included to cover other potential locations.

Table 19 J. C. Boyle Removal Cost Estimate

J. C. Boyle Cost Estimate				
Item	**Quantity**	**Unit**	**Unit Cost**	**Total**
Mobilization	1	LS	$ 525,000	$ 525,000
Construction Management Facilities	6	Months	$ 5,000	$ 30,000
Preparation of Disposal Sites	45	Acres	$ 2,000	$ 90,000
Upgrade Roads	1	LS	$ 5,000	$ 5,000
Excavate Material	110,000	CY	$ 3.50	$ 385,000
Haul Material 1 Mile	110,000	CY	$ 2.00	$ 220,000
Compact and Grade Material	110,000	CY	$ 1.00	$ 110,000
Demolish Spillway Concrete	3,000	CY	$ 210	$ 630,000
Demolish Structural Concrete in Dam	500	CY	$ 400	$ 200,000
Environmental Mitigation at Disposal Site	16	Acres	$ 5,000	$ 80,000
Remove Fish Ladder	500	CY	$ 400	$ 200,000
Remove Spillway and Gates	1	LS	$ 50,000	$ 50,000
Remove Intake Structure	1	LS	$ 50,000	$ 50,000
Subtotal				**$ 2,575,000**
Demolish Outer Canal Wall	10,000	CY	$ 400	$ 4,000,000
Load and Haul Material 10 Miles Round Trip	10,000	CY	$ 18	$ 180,000
Remove and Salvage Steel	800,000	lbs	$ 1.00	$ 800,000
Substation Removal	1	LS	$ 150,000	$ 150,000
Reservoir Hydroseeding	300	Acres	$ 1,500	$ 450,000
Remove Powerhouse and Generation Facilities	1	LS	$ 150,000	$ 150,000
Subtotal				**$ 6,725,000**
Contingencies		25%		$ 1,681,250
Total				**$ 8,406,250**

Table 20 Copco 1 Removal Cost Estimate

Copco 1 Cost Estimate				
Item	**Quantity**	**Unit**	**Unit Cost**	**Total**
Mobilization/Demob	1	LS	$ 1,200,000	$ 1,200,000
Upgrade Roads	1	LS	$ 50,000	$ 50,000
Tower Crane and Operator	6	Months	$ 55,000	$ 330,000
Construction Management Facilities	6	Months	$ 5,000	$ 30,000
Disposal Site Preparation	4	Acres	$ 25,000	$ 100,000
Drill and Blast Dam Concrete	35,000	CY	$ 210.00	$ 7,350,000
Haul Material	35,000	CY	$ 3.00	$ 105,000
Short Term Erosion Control	100	Acres	$ 1,000.00	$ 100,000
Hydroseed and Revegetation	800	Acres	$ 1,500.00	$ 1,200,000
Compact and Grade Material	35,000	CY	$ 2.00	$ 70,000
Remove Spillway and Gates	1	LS	$ 50,000	$ 50,000
Remove Intake Structure	1	LS	$ 50,000	$ 50,000
Low level Outlet Tunnel	800	CY	$ 650	$ 520,000
Roller Gate Flow Control Structure	1	Ea	$ 1,200,000	$ 1,200,000
Subtotal				**$ 12,355,000**
Demolish Powerhouse Structure	11,000	SF	$ 25.00	$ 275,000
Remove and Recycle Penstock	1	LS	$ 25,000	$ 25,000
Substation Removal	1	LS	$ 100,000	$ 100,000
Environmental Cleanup	1	LS	$ 100,000	$ 100,000
Subtotal				**$ 12,855,000**
Contingencies		25%		$ 3,213,750
Total				**$ 16,068,750**

Table 21 Copco 2 Dam Removal Cost Estimate

Copco 2 Cost Estimate				
Item	**Quantity**	**Unit**	**Unit Cost**	**Total**
Mobilization/ Demob	1	LS	$ 224,000	$ 224,000
Upgrade Roads	1	LS	$ 10,000	$ 10,000
Drill and Blast Concrete	6,000	CY	$ 210	$ 1,260,000
Temporary Diversion Cofferdam	1	LS	$ 50,000	$ 50,000
Plug Tunnels	400	CY	$ 500	$ 200,000
Demolish and Fill Canal	15,000	CY	$ 20.00	$ 300,000
Disposal Site Preparation	1	LS	$ 25,000	$ 25,000
Haul Material	6,000	CY	$ 13.00	$ 78,000
Environmental Prep at Disposal Site	1	Acres	$ 25,000	$ 25,000
Compact and Grade Material	6,000	CY	$ 2.00	$ 12,000
Remove Spillway and Gates	1	LS	$ 15,000	$ 15,000
Remove Structural Steel	1	LS	$ 10,000	$ 10,000
Remove Intake Structure	1	LS	$ 50,000	$ 50,000
Subtotal				**$ 2,259,000**
Substation Removal	1	LS	$ 150,000	$ 150,000
Environmental Cleanup	1	LS	$ 100,000	$ 100,000
Remove Penstock	1,000	FT	$ 35.00	$ 35,000
Remove Powerhouse Facilities	1	LS	$ 150,000	$ 150,000
Subtotal				**$ 2,694,000**
Contingencies		25%		$ 673,500
Total				**$ 3,367,500**

Table 22 Iron Gate Dam Removal Cost Estimate

Iron Gate Dam Cost Estimate				
Item	**Quantity**	**Unit**	**Unit Cost**	**Total**
Mobilization/Demob	1	LS	$1,470,000	$ 1,470,000
Operation/Management Facilities	1	LS	$ 100,000	$ 100,000
Tunnel Liner Modification	1	LS	$1,000,000	$ 1,000,000
Flow Gate Control Modifications	1	LS	$1,000,000	$ 1,000,000
Dam Material Disposal Site Preparation	40	Acres	$ 2,000	$ 80,000
Haul Road Upgrade	2	Miles	$ 25,000	$ 50,000
Load and Haul Surface Riprap	175,000	CY	$ 7.50	$ 1,312,500
Excavate and Load Dam Mat'l	925,000	CY	$ 1.43	$ 1,322,750
Remove Cofferdam	25,000	CY	$ 15.00	$ 375,000
Temporary Sheet Pile Cofferdam	3,200	SF	$ 25.00	$ 80,000
Remove Concrete Cutoff Wall	1,500	CY	$ 350.00	$ 525,000
Haul Material 12CY Truck 1/4 Mile Haul	250,000	CY	$ 3.50	$ 875,000
Haul Material 12 CY Truck 1.25 Mile Haul	675,000	CY	$ 4.15	$ 2,801,250
Grade Material	925,000	CY	$ 1.62	$ 1,498,500
Compact	925,000	CY	$ 0.35	$ 323,750
Short Term Erosion Control	100	Acres	$ 1,000	$ 100,000
Hydroseed and Revegetation	800	Acres	$ 1,500	$ 1,200,000
Remove Fisheries Facilities	40,000	SF	$ 25	$ 1,000,000
Demolish Dam Tunnel Gate	4,000	CY	$ 400	$ 1,600,000
Subtotal				**$ 16,713,750**
Substation Removal	1	LS	$ 150,000	$ 150,000
Remove Penstock	1	LS	$ 50,000	$ 50,000
Environmental Cleanup	1	LS	$ 100,000	$ 100,000
Remove Powerhouse Facilities	1	LS	$ 300,000	$ 300,000
Subtotal				**$ 17,313,750**
Contingencies		25%		$ 4,328,438
Total				**$ 21,642,188**

Table 23 Water Quality Protection Removal Cost Estimate

Water Quality Protection				
Item	**Quantity**	**Unit**	**Unit Cost**	**Cost**
New Drilled Well and Water Supply	40	Each	$ 40,000	$ 1,600,000
New Hatchery Facilities	1	Each	$ 4,500,000	$ 4,500,000
Off Stream Rearing	1	LS	$ 1,000,000	$ 1,000,000
Hatchery Water Supplies	1	LS	$ 2,000,000	$ 2,000,000
Subtotal				**$ 9,100,000**
Contingencies			40%	$ 3,640,000
Total				**$ 12,740,000**

Table 24 Summary of Costs

Total Cost		
Item		**Cost**
Iron Gate Dam Removal		$ 21,642,188
Copco 2 Dam Removal		$ 3,367,500
Copco 1 Dam Removal		$ 16,068,750
J. C. Boyle Dam Removal		$ 8,968,750
Total Structure Removal Cost		**$ 50,047,188**
Water Quality Protection		$ 12,740,000
Subtotal		**$ 62,787,188**
Construction Management	15%	$ 9,418,078
Engineering and Permitting	25%	$ 15,696,797
Total		**$ 87,902,063**

7. Conclusions

GEC conducted an investigation of the feasibility of removing four dams on the Klamath River. The investigation included analysis of the chemistry, grain size, and volume of sediment trapped in the reservoirs. It also included a feasibility investigation of sediment management and dam removal approaches. The study identified a feasible approach for dam removal and sediment management. The study also revealed that additional investigation would be required to refine this strategy.

The investigation concluded:

1. Approximately 20.4 million cubic yards of sediment is trapped in the four lower most reservoirs of the Klamath River Project. Most of the sediment, 78% of the total for all dams, is smaller than silt sized material.
2. Sediment located within the reservoirs poses no contamination risk if eroded downstream. With the exception of one location in Copco 1, none of the sediment tested exceeded PSDDA screening level criteria. That location contained volatile hydrocarbons that easily evaporate when exposed to air.
3. Predredging sediments would fail to substantially reduce suspended sediment levels caused by reservoir drawdown, would substantially increase project cost, and may not be feasible due to dredging depth limitations and lack of spoils sites.
4. Eroding sediment in the path of the predam river channel is a feasible approach to removing sediment following dam removal.
5. Erosion of sediment would occur as the reservoirs are drawn down. The small sediment particle size and high water content of the sediment will result in nearly instantaneous erosion of sediment in the path of flowing water. Once eroded, sediment would become suspended in the water column and remain in suspension in the river downstream of Iron Gate.
6. The highest concentrations of suspended sediment will result from eroding reservoir sediments in the predam river channel. Following drawdown, additional sediment will erode from newly exposed overbank surfaces along the sides of the predam river channel. Surface sediment erosion can be minimized by revegetation and sediment stabilization actions taken after reservoirs are drawn down.
7. The duration and intensity of suspended sediment are closely related. Shorter durations result in higher suspended sediment concentrations and vice versa. The objective of this approach to dam removal and reservoir drawdown was to propose a feasible means of reducing the duration of suspended sediment levels resulting from reservoir drawdown and dam removal.
8. A more rapid drawdown would: 1) shorten the duration of Total Suspended Sediment (TSS) resulting from river channel formation; 2) increase short term sediment erosion due to slope instability, and; 3) decrease long term TSS resulting from bank erosion caused by post-drawdown high flow events.

9. Drawing down the reservoirs concurrently results in the shortest duration of highly elevated suspended sediment concentrations immediately downstream of Iron Gate Dam.

10. Limits on the rate of drawdown determine the minimum duration of highly elevated suspended sediment concentrations immediately downstream of Iron Gate Dam. A rate of 1 foot per day drawdown would result in highly elevated suspended sediment concentrations lasting approximately 120 days. A more rapid drawn down would reduce the duration of elevated suspended sediment. A preliminary investigation of dam stability indicates that Iron Gate reservoir could be safely drawndown at a rate of 3 feet per day, resulting in highly elevated suspended sediment concentrations lasting approximately 40 days. More study regarding dam safety and slope stability is required to determine drawdown rate limits.

11. Sediment management approaches using higher reservoir drawdown rates may initially induce larger volumes of sediment to erode as sediment slopes fail. High drawdown rates may cause sediment on steeper slopes to flow into the river channel as reservoirs are drawndown. Consequently, less sediment remains in the reservoirs after drawdown. Less sediment remaining near the newly formed channel after drawdown would likely result in lower TSS levels subsequent to reservoir drawdown, due to the absence of material available for erosion caused by subsequent peak high flow events.

12. Iron Gate and J. C. Boyle dams have existing low level outlet facilities that would be used to lower reservoirs. Copco 1 Dam would require construction of a new low level outlet through the base of the dam. Iron Gate and Copco 1 would require new gated outlets to control drawdown rates.

13. All dams could be removed using conventional construction equipment. Material from dam demolition would be permanently stabilized at locations near the dam on property located within the project boundaries. Many of the materials salvaged from the dam removal would be available for sale or reuse.

14. Iron Gate Dam removal would be accomplished in low flow periods. High flows could overtop a partially demolished Iron Gate Dam if demolition were to occur in winter months. Copco 1 is a concrete dam that could survive overtopping if partially removed. J. C. Boyle dam contains only a relatively small volume of material that would be removed in low to moderate flows. Overtopping a partially removed J. C. Boyle Dam would not present a safety hazard.

15. Some protection for downstream water users may be required. A complete investigation of water quality protection was not undertaken. Water quality protection measures are feasible for downstream water users.

16. Dam removal and associated activities would take approximately 2 years to complete.

17. The cost for removing the dams including engineering, permitting, and construction management would be approximately $88 million.

8. References

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Appendix A

Upland Contaminant Source Study

Appendix B

Klamath Sediment Study
Sediment Sampling Plan

Appendix C

Sediment Grain Size and Volume Analysis

Appendix D

Summary Report, Sediment Sampling
Shannon & Wilson

Appendix E

Analytical Resources, Incorporated
Chemical and Grain Size Analysis Results

Appendix F

Aquatic Species Use Table

Appendix G

Water Users List

Appendix H

Stillwater Sciences Review of DREAM Model Study Results Memo to GEC

Appendix I

Summary of Project Features

Appendix J

Additional Studies Required to Complete Dam Removal Investigation

Appendix K

Preliminary Assessment Of Slope Stability

Iron Gate And Copco Dams And Reservoirs, Under Rapid Drawdown