

SEDIMENT BEHAVIOR ANALYSIS REPORT

Table 3 and Table 4 show average and high flow conditions for the river. A new average daily flood frequency analysis was conducted based on the highest flows for each of 81 years of record using Log Pearson Type III (LP3) distribution techniques. Table 5 presents the flood levels for various return frequencies. The larger record set primarily affects the size of the higher frequency flows in the 2 to 10 year recurrence frequency range. Figure 15, a plot of ranked high flows for each year and the flows predicted by the LP3 analysis, shows good correspondence between predicted flows and the data set.

Table 3 illustrates the average range of flows that occur in the winter months of the year immediately after dam removal activities begin and before major construction activities are anticipated to end.

Table 3. Average Daily Mean, Maximum, and Minimum Flows from October to April

Description	Avg. Daily Flow - cfs
Maximum Average Flow	1,963
Mean Average Flow	1,214
Minimum Average Flow	568

Table 4. Flood Frequencies from USGS 1985 Report

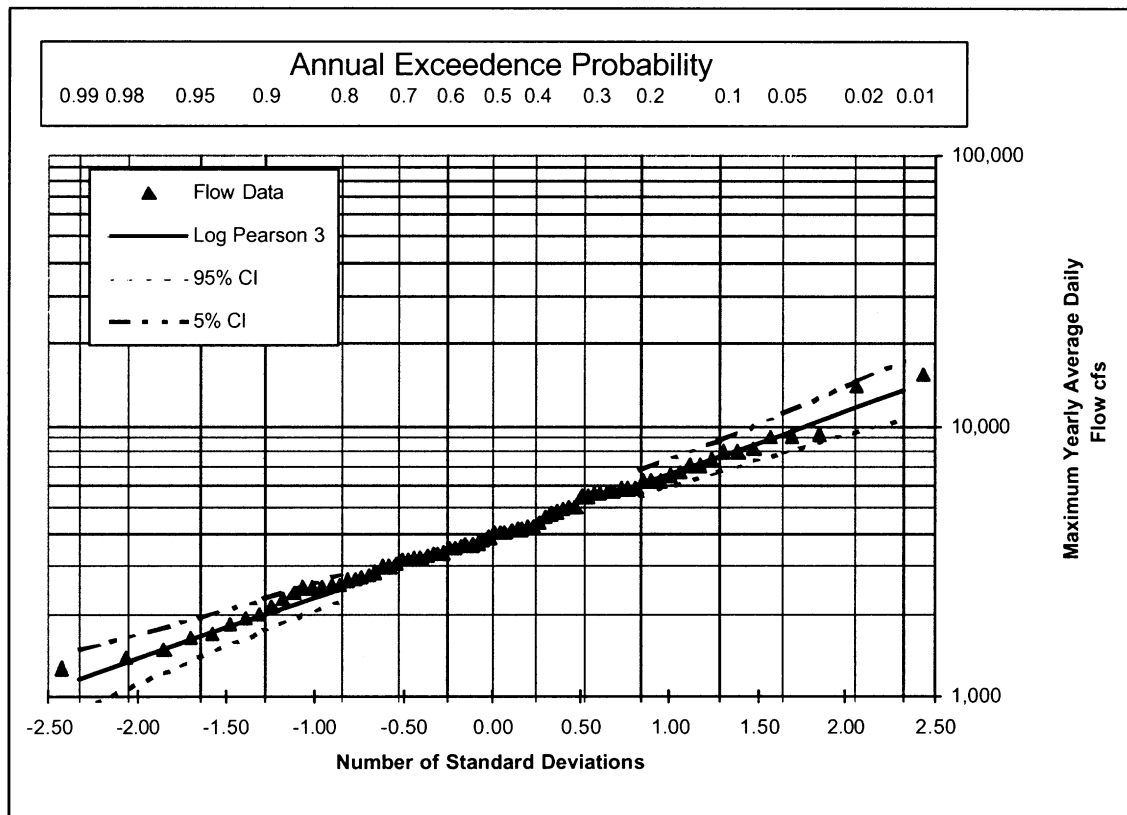
<i>Flood Frequency Data⁴</i>	
Recurrence Interval of Flood	Avg. Daily Flow - cfs
100 Year	13,600
50 Year	12,000
10 Year	8,500
5 Year	7,000
2 Year	4,700

⁴ *Final Environmental Impact Statement*, p 3-11, Table 3-4

SEDIMENT BEHAVIOR ANALYSIS REPORT

Table 5. Revised Yearly Flood Frequency

<i>Flood Frequency Data</i>	
Recurrence Interval of Flood	Avg. Daily Flow - cfs
100 Year	13,400
50 Year	11,600
10 Year	7,700
5 Year	6,100
2 Year	3,900

**Figure 15. Yearly Flood Frequency**

A flow duration curve covering all average daily flow records from WY 1912 through WY 2001 is shown in Figure 16 below.

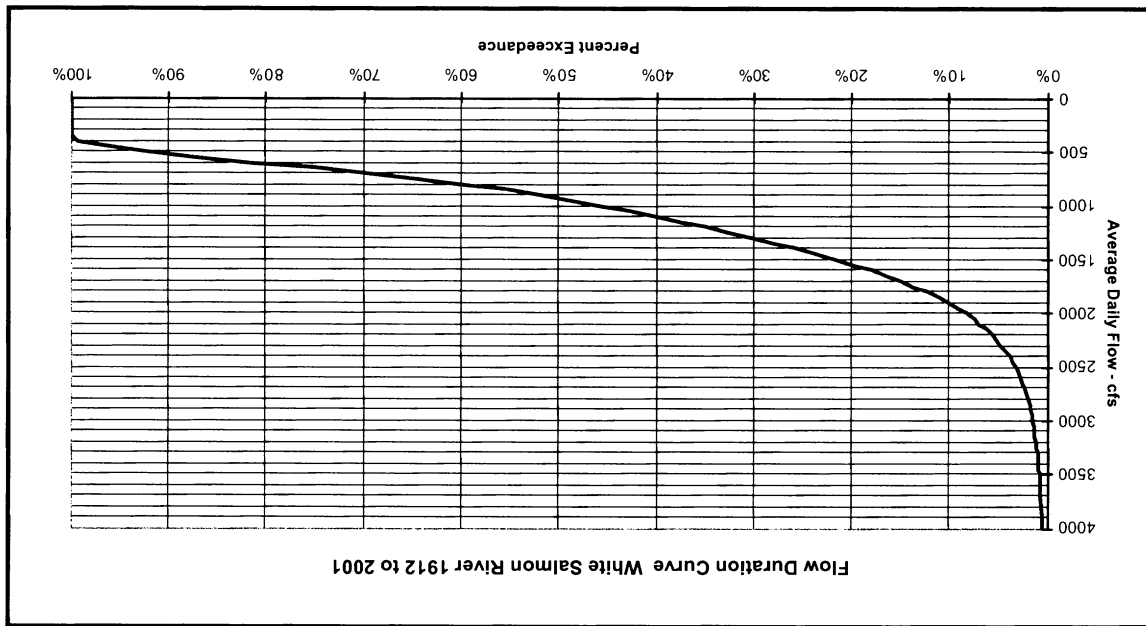


Figure 16. Flow Duration for White Salmon

3.1.3. PEAK STREAM FLOWS

The annual hydrograph for the WSR shows peaks occurring both in winter and spring months (Figure 14). The largest floods at this site generally occur between November and February when peak discharge is driven primarily by rain-on-snow. High flows occurring during these times commonly result from warm, wet frontal systems coming from the Pacific Ocean. These systems bring rainfall, warm temperatures, and high winds, and are capable of melting a large volume of snow in addition to the rainfall they deliver. Peak flows may occur for only a few hours. Most records available are for average daily flows. The USGS has also recorded instantaneous peak flow yearly maximums. Figure 17, below, shows the average daily and instantaneous peak flows. On average, the values of instantaneous peaks exceed average daily flows by an average of 60%.

However, in 1996 a flood destroyed the flashboards at the dam and released the top 8 feet of water from the reservoir causing the flow downstream of the dam to increase to over 45,000 cfs. The highest flows downstream of the dam from dam removal are anticipated to be approximately 11,000 cfs by comparison.

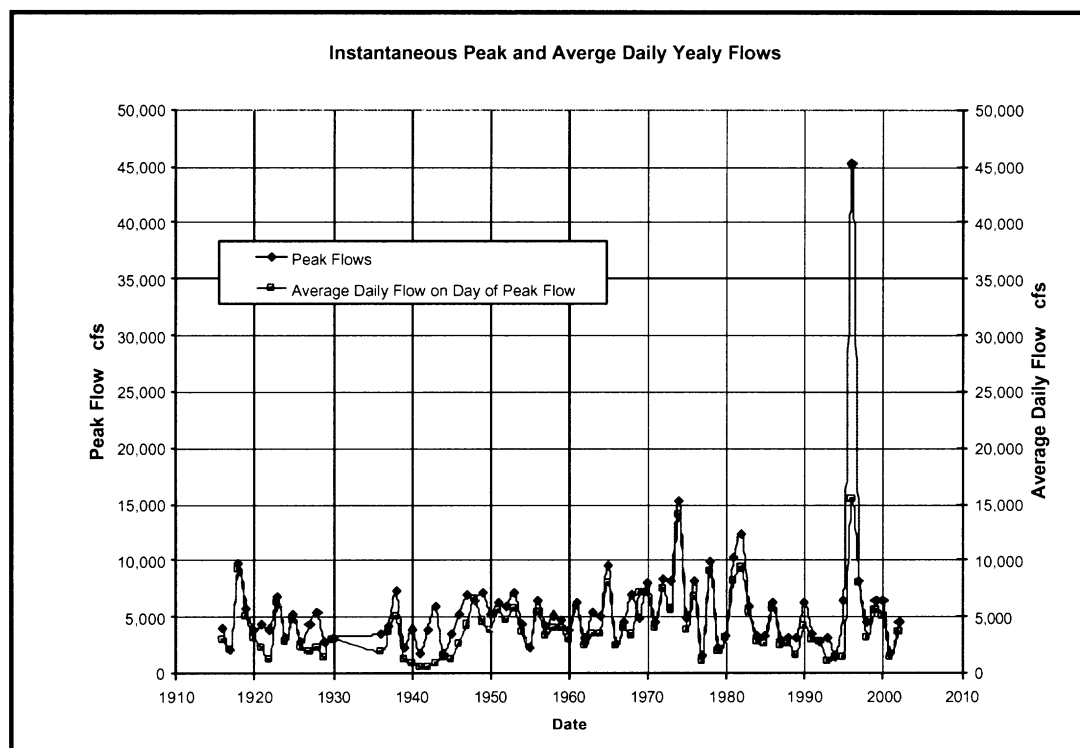


Figure 17. Instantaneous Peak Flows

SEDIMENT BEHAVIOR ANALYSIS REPORT

3.1.4. SEVEN DAY AVERAGE HIGH FLOWS

Daily records were averaged over seven days to determine peak seven-day average (7Q) flows for the period of record. Flows equal to or above the 7Q flow that occurs at a 10-year recurrent interval (7Q₁₀) are generally considered to be extreme conditions. To determine the recurrent intervals, the maximum 7Q for each year was determined and plotted using LP3 techniques. Results are shown below in Table 6.

Table 6. Seven-Day Average Flood Frequency

<i>Flood Frequency for Seven Day Average Flows</i>	
Recurrence Interval of Flood	Seven Day Average Daily Flow - cfs
100 Year	7,750
50 Year	6,890
10 Year	4,950
5 Year	4,100
2 Year	2,860

4. WSR RIVER SEDIMENT TRANSPORT

Two sets of turbidity data on the WSR were found. Both were very small data sets and neither extends the sampling at consistent intervals through an entire year. The U.S. Forest Service, assisted by the Underwood Conservation District, measured turbidity from grab samples taken infrequently over the period of late 1975 through late 1980 and 1992 through 1994⁵. Samples were taken in an upper watershed, many miles upstream of the dam, on the WSR.

Because this data set is small, gathered at random times, and gathered at various locations well upstream of the dam, it is not sufficient to represent conditions of the WSR as it flows into the reservoir.

USGS records for gage 14123500, just downstream of the Condit Dam, contain twenty-five recorded measurements of turbidity taken from September of 1978 through June of 1980. For nine of these records suspended sediment concentrations were also recorded. This data set is also too small to develop a relationship between flow, turbidity and TSS. Suspended sediment concentrations would be affected by the reduction of sediment in the water column at the reservoir.

USGS data is shown below in Figure 18. The small amount of data available from this site fit fairly well with predicted TSS based on analysis discussed in section 4.1, below. TSS predictions, based on the relationship developed in section 4.1 between flow and TSS, shows slightly higher values than measured TSS. This result would be expected because the reservoir captures some of the larger suspended particles and generally reduces TSS concentrations downstream of the dam.

Section 4.1 develops a relationship between suspended sediment concentrations and river flow.

⁵ Upper White Salmon Watershed Analysis, Mt. Adams Ranger District, Gifford Pinchot National Forest, United States Department of Agriculture, Forest Service, March 2000

SEDIMENT BEHAVIOR ANALYSIS REPORT

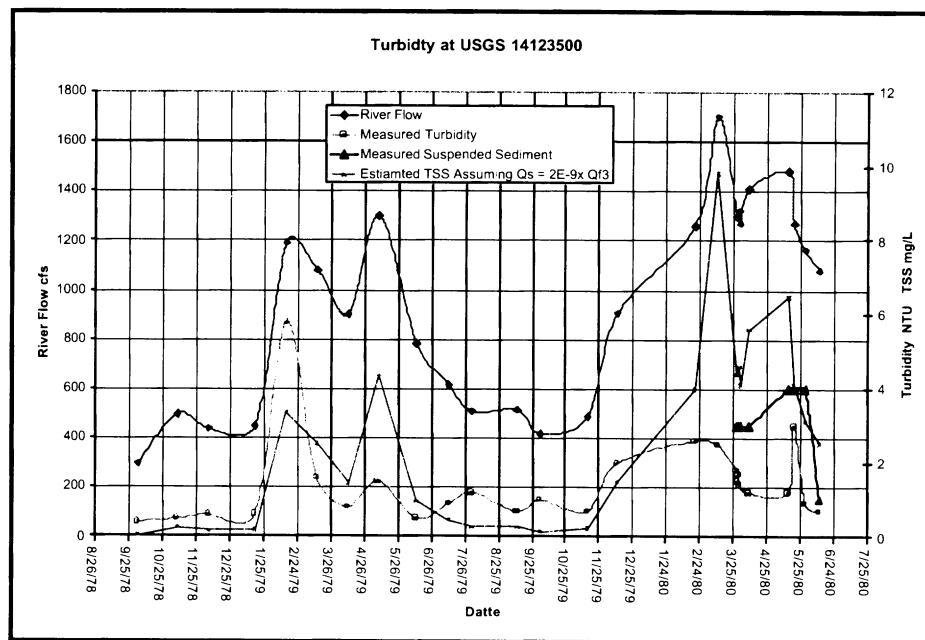


Figure 18. Turbidity Data near the Mouth of the WSR

4.1. SEDIMENT RATING CURVE

Sediment entering the WSR will depend on events such as embankment failures, fires, glacial rock flour from snow melt, timber harvesting, roads, and other activities in the watershed above the measurement point. Because of the variety of sources of sediment, prediction of sediment loads is very uncertain. Analysis techniques generally use relationships that show sediment flow related to river flow in the form $Q_s = a \times Q_w^b$, discussed further below. The relationship, known as a rating curve, provides a model for sediment flow variations when direct measurement of sediment flow data is not available.

The sediment-rating curve estimates the anticipated range of sediment flow in the WSR at the dam site from natural processes and human activities upstream of the dam. For the WSR, good data exists for the *quantity* of sediment and *flow* in the river over the 81 years of flow records. The size of the reservoir allows it to capture essentially all sediment particles greater than about .1 mm in diameter. Based on a bathymetric survey conducted in 1997 approximately 2.42 million cubic yards (mcy) of sediment had accumulated in Northwestern Lake since construction of the dam was finished in 1913.

Of the 2.42 mcy, approximately 1.84 mcy would have been transported as suspended sediment. About 80,000 cubic yards of sediment larger than 2 mm would probably have been transported as bedload in most flows. Approximately 500,000 cubic yards could have been transported as bedload or suspended sediment, depending on the flow.

No sediment transport measurements were made to determine the relationship between flow and sediment transport for this project. However, sediment measurements were made for a similar project on the Elwha River, in western Washington. The procedure used to develop the rating curve for sediment inflow to the dam site between 1913 and 1996 was similar to the procedure used to develop the rating curves for the Elwha Project⁶.

4.1.1. SEDIMENT TRANSPORT UPSTREAM OF DAM

A relationship between flow and sediment concentration was developed based on accepted generalized relationships between flow and sediment concentration and known river flow and sediment volumes. The general formulation for sediment concentration $Q_s = a * Q_w^b$ was used as the basis for sediment concentration as a function of flow, where a and b are constants to be determined from the available sediment volume and flow data, Q_s represents the sediment concentration in milligrams per liter, and Q_w represents river flow in cubic feet per second. Because the reservoir traps only a fraction of the fine material, the trapping efficiency of the reservoir, which varies as a function of river flow, was also considered when determining total sediment concentration.

Julien⁷ proposes the relationship $Q_s = 3.89 \times 10^{-6} \times Q_w^{1.3}$, where Q_s is expressed in mg/l. Trapping efficiency expressed as a percentage, P , can be expressed by the following formula,

$$P = \left[1 - \left(\frac{1}{e^{\left(\frac{1.055 L \omega}{V d} \right)}} \right) \right]$$

where L is the length of the basin, w is the settling velocity, d is the average depth of the basin, and V is the average velocity of the flow. Settling velocity was calculated as $w_s = g (r_1 - r) d_2 / 18m$ (Stokes).

The following values were used to estimate the volume of sediment in the reservoir.

- The average suspended sediment particle size used to estimate trapping efficiency was 0.03 mm.
- L was the length of the reservoir, 10,000 feet.
- V , the velocity of the water flowing through the reservoir was equal to Q divided by average depth, d , and width of the reservoir.

Using these relationships the coefficients, a or b , can be calculated if one of the variables is assumed. The frequency of each flow increment, between the lowest and highest

⁶ Elwha River Restoration Project, Washington Elwha Technical Series, Pn-95-9, *Sediment Analysis And Modeling Of The River Erosion Alternative*, U.S. Department Of Interior, Bureau Of Reclamation, Pacific Northwest Region, Boise, Idaho, August 1996

⁷ *Erosion and Sedimentation*, Peirre Y. Julien, Cambridge Press 1998, pg 235

SEDIMENT BEHAVIOR ANALYSIS REPORT

recorded flows in 50 cfs increments, was calculated based on average daily flow records. The volume of sediment trapped in the reservoir for each daily flow increment was calculated using the relationship shown in Figure 16 multiplied by the number of daily flows that had occurred over the life of the dam at that particular increment. The volume of sediment trapped by all flows over the life of the dam up to the time of the bathymetric survey was summed to produce the total volume predicted by the equation.

The sediment-flow relationship predicts a suspended sediment concentration in milligrams per liter (mg/l) for a particular value of river flow. The concentration in mg/l was converted to sediment weight deposited for each flow increment. Weight was converted to volume and compared to the volume of suspended sediment. Coefficients, a and b, were varied until predicted volume equaled trapped volume.

The power coefficient, b, chosen was similar to that used for development of a rating curve for sediment on the Elwha River⁸. The Elwha River has a similar upstream flow source (glacier) and is in a similar geologic region. In addition, the Elwha curve was based on measured sediment flows. Sediment weight was taken from the geotechnical report conducted for the 1998 R. W. Beck Report for the various sized particle classifications.

Figure 19 shows the results of the analysis. Figure 20 shows predicted TSS for an average year and Figure 16 shows flow frequency used for the analysis. Two separate relationships were developed, one for suspended sediment and one for bed load. Both are shown in Figure 19.

⁸ Elwha River Restoration Project, Washington, Elwha Technical Series, Pn-95-9, *Sediment Analysis And Modeling Of The River Erosion Alternative, Chapter V/II*, U.S. Department Of Interior, Bureau Of Reclamation Pacific Northwest Region, Boise, Idaho August 1996

SEDIMENT BEHAVIOR ANALYSIS REPORT

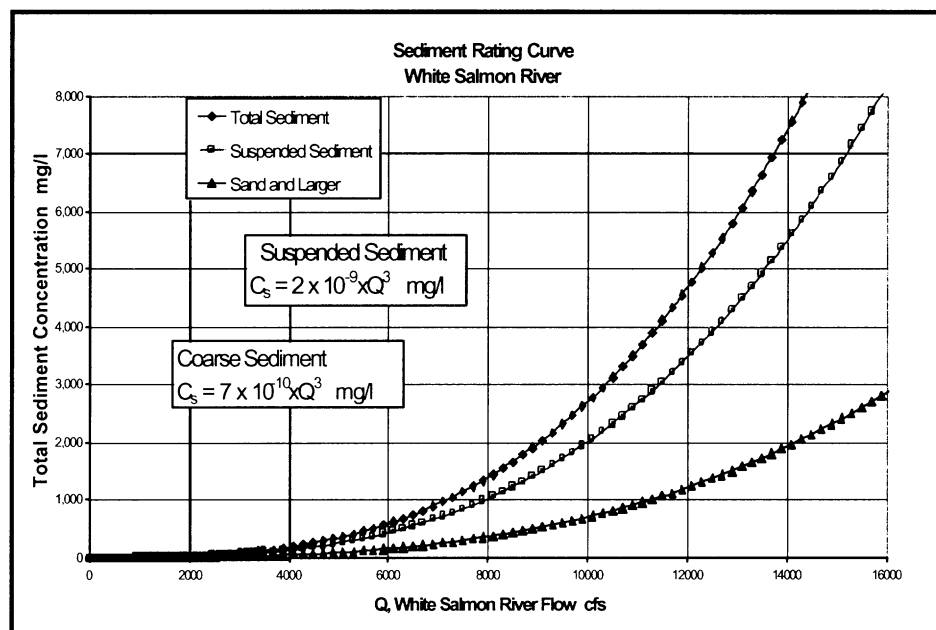


Figure 19. Sediment Rating Curve for White Salmon River U/S of Condit Dam

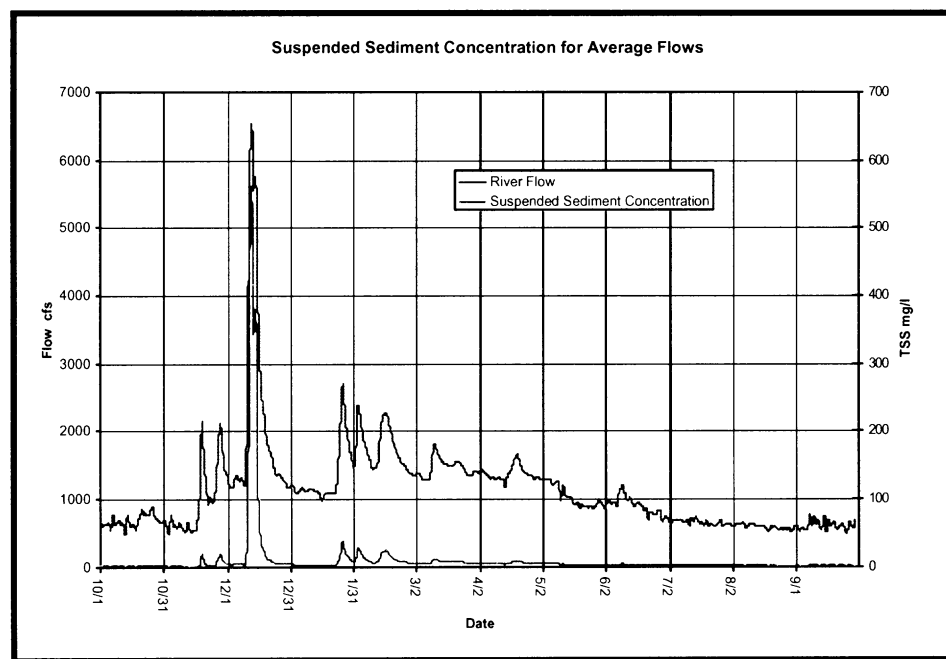


Figure 20. Suspended Sediment Concentrations for Average Year

4.2. TURBIDITY VERSUS TOTAL SUSPENDED SEDIMENT CONCENTRATIONS

Erosion of the reservoir sediments will increase TSS concentrations in the WSR and CR downstream of the reservoir after dam removal. Regulatory requirements regarding water quality, however, are generally tied to turbidity levels rather than TSS levels. Turbidity is generally measured in nephelometric turbidity units (NTU) and TSS is generally reported in either parts per million (ppm) or in milligrams per liter (mg/L). At low concentrations ppm and mg/L are essentially equal.

Two approaches were employed to develop the relationship between TSS and turbidity. The first involved taking a sample of material from the reservoir to use in constructing a test for both TSS and turbidity simultaneously in a laboratory on the same material. The limitation of this type of test is the inability of the laboratory environment to actually replicate activity in the river.

As sediment moves down the river it is entrained in an aerated environment. Because turbidity measurement relies on light measurement techniques, changes in the color of suspended sediment can change the relationship between TSS and turbidity. This is especially true for sediment that contains organic material, such as the sediment in the reservoir. Sediment in layers beneath the surface may be in an anoxic condition. Oxidation in the water column can, then, have an effect on the relationship between TSS and NTU readings for a given concentration of suspended sediment.

Laboratory analysis was conducted primarily due to a lack of available data regarding the historic relationship between TSS and NTU in the CR. Subsequent to the laboratory analysis a large number of simultaneous suspended sediment and turbidity readings on the CR were obtained from the USGS at several locations downstream of Bonneville Dam. Both approaches are presented below.

4.2.1. LABORATORY ANALYSIS

An analysis of the relationship of turbidity as measured in NTU and suspended sediment measured in ppm was conducted. North Creek Analytical, Inc. of Beaverton, Oregon, developed the relationship using sediment from Northwestern Lake and CR water. Results of their analysis are contained in Section 7.5

To develop a relationship, expressed as a formula for converting TSS in ppm to NTU, sediment from the reservoir was mixed with water and the suspended portion was removed and analyzed to determine concentrations in ppm. Suspended sediment concentrations were calculated based on known sediment weights and increased incrementally to produce a series of sediment concentrations. Turbidity, measured in NTU, was recorded for each known concentration to develop the curve shown in Figure 21.

Two sets of data were developed. In the first set, only sediment smaller than 0.1 mm was used. Subject to limitation discussed above, this represents the conditions in the

Bonneville Pool after mixing of the WSR and CR is complete. No particle greater than .1 mm in size coming from the WSR is expected to remain in suspension.

Downstream of the Bonneville Dam particles from Condit Dam removal that remain in suspension will be primarily silt and clay. Particles smaller than 62 microns (.0624 mm) are classified as silt and those less than 4 microns are classified as clay. Most clay-sized particles will stay in suspension throughout the river system. Another laboratory analysis was developed using only silt and clay particles. Figure 22 shows the results for suspended particles smaller than 6 microns.

For the larger sized particles (which will settle out in and above Bonneville Pool) the value for NTU is approximately 13% higher than the corresponding value of TSS expressed in ppm. Downstream of the Bonneville Dam only the finest particles will stay in suspension. When only very fine particles are used in the correlation the ratio of weight to particle surface area decreases and the relationship between NTU and ppm changes as illustrated by the differences between Figure 21 and Figure 22. For very fine particles, in this case those smaller than 6 microns or essentially silt-sized material, NTU readings were 2.8 times as large as sediment concentrations expressed in ppm.

In general, NTU is a less reliable means of determining suspended sediment concentrations because readings can be influenced by temperature, dissolved material, and sediment coloration, none of which are related to the weight of suspended sediment.

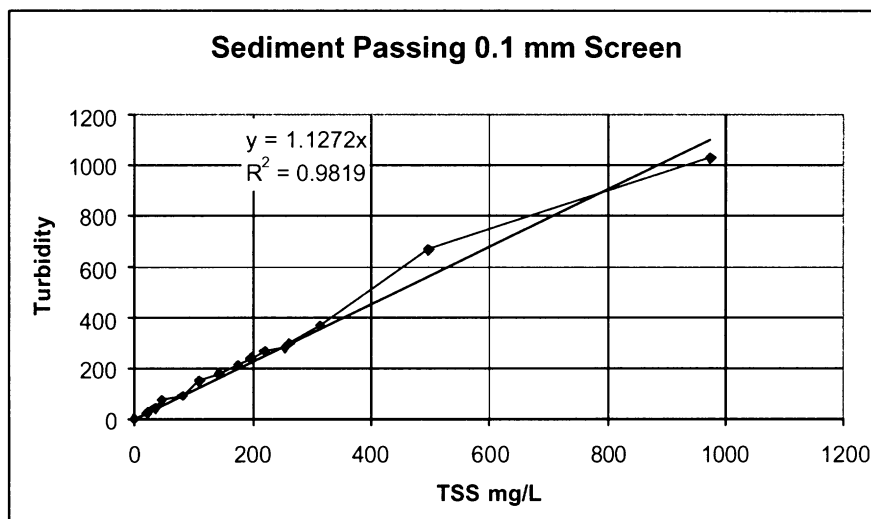


Figure 21. Turbidity vs. Suspended Sediment - .1 mm and Smaller

SEDIMENT BEHAVIOR ANALYSIS REPORT

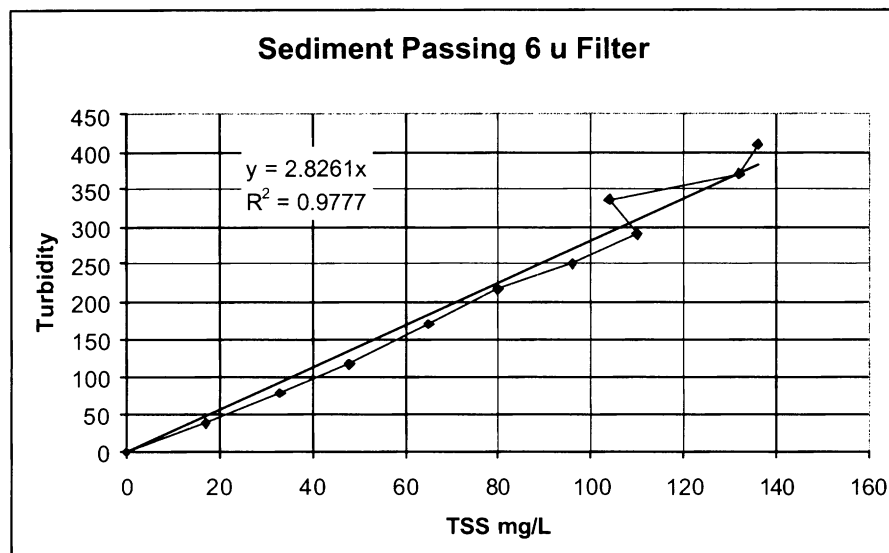


Figure 22. Turbidity vs. Suspended Sediment - 6 Microns and Smaller

4.2.2. DATA FROM USGS RECORDS

The USGS provides access to historical water quality data via the Internet. A review of the USGS web site produced two locations on the CR, at Quincy, OR (14246900), and Warrendale, OR (14128910), where compiled water quality data included same sample total suspended sediment readings and turbidity readings. Recorded suspended sediment concentrations ranged from less than 1 to 363 mg/l while turbidity levels ranged from less than 1 to 73 NTUs at these sites. Average TSS for all readings was 25 mg/L and average turbidity was 8 NTU. In general, the average turbidity readings in NTUs were about ¼ the value of the TSS concentrations in mg/L.

Both TSS and turbidity increase in the spring and fall of the year. Because the readings are intermittent and not continuous, a better understanding of seasonal changes cannot be developed. Higher TSS and turbidity correlates with higher flows for all seasons. Review of the daily flow records indicates that turbidity and TSS readings were not made at the highest flows for the season. This suggests that even higher readings might have been recorded if continuous records had been kept.

The closest site found to the confluence of the WSR and CR was at Warrendale, Oregon just downstream of the Bonneville Dam. The USGS site, station 14128910, provided a wide range of water quality information including daily flow records, parameter code 60 (PC 60), turbidity (PC 76), and suspended sediment concentration in mg/L (PC 80154). Not all of the information was same-sample. However, there were over 100 same-sample readings for turbidity and suspended sediment for this site starting in 1968 and ending in the 2000.

Data from this site is more representative of the expected conditions of sediment eroded by dam removal. This data more closely represents the relationship between suspended sediment concentrations and turbidity that will occur after dam removal because of the large number of samples and because in-river mixing more closely approximates conditions that will be experienced upon dam removal. Comparison of NTU and mg/L (essentially equal to ppm for values in these data) for same-sample readings shows a variable relationship based on season. On average the value for TSS in mg/l was 4 times as large as the value for turbidity in NTU but varies widely as illustrated by Figure 25.

All the data from both the Warrendale and Quincy sites with turbidity plotted against suspended sediment is shown in Figure 25. The best-fit regression equation for the data was a linear relationship between TSS and turbidity. For all data, the best-fit relationship is that turbidity equals 2.66 times the suspended sediment value.

However, most of the data, 78 %, was for turbidity readings less than 10 NTU that show a correlation of approximately 4 NTU to 1 mg/L. Because turbidity resulting from dam removal will have a wide range, two relationships were developed. Above TSS of 40 ppm the relationship used throughout this document is: $NTU = 10 + (TSS - 40)/1.97$. Below TSS values of 40 the relationship used is: $NTU = TSS/4$. This relationship is shown graphically in Figure 25.

USGS data show an opposite relationship to that developed in the laboratory. Laboratory results showed that turbidity readings would have higher values than suspended sediment readings for the same sample while information in the USGS records show TSS readings higher than turbidity readings for the same sample. Due to the larger data set and more similar in-river conditions, the USGS data was used to analyze the expected turbidity levels throughout this document.

SEDIMENT BEHAVIOR ANALYSIS REPORT

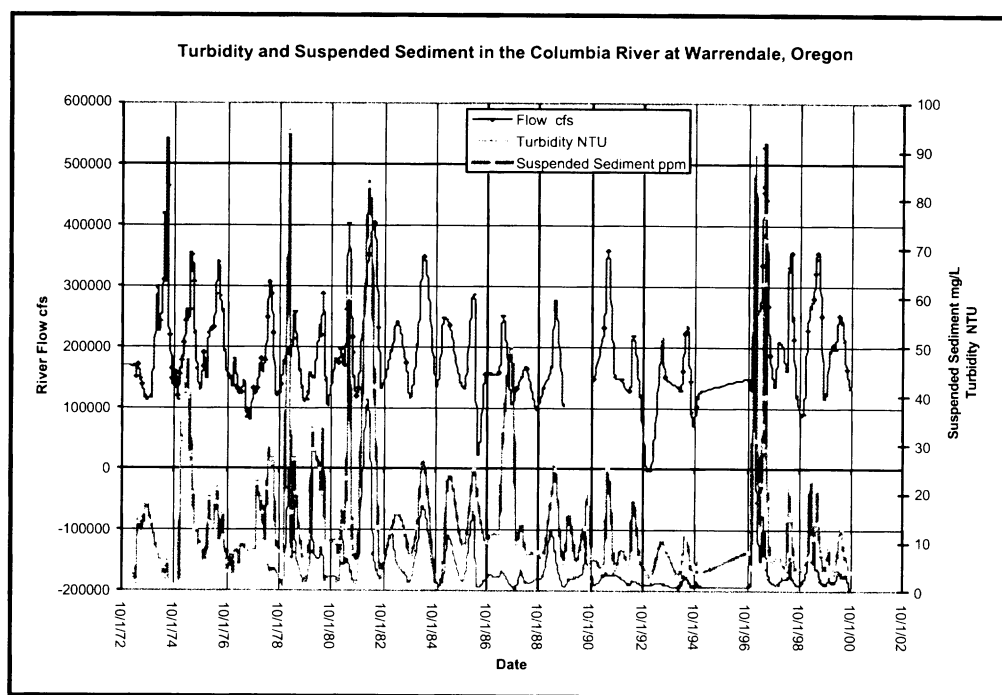


Figure 23. Turbidity and Suspended Sediment at Warrendale, Oregon

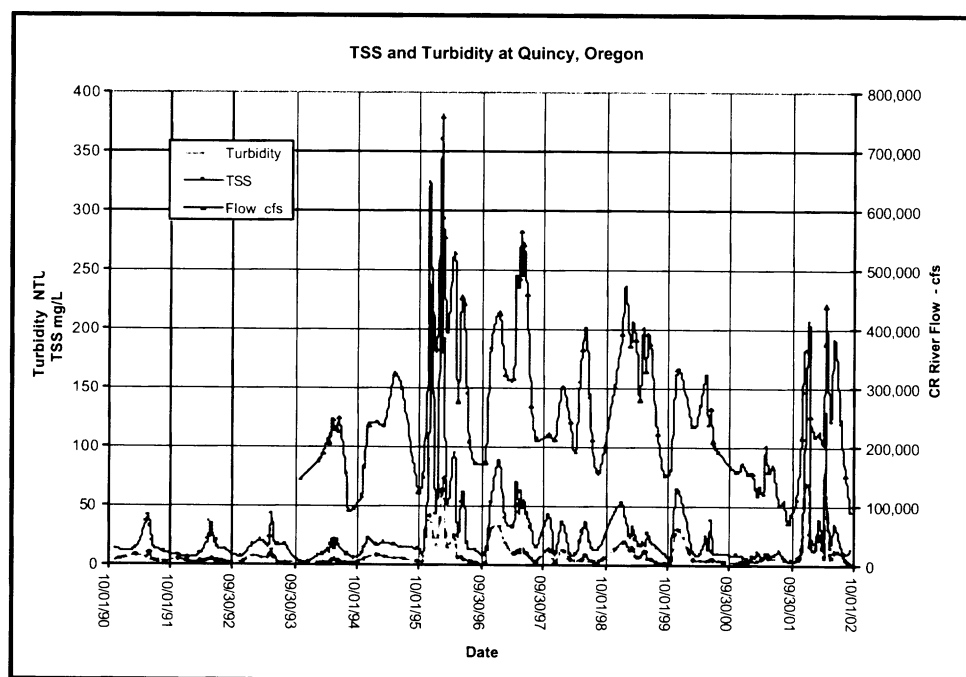


Figure 24. TSS and Turbidity at Quincy, Oregon

SEDIMENT BEHAVIOR ANALYSIS REPORT

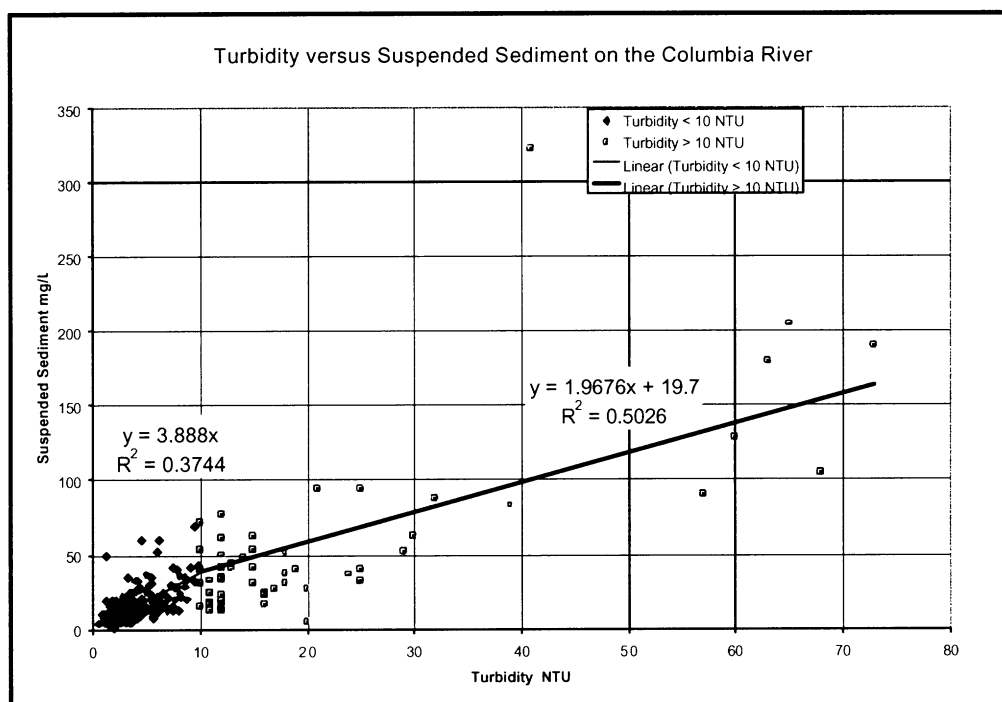


Figure 25. Suspended Sediment versus Turbidity

5. SEDIMENT EROSION ANALYSIS APPROACH

5.1. SEDIMENT EROSION PROCESSES IN THE RESERVOIR AREA

Analysis of the rate and volume of sediment erosion was based on several procedures depending on the location, when eroded, and type of sediment. Generally, three separate processes covering three separate time spans will erode sediment from the reservoir after the dam is breached. The three processes discussed in more detail below are:

- 1) Erosion of silt, sand, and gravel above the pre-dam river channel. This type of erosion will form the new river channel in the first twelve months after dam breach. This initial process is termed *Near Term Erosion– River Channel Formation* in the detailed discussion following.
- 2) Surface erosion of embankments above and to the side of the river channel will form gullies and rills in embankments now inundated by the reservoir but not in the post-dam river channel. Surface erosion will start as soon as the embankments are exposed and continue with decreasing intensity over the first 3 to 5 years until vegetation inhibits surface erosion and minor conveyances are fully formed. This surface erosion process is described in

SEDIMENT BEHAVIOR ANALYSIS REPORT

more detail in the following section entitled *Mid Term Sediment Erosion – Surface Erosion and Upland Conveyance Formation*.

- 3) Embankment failures during extreme high flow events will continue to erode as progressively higher water elevations reach new sediment. This process will occur infrequently (approximately 2-3 times in 20 years) and for short duration (i.e., hours or days) over many years with decreasing intensity and frequency. This process is described in more detail in the following section entitled *Long Term Sediment Erosion – Flood Plain Formation*.

The River Channel Formation process will erode sediment in the mainstem of the river and form a new channel. Most of the material eroded will be fine sediment. Some (approximately 1/3) of the material will stay in suspension until it reaches the CR. Most of the very fine sediment will erode with the initial flush of water leaving the reservoir. The river channel formation process will begin immediately after the dam is breached. The reservoir will empty in approximately 6 hours. This initial river channel formation process will continue through the first year after dam removal. Sediment removed from the reservoir in the first 6 months will primarily be removed by embankment failure and vertical erosion of the channel.

After the initial lowering of the reservoir, river channel erosion and formation will occur until a relatively stable channel location is attained sometime within the first month. In alluvial material this channel would migrate and form a flood plain and a channel. Since the natural pre-dam channel is located in bedrock, very little lateral migration will be possible after the river erodes to the bedrock interface. Vertical erosion will continue to occur until the bed layer becomes armored sufficiently to resist shear forces from the river flow.

The second process, Surface Erosion and Upland Conveyance Formation, involves surface erosion from newly formed overbank areas in the reservoir area. Not all of the reservoir sediment outside the channel is expected to erode with the initial flush and subsequent erosion. Some of the sediment will remain on the banks above the channel undisturbed by normal river flow. Flatter areas will be reseeded and within a few years will behave in a similar manner to areas outside the reservoir.

Drawdown of the reservoir is expected to leave the sediment outside of the river channel with a relatively smooth contour, without gullies or rills. Water from rain and snow and over land flow from higher elevations will create a more varied topography and drainages will be eroded to convey surface runoff. Material eroded to form these gullies and rills will return sediment to the river. This process will start immediately after the dam breach and should be substantially complete when vegetation is firmly established or pre-dam rock surfaces are exposed (i.e., by the end of year five following dam breach). Sediment erosion should occur primarily with rainstorm events although flow from springs and upland snowmelt will add to the process.

The third process, Long Term Sediment Erosion – Flood Plain Formation, occurs over a much longer time span. After the initial processes of river channel and upland contour formation are complete, normal flows will erode only minor amounts of sediment from

the reservoir area, similar to erosion rates elsewhere in the watershed. However, infrequent high flow events will cause the river water elevation to rise higher than previous high flow events after dam breach.

On these rare occasions, the upper part of the water column will cause river flow to erode sediment particles on the higher embankment areas that normally are not affected by river flow, which can cause erosion and undercutting of embankments. However, once an embankment fails and sediment is eroded, the same level of river flow on a following event will not erode that embankment.

Because undercutting and embankment failure occur only during successively higher flows, the frequency of this type of activity decreases with time after the dam breach. During high flow events background TSS concentrations in the river entering the reservoir area will also be relatively high. In addition, since ever-increasing flows are required to access and erode embankment material, the TSS concentrations from this type of erosion decreases with time after the dam breach.

The three processes are discussed in more detail below, including estimates of suspended sediment concentrations in the WSR and the CR.

5.1.1. NEAR TERM EROSION— RIVER CHANNEL FORMATION

Immediately after the opening in the base of the dam is created, the reservoir water elevation will begin to decline. Average flows into the reservoir in the fall of the year when the opening will be created are approximately 700 cfs and are consistently lower than 1000 cfs. Flow out of the reservoir will immediately exceed 10,000 cfs but will decline rapidly as the reservoir level drops. See Figure 12 and Figure 13.

5.1.1.1. *White Salmon River Suspended Sediment Concentrations*

Because the exact nature of the sediment is unknown, some uncertainty exists concerning the volume of sediment that will erode in the very near term after the dam is breached. To bracket the range of possible eroded volume and sediment concentrations that will occur immediately after the breach, different assumptions were made regarding the amount of material eroded and the timing of that erosion. Two scenarios were analyzed; one assuming massive slope failures immediately after dam breach and one assuming steeper slopes after the breach. The former assumption results in faster erosion, higher initial TSS concentrations, and larger eroded volume than the latter.

The lower volume scenario was based on embankment slopes forming at the same inclination throughout the length of the reservoir. This scenario assumed that embankments form at an angle of 1 vertical to 1.73 horizontal or steeper if pre-dam surfaces are encountered as provided by the geotechnical report⁹ conducted in 1997. Estimates of material eroded from the reservoir discussed in the RW Beck report are

⁹ Squire Associates, November 20, 1997

SEDIMENT BEHAVIOR ANALYSIS REPORT

based on this assumption. The estimated eroded volume in the first year in that report was 1.57 mcy using the geotechnical report criteria.

Assumptions that fine sediment will behave in the same manner as coarse sediment may over estimate slope stability during the drawdown period. Therefore an upper volume range was calculated. The upper range is based on the assumption that slope failure in fine-grained materials can occur at approximately 10 horizontal to 1 vertical.

Based on material in-situ density information provided in the geotechnical report, an upper limit on concentration of suspended sediment immediately after the breach can be calculated. Sediment in the lower part of the reservoir near the dam will erode first because of its location and grain size. The geotechnical report does not directly address the density of this material in this location but similar material in accessible areas of the reservoir had a dry density of approximately 70 pounds per cubic foot.

The in-situ mixture of sediment and water trapped in pore spaces of the sediment has a concentration of approximately 650,000 ppm without considering water in the reservoir above the sediment elevation. As the reservoir drains the material near the dam will be mixed with the water in the reservoir, some of the water trapped in the pore spaces of the granular material, and water entering the reservoir from upstream during the drawdown. As the fine sediment near the dam mixes with this additional water the concentration in the WSR downstream will decrease to a peak average daily concentration of around 150,000 ppm.

SEDIMENT BEHAVIOR ANALYSIS REPORT

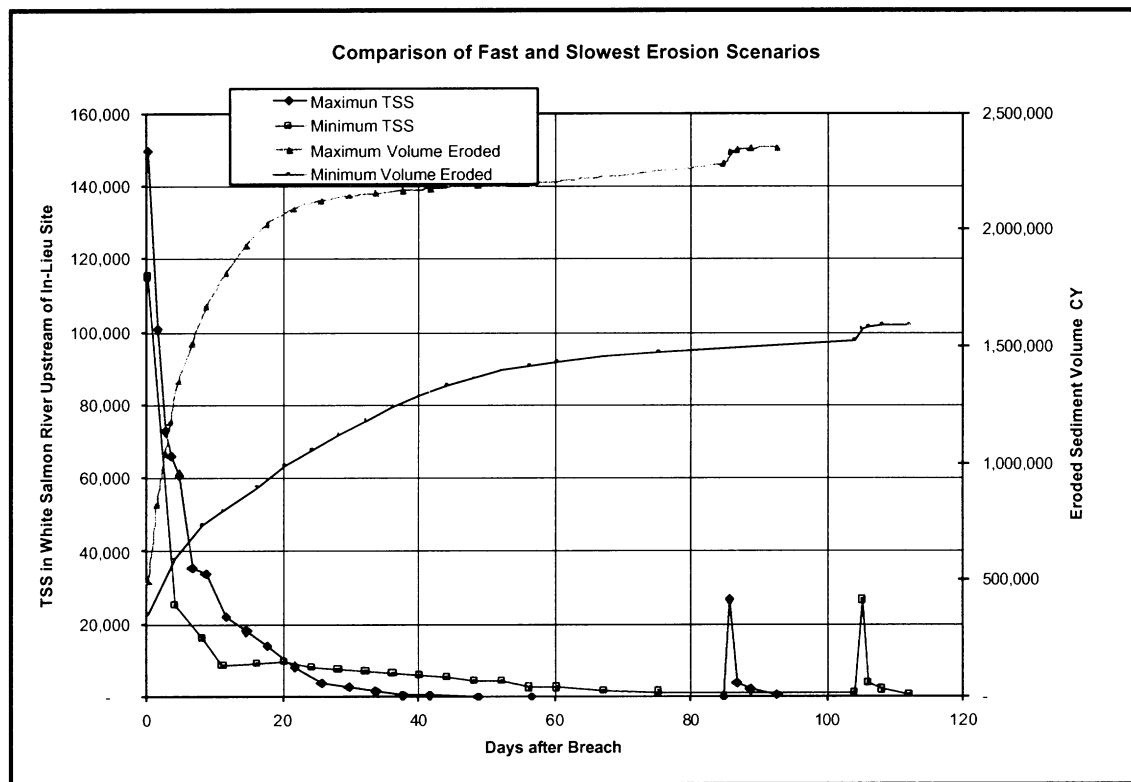


Figure 26. Estimated Maximum and Minimum TSS Concentration and Sediment Removal Volume

After the initial drawdown, concentrations will decline as sediment is moved out of the immediate path of the river and erosion occurs only where direct contact with river flow exists. Figure 26 shows the two scenarios that define a range of initial sediment erosion. The most rapid erosion, which results in the highest initial TSS concentration, has the most rapid drop in TSS levels because most of the sediment is eroded earlier by slope failure associated with rapidly dropping water elevations. The volume of reservoir sediment available for erosion, concentration of in-situ sediment, free water in the reservoir, and maximum flow through the ungated opening limit later TSS concentrations.

The rapid erosion scenario assumes that new surface features are formed at 10 h. to 1 v. or pre-dam slopes, whichever is steeper, and that only a few feet of material, on average, remains on surfaces after the reservoir is drained. For fine-grained sediment this assumption is probably closer to conditions that will exist after the dam breach. For this condition, 90% of the fine material erodes with reservoir drawdown within 2,000 feet of the dam. The remaining upstream suspendable material erodes in the first few months after the dam breach.

The slower scenario, which assumes only 1.57 mcy of sediment erodes, shown in Figure 26, assumes that slopes fail at steeper angles and only do so as the river erodes vertically and horizontally to access embankment materials. This approach assumes that slopes fail

SEDIMENT BEHAVIOR ANALYSIS REPORT

at approximately 30 degrees and larger amounts of sediment remains on embankments above the river as discussed in the geotechnical report. This slower erosion scenario results in higher TSS concentrations after about 20 days following dam breach because more sediment remains available to erode at a later time than for the faster erosion scenario.

Figure 26 shows the upper and lower range of estimated sediment concentrations. It also shows the volume of sediment removed, as a function of time in the two approaches, shortly after breaching the dam. Suspended sediment concentrations shown are for the WSR immediately downstream of the dam site. The spike in TSS concentration around 90 days after dam breach is associated with removal of the cofferdam, flume, and other structures in the lower reservoir elevation used to divert the river during dam construction. The timing of cofferdam removal shown is intended to illustrate TSS concentrations from the activity. Actual timing of these activities will depend on conditions encountered after the dam breach. The cofferdam can be removed at any time after dam breach and before the end of the construction season.

The sediment volume removed shown in Figure 26 includes bed load erosion in the total. Several methods were used to analyze the rate of coarse material erosion. The RW Beck Report includes analysis of sediment erosion using HEC-6 modeling. Models such as HEC-6 can provide greatly varying results and may not be adequate to provide short-term erosion estimates without a means to calibrate the results. Several sediment erosion processes observed in field studies are not fully represented in the model. These include head cutting, embankment failure, lateral migration, varied sediment layers, multiple channels, and changes in stream width. Because of these limitations other methods were used to provide a general estimate of bed load erosion.

The ability of the river to erode the sediment in the channel was discussed in a letter report to the Federal Energy Regulatory Commission¹⁰. This document used empirical data regarding sediment erosion gathered during the Elwha Dam removal studies and other general analytical analysis tools to show that even for low flow years, most coarse sediment will erode from the reservoir area.

The capability of the river to erode channel sediments can also be illustrated by higher than typical velocities in the rock bounded river channel. The RW Beck¹¹ report analyzed typical stream widths for alluvial streams with the WSR flow regime and found that expected stream width would be approximately 125 feet wide. The width of the river in the reservoir however, is limited by rock boundaries to approximately ½ the anticipated width. This narrower river channel will create higher flow velocities than

¹⁰ Response to Request For Additional Information Regarding PacifiCorp's Estimation Of Erosion Rates Related To Proposed Dam Removal, FERC Request for Additional Information, G&G Associates for PacifiCorp, August 2001

¹¹ *Condit Hydroelectric Project Removal*, R W Beck, Appendix A, D.R. Gathard and Associates, page 40

alluvial channels that will increase sediment erosion when compared to an alluvial stream of the same slope and flow.

5.1.1.2. *Sediment Trapped at the In-Lieu Site*

The In-Lieu site is located at the mouth of the WSR. The elevation of the Bonneville Pool controls the volume of water contained in this lower 4,200 foot long reach of the river. Table 7 shows the range of the volume of this site, depending on the Bonneville Pool elevation. Due to the relatively large pool volume at this site much of the heavier material will settle out of suspension, reducing TSS concentrations leaving the mouth of the WSR until the pool fills with sediment.

Table 7. In-Lieu Site Volume

<i>Potential Storage Volume of Lower Reach</i>			
At Columbia River elevation NAVD88	Storage in Cubic Yards	Storage in acre - feet	Estimated Time Range to fill
77	451,000	280	3 to 10 days
86	897,000	556	5 to 30 days

The trapping efficiency of the site will depend on the flow entering the site and the volume of material already trapped. Trapping efficiency will decrease as the site fills with sediment. The RW Beck Report provides an estimate of the amount of each sediment size that will be trapped in the In-Lieu site. This estimate was based on HEC-6 modeling of erosion of the reservoir. For a number of reasons HEC-6 modeling may not accurately estimate the behavior of sediment erosion.

Analysis of the trapping ability of the In-Lieu site was conducted as means of estimating effects on TSS in the CR. The approach involved using a general trapping efficiency formula, shown below, to determine the sizes and volume of sediment trapped based on the sediment concentrations shown in Figure 26.

$$P = \left[1 - \left(\frac{1}{e^{\left(\frac{1.055 L \omega}{V d} \right)}} \right) \right]^{12}$$

Where P = fraction of sediment deposited over the total basin length

¹² Pemberton, E.L. and J.M. Lara, 1971. "A Procedure to Determine Sediment Deposition in a Settling Basin," Sedimentation Investigation Technical Series, Section E. Intake Works and Desilting Basins, U.S. Department of the Interior, Bureau of Reclamation, Sedimentation Section, Denver, Colorado

SEDIMENT BEHAVIOR ANALYSIS REPORT

L = total basin length, in feet or meters

v = particle fall velocity, in ft/s or m/s

V = average flow velocity within the settling basin, ft/s or m/s

d = average settling basin flow depth, in feet or meters.

Figure 27 shows the results of this analysis for various particle sizes. As shown by the figure, on average, about 30% of the silt and smaller sized particles are trapped. During the initial 6 hours after breach, river flow will be higher increasing average velocity and decreasing trapping efficiency. Trapping efficiency will increase as flows decrease but start to decrease again as the pool fills.

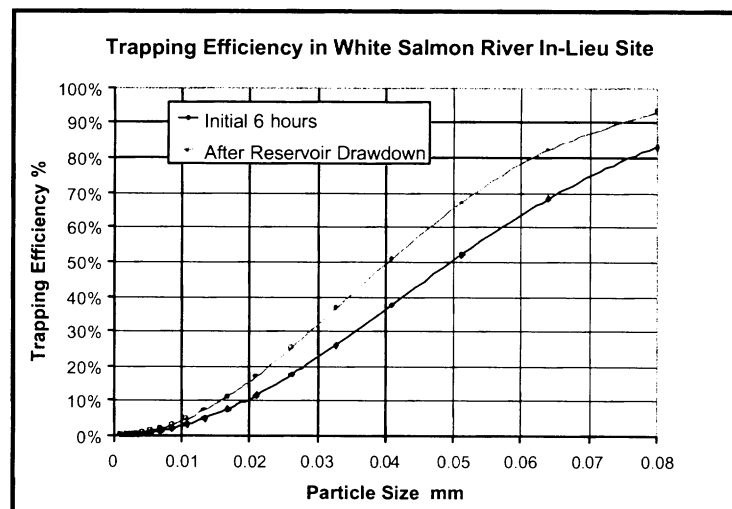


Figure 27. Trapping Efficiency of In-Lieu Site

Table 8. Material Quantities Trapped by In-lieu Site

Material Quantities Trapped in In-lieu Site					
Type of Material	Median Particle Size mm	Volume in Increment CY	Trapped %	Trapped Volume CY	Passed Volume CY
Sand and Larger	>1	1,323,100	32%	427,565	895,535
Silt	.03	723,400	34%	245,500	477,900
Clay	.002	153,500	0%	335	153,165
Total		2,200,000		673,400	1,526,500

5.1.1.3. Columbia River Mixing Zone

Immediately after breaching the dam, high sediment concentrations from the WSR will mix with CR water. Aerial photographs of the confluence of the two rivers, taken by the Washington Department of Transportation, were used to estimate the behavior of the

plume of high concentration water in the CR and the distance downstream before the plume is completely mixed in the CR water.

Several actions occur at the confluence of the two rivers. Medium sized sand particles that arrive at the In-lieu site after the pool is filled will move into the CR system. Most sand particles will settle near the confluence. Suspended sediment concentrations of WSR water entering the CR will be less than the concentrations in the river at the top of the In-lieu site due to settling in the In-lieu site. Silt particles will settle in the CR in the pool created by Bonneville Dam as discussed below. Most clay-sized particles will stay in suspension to the mouth of the CR.

Figure 28 shows the estimated length of the plume on average before the two rivers become completely mixed. The estimated distance is approximately 3 miles based on the angle of the mixing waters shown in Figure 29, which is an aerial photograph of the mouth of the WSR. The dark area in the upper right corner is the WSR, which was less turbid than the CR. Swirls in the mixing area have been photographically enhanced to show the angle of mixing. This angle is extended downstream to its interception on the Oregon side of the river where water from the WSR should be thoroughly mixed with CR water.

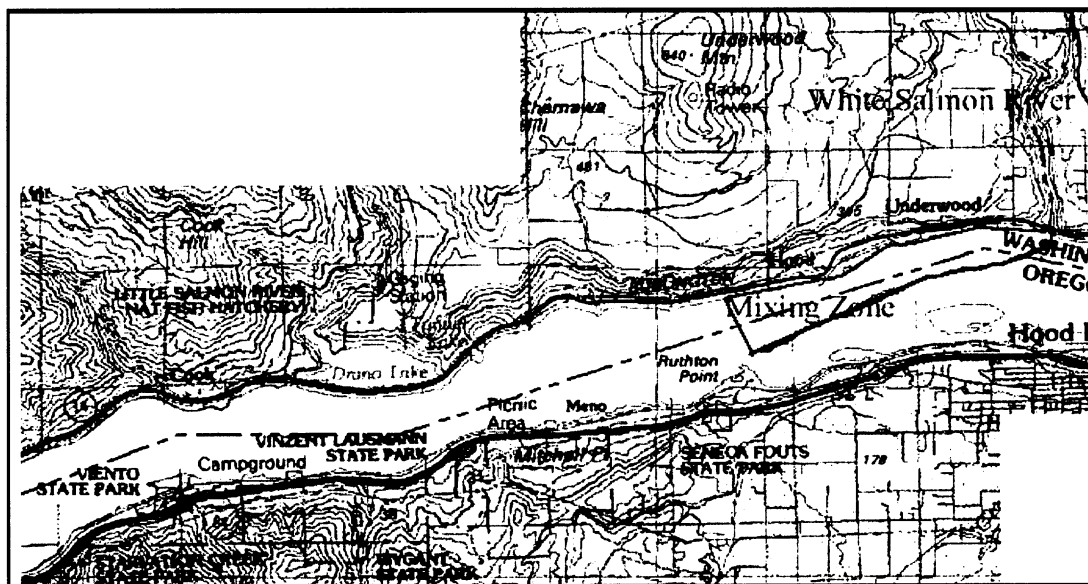


Figure 28. Columbia River Mixing Zone

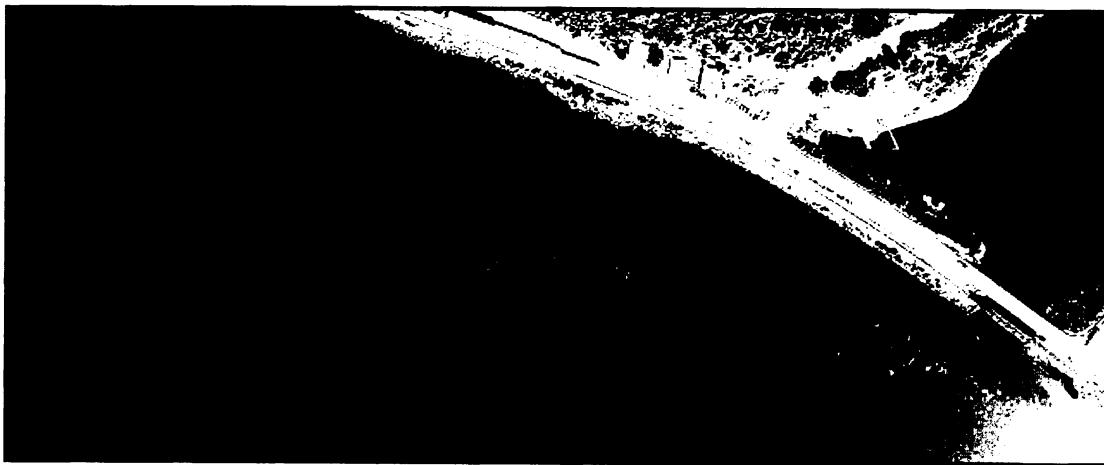


Figure 29. Mixing at Mouth of White Salmon River

5.1.1.4. Bonneville Pool

As illustrated by Figure 27, only a portion of the suspended material eroded from the reservoir will be trapped in the In-Lieu site. The remaining sediment will be transported into the CR. TSS concentrations in the CR will decline downstream for several reasons; 1) larger suspended particles will continue to settle out of the water column, 2) particles will travel at different velocities causing a longitudinal spreading of the initial sediment plume, and 3) tributaries to the CR will add flow to the river and continue to dilute suspended sediment concentrations.

The Bonneville Dam Pool controls the elevation of the CR in this reach. The Pool will cause the river to trap most of the remaining sediment. As the In-Lieu site fills, heavier material will be deposited at or near the mouth of the WSR. The finest material will stay in suspension until it reaches the Pacific Ocean.

Figure 30 shows the approximate sediment concentrations above background levels after dam breach due to sediment from the reservoir. Actual concentrations will depend on river flow volume on the CR. Suspended sediment concentrations in the CR will vary dramatically depending on the rate at which sediment is flowing into the CR. Two periods are discussed separately below because of large difference in the extent of dilution of WSR water in the CR.

5.1.1.4.1. Draining the Reservoir

In the first 6 hours after the dam is breached the flow downstream of the dam will increase to slightly over 10,000 cfs. Average flow during this period is around 8,000 cfs. Normal river flow for this time of year on the WSR is between 600 and 700 cfs. Average flow on the CR for this time of year is approximately 125,000 cfs. The TSS concentration in the CR after WSR and CR waters are fully mixed is the ratio of the CR to WSR flows multiplied by WSR TSS concentration. Because of the higher flow coming out of the WSR during this period the dilution ratio 15.6 to 1.

Figure 30 shows that initial concentrations in the CR, during the first six hours after the breach, will be high. After approximately 6 hours concentrations in the CR drop by approximately an order of magnitude because flow in the WSR drops by an order of magnitude after the reservoir drains and river flow downstream is the same as upstream of the dam.

5.1.1.4.2. After Reservoir is Drained

Figure 30 shows TSS concentrations for WSR water entering the CR, concentrations for of the totally mixed water several miles downstream of the confluence, and concentrations of completely mixed water at Bonneville dam after heavier suspended particles settle. Settling characteristics in the Bonneville Pool were based on average flows, river depth, and river width. For this analysis the river was assumed to be 45 feet deep by 4,000 feet wide and the confluence of the rivers was assumed to be 23 miles upstream of Bonneville Dam.

No significant settling was assumed to occur in the CR after Bonneville Dam. TSS and turbidity levels were assumed to decrease by approximately 20% at Quincy, OR due to additional dilution from increased flow in the CR downstream of Bonneville Dam. As shown by Table 9, most of the material passing Bonneville Dam is smaller than 1/100 of a millimeter in size. The initial sediment pulse will take about 48 hours to reach Bonneville Dam and another 50 plus hours for the plume to reach the ocean.

Table 9. Material Quantities Trapped in the Bonneville Pool

Material Trapped in Bonneville Pool					
Type of Material	Median Particle Size mm	Volume ¹³ in Increment CY	Trapped %	Trapped Volume CY	Passed Volume CY
Sand and Larger	>1	895,535	100%	895,535	0
Silt	.03	477,900	71%	336,920	140,981
Clay	.002	153,165	6%	8,424	144,741
Total		1,526,600		1,240,879	285,721

¹³ See Table 8 for quantities entering the CR

SEDIMENT BEHAVIOR ANALYSIS REPORT

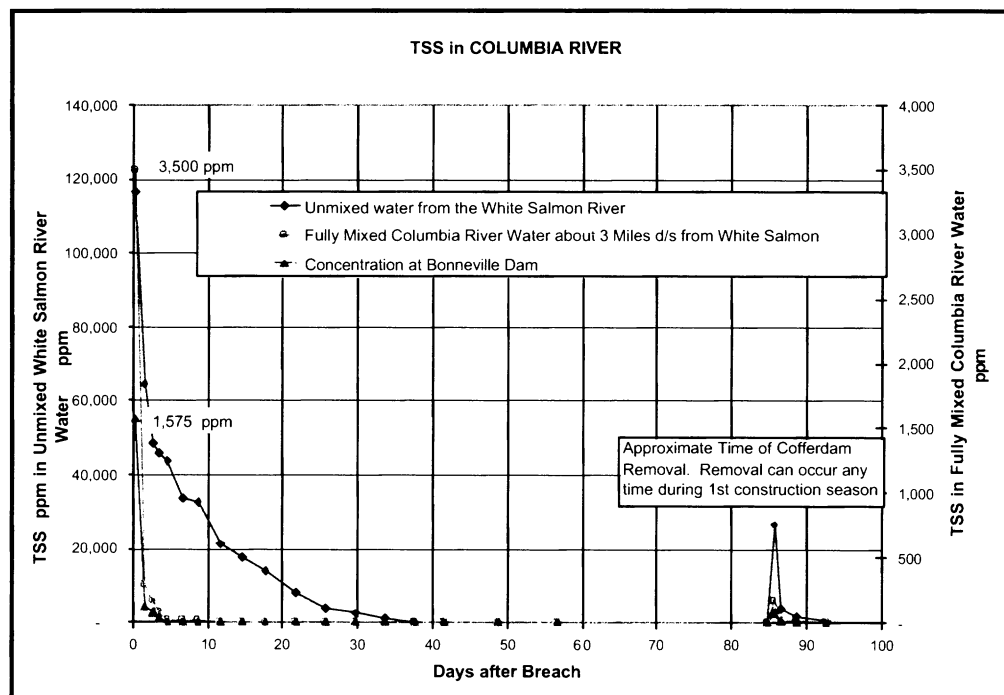


Figure 30. Suspended Sediment Concentrations in Columbia River

5.1.2. MID TERM SEDIMENT EROSION – SURFACE EROSION AND UPLAND CONVEYANCE FORMATION

Midterm erosion as discussed in this document is the time period after initial channel formation erosion, discussed above, until the reservoir area returns to conditions similar to the surrounding environment. The following discussion examines sediment erosion and suspended sediment in the White Salmon and Columbia Rivers due to upland contour formation and formation of small conveyances such as rills and gullies. Erosion of major tributaries in the reservoir is included in the previous discussion.

As illustrated by Figure 14, flow in the WSR decreases dramatically after the month of June. Most of the effects of the initial sediment erosion processes will be complete by the end June of the first year after the dam breach. At this point in time the river channel will be located inside the pre-dam channel and embankments above the river water level will be stable. Approximately 30 acres of the 90 acres of reservoir area will be directly affected by river flow and should have no surface erosion because river flow will erode all material on the surface. The remaining 60 acres can be divided into flat surfaces with slopes less than 20% and steep surfaces with slopes between 20% and 100%. Approximately 21 acres have been identified as flat slope areas. The remaining 39 acres

SEDIMENT BEHAVIOR ANALYSIS REPORT

are relatively steep. For analysis purposes erosion was calculated separately for the steep and flat surfaces.

Upland precipitation will be the primary source of erosion for both areas. Most upland precipitation will either flow into an already defined channel leading to the river or seep into the ground. Based on USGS topographic maps, an area of 250 acres around the perimeter of the reservoir was used as the area contributing overland flow that will cause surface erosion from the 60 acres of exposed reservoir lands.

Figure 31 shows the reservoir area, upland area above the reservoir contributing to surface erosion, and areas of flatter slopes. Initially, all surfaces not directly affected by river flow will be relatively even, without plants and roots to stabilize the surface, and susceptible to high surface erosion. Surface erosion from direct precipitation and from runoff in the immediate upland area will begin immediately after the reservoir is drained. Water from precipitation in the upland areas around the reservoir will flow across these areas and form streams, gullies, and rills. This process involves the mechanisms to adjust the unnaturally even topography of the former reservoir bed into the naturally contoured topography of a vegetated or exposed rock upland surface in the WSR Basin.

The volume of the sediment remaining on the exposed slopes in areas shown in Figure 31 cannot be directly calculated because of uncertainty regarding initial soil angle formation and the thickness of the remaining sediment. The bounds of this quantity of the material can be estimated based on the two extremes of material erosion analyzed by the initial channel formation discussed previously.

The lower limit, assuming the highest estimated volume of sediment is eroded, results in an average of about 4 feet of sediment over the entire flatter area and 1 foot on the steeper slopes or about 200,000 cubic yards of sediment. This limit is intended to reflect resistance to sediment movement from tree stumps and water logged large woody debris and material left on the reservoir bottom surfaces when the dam was filled. The upper bound on the volume of sediment remaining after the initial erosion process is complete is based on the assumption that all slopes fail at an angle of approximately 1.73 horizontal to 1 vertical. In this case the amount of sediment eroded would be approximately 1.6 mcy, leaving about 800,000 cubic yards in the reservoir area.

SEDIMENT BEHAVIOR ANALYSIS REPORT

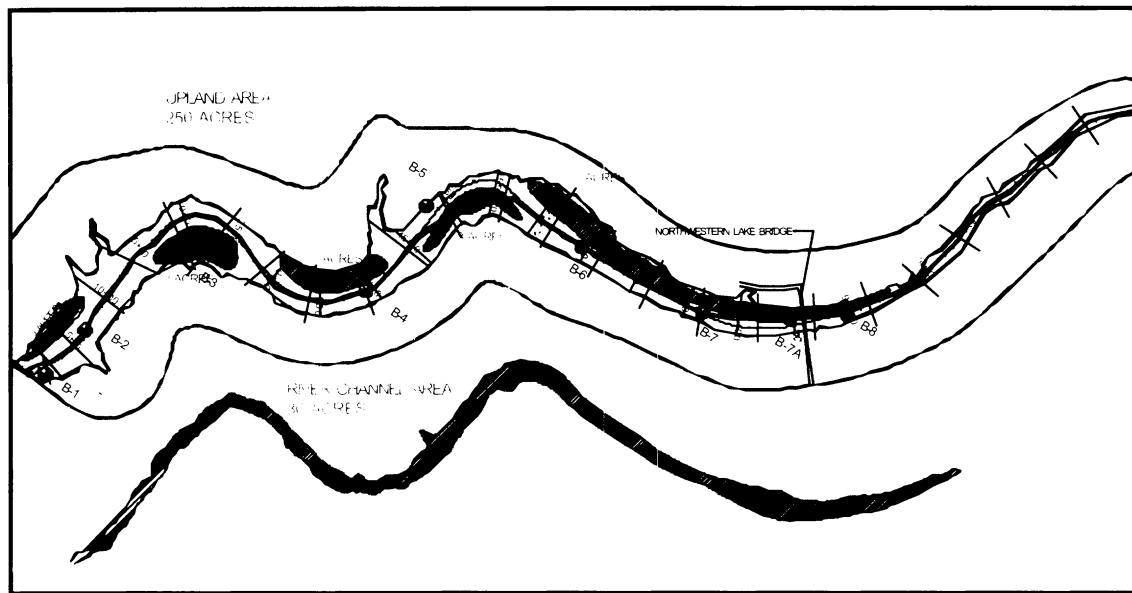


Figure 31. Flat Slopes and Upland Area Contributing to Erosion

The Universal Soil Loss Equation (USLE) was used to analyze the volume of sediment eroded by surface erosion. However, data on duration versus intensity of rainfall was not available for this area. Average and maximum daily rainfall values for Hood River, Oregon were used instead to conduct the analysis.

The USLE for estimating average annual soil erosion is:

$$A = RKLSCP$$

- A = average annual soil loss in t/a (tons per acre)
- R = rainfall erosivity index
- K = soil erodibility factor
- LS = topographic factor - L is for slope length & S is for slope
- C = cropping factor
- P = conservation practice factor

Soil loss for steep and flatter areas was analyzed separately. Values used for these analyses are discussed below.



Figure 32. R Factor for the United States

Values for K, LS, C, and P, discussed below, are taken from Julien¹⁴ and the tables containing the range of these values are not reproduced here.

5.1.2.1. Soil Loss for Flat Areas

K = .48 This is the value given for silt and loam and represents the highest value possible.

R = 35 See Figure 32. This value was increased by the ratio of upland area that flows directly onto reservoir surfaces (240 acres) to exposed reservoir surface area (60 acres). Precipitation on upland surfaces outside the 240 acres around the reservoir was assumed to flow into an already established drainage.

LS = 2.5 Taken from Julien, Figure 3.25. Length = 350 feet (to account for upslope precipitation). Slope = 10%

C = 1.0 This value will decrease significantly over time. The value of 1.0 listed for tilled fields continuously lying fallow (Julien, Table 3.5b). The value should decline to approximately .003 (Table 3.5a) in 3 to 5 years.

P = 1.0 for all conditions and time.

A per acre = $35 \times 240/60 \times .48 \times 2.5 \times 1 \times 1 = 42$ tons per acre per year $\times 21$ acres = 3,529 tons/year = approximately 3,400 cubic yards per year.

¹⁴ *River Mechanics*, Pierre Y. Julien, Cambridge University Press, 2002, pages 63-71

5.1.2.2. *Steep Slopes*

K = .48 This is the value given for silt and loam and represent the highest value possible.

R = 35 See Figure 32. Increased by 240/60 to account for surrounding overland flow.

LS = 6 Taken from Julien, Figure 3.25. Length = 350 feet (to account for upslope precipitation). Slope = 20%

C = 1.0 This value will decrease significantly over time. The value of 1.0 listed for tilled fields continuously lying fallow (Table 3.5b). The value should decline to approximately .003 (Table 3.5a) in approximately 3 to 5 years.

P = 1.0 for all conditions and time.

$A = 35 \times 240/60 \times 6 \times .48 \times 1 \times 1 = 403 \text{ tons/ acre / year} \times 39 \text{ acres} = 15,725 \text{ tons/ year}$

Total Soil loss per year would result from adding the loss for steep and flat areas. In year 1 total soil loss would be $3,529 + 15,725 = 19,254 \text{ tons} = 19,060 \text{ cubic yards}$.

This amount accounts for surface erosion only and does not account for major stream formation that is included in the discussion of initial channel formation. To simulate the declining effect of surface runoff the value of "C" was varied over time from the initial value of 1.0 corresponding to a bare surface to .003, which corresponds to forestland fully covered. Total estimated erosion for a 3-year period is approximately 38,000 cubic yards. If the process were to last 5 years calculations indicate approximately 57,000 cubic yards would be eroded. Simulations were conducted for a 3-year period. TSS and NTU levels are shown in Table 11 through Table 14. The worst-case assumption was made that 3rd year levels would extend through the 4th and 5th years to illustrate potential levels should adverse weather conditions retard upland plant development.

5.1.2.3. *Suspended Sediment Concentration in the White Salmon River*

Figure 33 shows the effects of declining exposed surface area over a three-year period on sediment concentrations in the WSR. The "C" value for the last day of year 3 was assumed to be .003 (Julien, Table 3.5a). Precipitation was based on average daily precipitation at recorded Hood River, Oregon¹⁵. River flows are based on 3 average years. The results of this analysis should be considered order of magnitude since many assumptions were made to develop the results. Two assumptions primarily affect the results; that average rainfall occurs each day and that all of the rainfall occurs over a time of several hours and the remaining part of the day has no rainfall.

¹⁵ U.S.G.S. Experimental Station 354003. Daily records from 1928 to 2001

SEDIMENT BEHAVIOR ANALYSIS REPORT

Figure 33 shows that sediment contributed from surface erosion happens in the late fall through late spring of the year relating to the timing of rainfall. High river flow and associated high sediment load from upstream occurs in the winter and spring of the year. Estimated natural TSS from upstream was based on the sediment-rating curve for the WSR discussed previously. This approach shows the average *daily* high and peak concentration of TSS from surface erosion to be approximately 22 ppm and 158 ppm, respectively, the first year declining to about 15 ppm and 104 ppm respectively the 2nd year and 7 ppm and 62 ppm respectively the 3rd year. By the end of the 3rd year, mature vegetation and surface water conveyances should be well established and the exposed surfaces will act in a manner similar to other mature areas in the watershed.

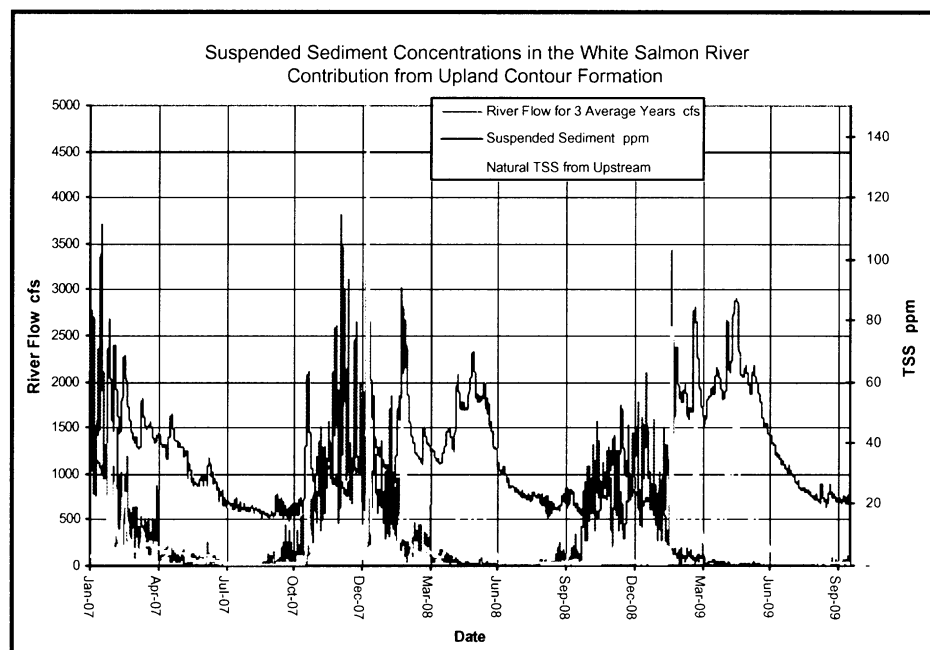


Figure 33. Suspended Sediment from Surface Erosion of Reservoir Area Only

SEDIMENT BEHAVIOR ANALYSIS REPORT

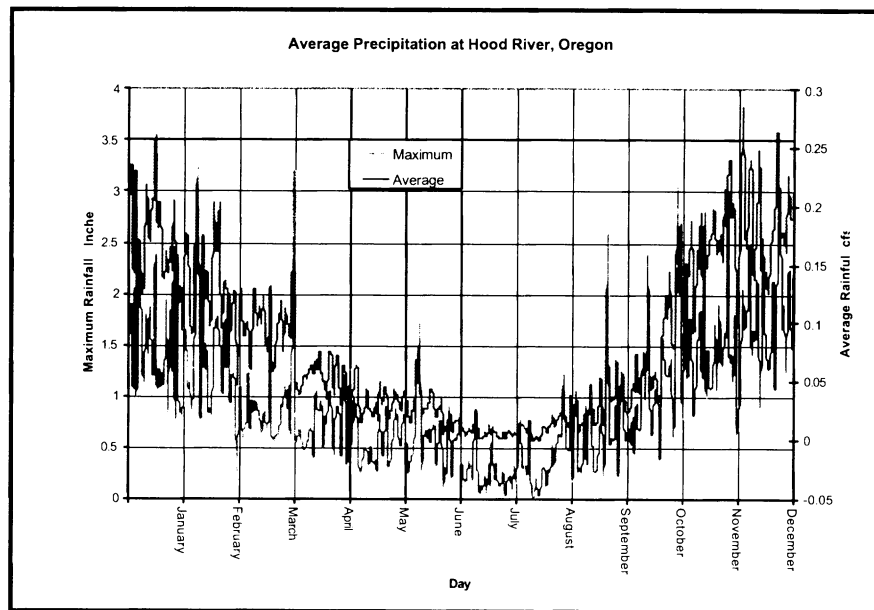


Figure 34. Rainfall at Hood River, Oregon

5.1.2.4. *Suspended Sediment Concentrations in the Columbia River*

Due to the large degree of dilution in the CR, the relatively low TSS concentration from surface erosion results in very small increased concentrations in the CR. Figure 35 shows TSS levels in the CR assuming no trapping occurs at the In-lieu site.

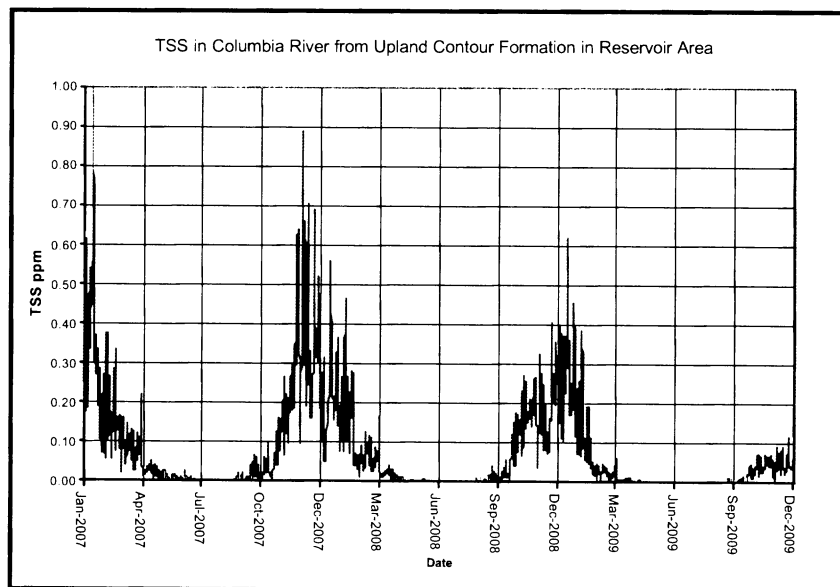


Figure 35. Suspended Sediment in Columbia River from Surface Erosion

5.1.3. LONG TERM SEDIMENT EROSION – FLOOD PLAIN FORMATION

Long-term sediment erosion involves river widening processes that contribute to flood plain formation. Because of the narrow entrenched rock canyon that characterizes the river through the entire reservoir reach the width for various flood flows can be defined. To conduct the analyses, several basic assumptions, discussed below, were made about the response of the sediment and the river.

5.1.3.1. *River Flow Sequences*

United States Geological Survey (USGS) recorded (station 14123500) average daily flow for the WSR approximately 1.9 miles upstream of the mouth of the river from 1912 through 2002. These flow records were used to analyze possible post-dam removal flows in the river. Flow records were organized in groups of three years. These groups were ranked based on the *maximum* average daily flow for the three-year period from highest to lowest. Five sequences; low, medium low, average, medium high, and high flow increments, were included in the analysis. Analysis of suspended sediment concentration variation after dam removal was conducted over six year periods (two groups of three year periods), one nine year period, and a thirty-year period using various combinations of flow patterns in succession.

5.1.3.2. *Hydraulic Analysis*

Typically over the course of a year, a river will become wider or narrower as the flow increases and decreases. As periodic flow increases occur, the river widens and embankments will fail leaving a wider flood plain. After dam removal each succeeding higher flow will result in a wider flood plain.

Hydraulic analysis of the river in the reservoir reach was conducted using HEC-RAS software to determine river width, depth, and flow volume. To conduct the analyses, pre-dam river cross sections spaced at 500-foot intervals upstream of the dam were used. Roughness coefficients used for the analyses were similar to rivers in western North America. Mainstem values used were $n = .02$ and embankment values were $n = .04$. Average daily flow records were used for the steady state flow analysis based on data from USGS station #14123500.

5.1.3.3. *Erosion Characteristics*

Analysis of the quantity of reservoir sediment eroded was based on the assumption that all sediment in the mainstem of the channel would already have been eroded up to the edge of the flow. Embankment erosion was based on the assumption that embankment formation starts at the water's edge and extends laterally at the angle of repose for the embankment material. For all reservoir sediment the surface of the embankment material or angle of repose was assumed to have a ratio of 1.73 horizontal to 1 vertical. For pre-dam surfaces no erosion was assumed.

5.1.3.4. *Volume of Sediment Eroded*

The volume of sediment eroded from the reservoir was assumed to be the volume eroded in the mainstem plus embankment erosion as discussed above. Eroded volume depends

on river width for the maximum flow in the sequence of flows experienced after dam removal, since the highest flow will create the widest river and the most embankment erosion. Therefore, based on these assumptions, a high flow that was preceded by a previous higher flow will not erode embankments because the river water will not access the toe of the embankments. The incremental eroded volume is the total volume eroded during the highest flow event minus the total volume eroded for the previously highest flow.

5.1.3.5. Analysis Procedure

Analyses were conducted to determine the effects of varying flow conditions in the reservoir after dam removal. Hydraulic analyses were used to calculate river width, flow volume, water depth, and stream width. Varying flow conditions will cause varying river widths over time.

Figure 36 illustrates the assumptions made regarding river water elevation and width for low and high flow conditions and shows the boundaries of the eroded cross section. This section is located at a wide section of the river approximately 3,500 upstream of the dam. The volume of embankment eroded is calculated based on the difference in the river cross sectional area for the successively higher flow events. The eroded area for each cross section is determined by calculating the area between boundaries of the current sediment surface and eroded surfaces.

The volume of eroded sediment for a particular flow event is calculated by multiplying the average eroded cross sectional area between two adjacent cross sections by the distance between them. Using the HEC-RAS results, the width of the river at each cross section can be determined for a given flow. The volume of sediment eroded from the reservoir for a particular flow is then calculated based on river width. Eroded volume was plotted for a series of maximum flow events through the reservoir. Results of this analysis for five flow events are shown in Figure 37.

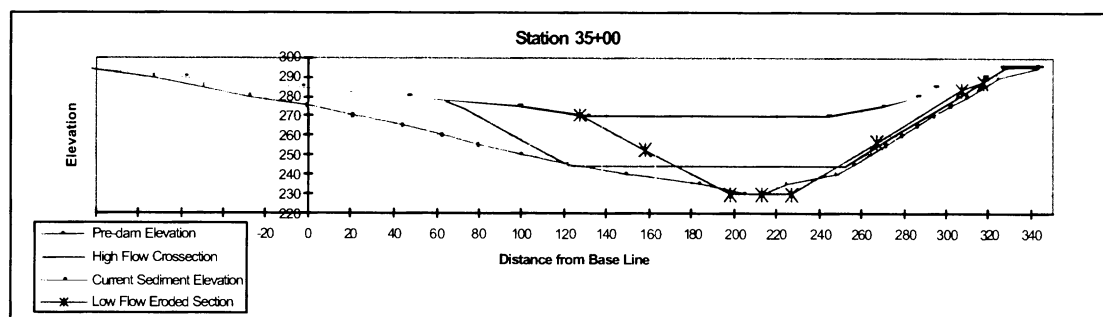


Figure 36. River Section Showing Width for 10-Year Flow

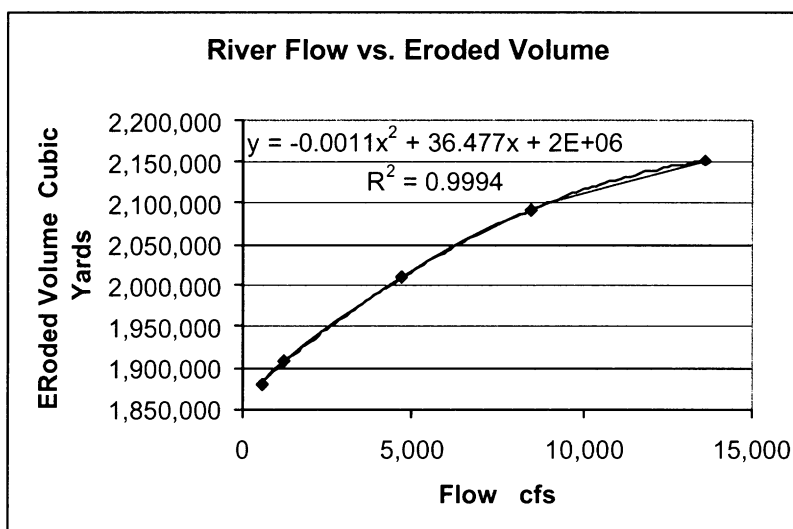


Figure 37. Eroded Volume vs. Flow

Based on the eroded volume curve developed from regression analysis of Figure 37, the incremental eroded volume can be determined. For example, if at some point in time after dam removal the river experiences a flow of 5,100 cfs and the highest previous flow the river experienced was 5,000 cfs, the amount of material eroded would be the volume eroded for 5,100 cfs minus the volume previously eroded for the maximum flow of 5,000 cfs.

To analyze the concentration of TSS the river experiences during this high flow event the differential volume of sediment is multiplied by the in-situ unit weight of the sediment and divided by the total weight of water and sediment which flowed through the river during the time period (one day), to provide sediment concentrations in parts per million. To simulate sediment concentration variation over time, various sequences of daily flow records were used. The results of this analysis are presented below and in graphs of TSS versus time, for various flow conditions in the Appendices.

5.2. RESULTS OF ANALYSIS

As shown in the graphs of TSS versus time after dam removal, below and in Appendices, TSS concentrations immediately after dam removal are very high. This initial high concentration represents initial flushing of fine material in the river channel and slope failures of the embankments that result in formation of a well-defined river channel.

After the initial 3 to 4 day period, suspended sediment concentrations begin to drop and a river channel is formed over the next 1 to 2 months with relatively stable embankments. However, the next flow that exceeds the flow experienced during the channel formation will cause the river to be slightly wider and cause an incremental amount of sediment on the embankments to erode. This next higher flow results in a spike in TSS.

SEDIMENT BEHAVIOR ANALYSIS REPORT

Figure 38 illustrates the process. Initial TSS concentrations are high following dam removal. The years presented in the figures are not the actual flow record for particular years but are chosen as reference only. In this case a series of 3 low flow years began in 1941 but subsequent average flow and high flow years were chosen from flow year groups that matched the average and high flow criteria, not years necessarily following the 1941 group. The start date will be some time in October. October 1st is shown for convenience but is not meant to reflect the actual start date.

As shown, during the initial year, the flows are low compared to average river flows but several high levels of TSS are experienced. However, while the flows increase in the spring of the first year, no TSS spikes are experienced because a previous flow exceeded all spring flows.

The second year shows several spikes of TSS as flow levels successively increase. Successive high flows in the 3rd and fourth years do not cause TSS spikes and none is experienced until a higher flow in the 5th year. This illustrates the rapidly declining frequency of TSS spikes. Actual behavior will depend on flows. A range of flow conditions is further illustrated in Appendices.

This graph and the graphs in the Appendices illustrate that after the initial period of sediment erosion, high TSS events resulting from embankment failure will occur only in events that become progressively more infrequent. For all the simulations conducted, only two or three TSS spikes, lasting approximately one day, will occur after the initial three-year period after dam removal.

Figure 39 shows the results of thirty continuous years of simulation from flow records collected near the dam, from 1944 to 1974, covering dry and wet periods in the basin. Only two TSS spikes, lasting approximately one day, occur after the initial three-year period. As shown, in this thirty-year period there are numerous high flow events without TSS spikes but only two events, which exceed the previous high flows, cause TSS spikes.

While the exact floods that will occur post-dam removal are unknown, the likelihood of an extreme event can be calculated for a five-year period based on the assumption that an extreme event is represented by the 7Q10 flow, which was calculated to be 4,950 cfs. A five-year flood was estimated to be 6,100 cfs. The likelihood that a 7Q10 flood level flow will occur for *one* day during a five-year period is relatively high, approximately 86%.

SEDIMENT BEHAVIOR ANALYSIS REPORT

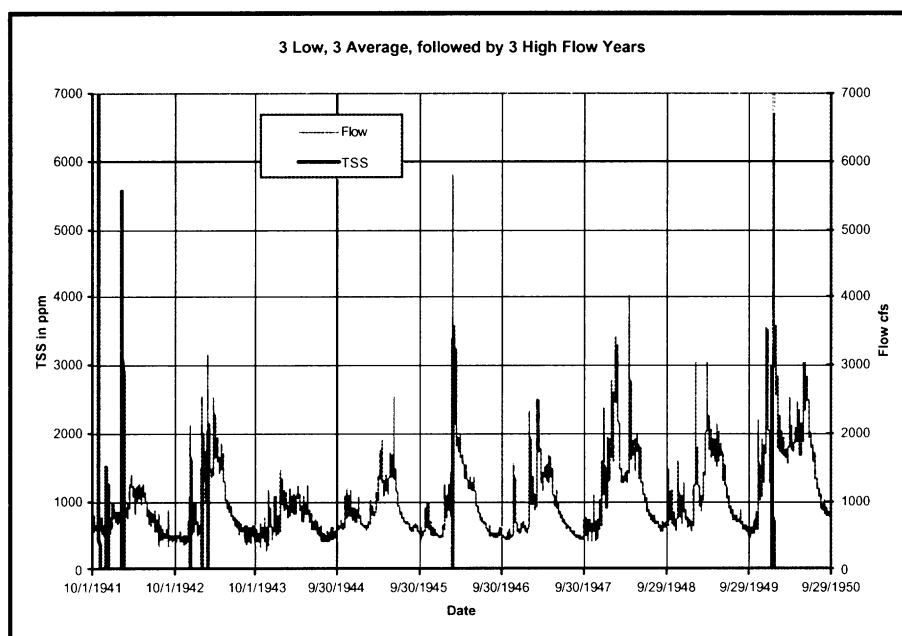


Figure 38. Three Low Flow Years followed by Three Average Flow Years

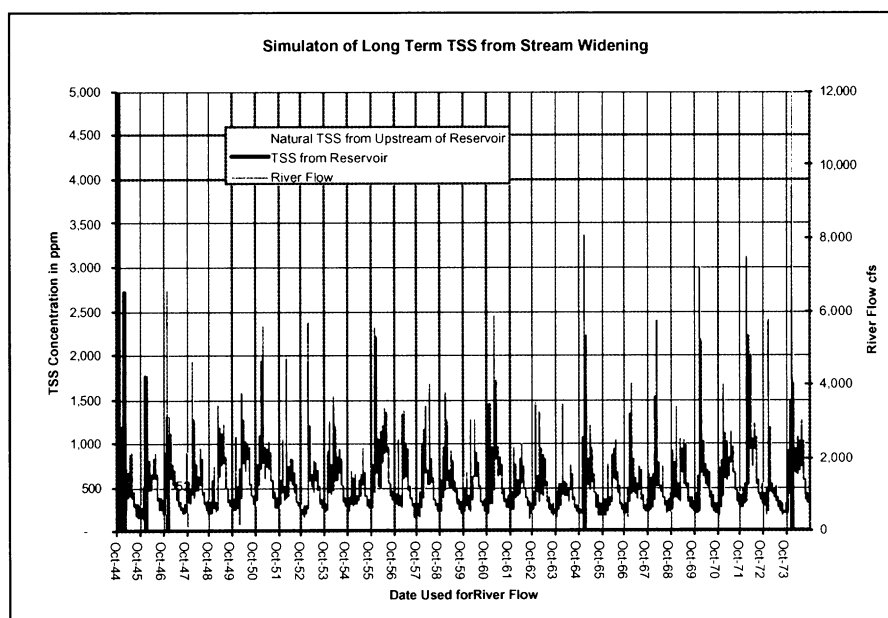


Figure 39. Thirty Years of Simulation

5.2.1. WORST CASE ANALYSIS

As discussed above, an infinite number of flow arrangements could occur after dam removal. The scenario that removes all sediment from the reservoir in first post dam year would be considered the "best case" scenario. By comparison, the "worst case" could be considered the condition that incrementally increased the yearly high flow each year for a number of years in a row. As flow records indicate, this sequence of flows would be highly unlikely to occur but could be considered the worst case from the perspective of frequency of events.

To simulate this condition, the range of flow events equally spaced, from the lowest recorded yearly high flow value to the highest was created. This flow sequence reflects an annual increase in yearly high flow over the previous post-dam high flow condition. For illustration of a particular sequence, in the first year after dam removal the highest flow through the reservoir reach was assumed to be 1,000 cfs, and in each subsequent year for ten years the flow increased over the previous year until the highest flow of record was reached. In this scenario each year would see an event that caused erosion and suspended sediment. As illustrated in the flow records shown previously, it is highly unlikely that yearly high flows will reach incrementally higher values in each subsequent year. The condition shown in Table 10, therefore, illustrates a sequence of events that has a very low probability of occurring. This sequence of flows represents a condition that has numerous events after the initial dam removal year and illustrates the trend in TSS in response to subsequent high flow events.

It is possible that the increments could be smaller (say increasing for 15 straight years in a row for instance) but not probable. Appendix 7.2 provides other possible arrangements of flow sequences. These sequences also show the same tendency for the affects on suspended sediment and turbidity.

As shown in Table 10, the level of TSS decreases with successive flows and the "natural" TSS from upstream of the dam increases with successively higher flows. The result is that TSS from the reservoir becomes an ever-decreasing percentage of the natural sediment regime with increasing flows and increasing time after dam removal.

There is approximately a 41% likelihood that a one-day average flow of 7,500 cfs (approximately equal to a 10 year RI storm event) will occur within the first 5 years after dam removal. After a flow of 7,500 cfs, TSS declines significantly in absolute terms and as a portion of the natural sediment regime. Estimated turbidity in the CR is also shown based on the relationships between turbidity and TSS discussed in section 4.2. For this analysis the CR was assumed to experience flood flows at the same time that WSR flows increase. It is important to note that each of the events shown in Table 10 is a one-time event. Flows equal to or less than a specific flow after the flow event will not cause increase TSS in the WSR.

SEDIMENT BEHAVIOR ANALYSIS REPORT

Table 10. Suspended Sediment Concentrations in the WSR for Ten Years of Successively Higher Annual Flows

River Flow cfs	Additional TSS in WSR from Event ppm	Natural Suspended Sediment entering Reservoir ppm	Increase in WSR TSS as a Percentage of Natural	CR TSS from Reservoir Sediment ppm	CR Turbidity from Reservoir Sediment NTU	Volume of Sediment Eroded CY
2,300	4,230	61	6884%	70	25	42,701
3,600	2,467	236	1047%	49	15	38,983
4,900	1,640	594	276%	37	9	35,265
6,200	1,159	1,204	96%	28	7	31,547
7,500	846	2,131	40%	21	5	27,829
8,800	624	3,442	18%	16	4	24,111
10,100	460	5,204	9%	12	3	20,393
11,400	333	7,483	4%	9	2	16,675
12,700	232	10,345	2%	6	2	12,957
14,000	150	13,859	1%	4	1	9,239

6. CONCLUSIONS AND SUMMARY OF RESULTS

6.1. EXISTING CONDITIONS

6.1.1. ACCUMULATED SEDIMENT

Condit Dam is located approximately 3 miles upstream of the mouth of the WSR. The dam has accumulated over 2.42 mcy of sediment in the 90-acre reservoir since it was constructed in 1913. Most of the sediment is composed of small sized particles that are easily eroded and carried as suspended sediment in a river.

6.1.2. WHITE SALMON RIVER FLOW

Average daily flows have been recorded just upstream of the mouth of the WSR since 1912. The recorded flows range from just over 500 cfs to 14,000 cfs. Peak flows have been recorded up to 45,000 cfs. The river has a good base flow from glaciers on Mount Adams. Average daily flow is 1,005 cfs. An average daily flow of at least 3,900 cfs has occurred on average every other year (2 year flood). An average 7-day flow of 4,950 cfs occurs, on average, once every ten years.

6.1.3. TURBIDITY AND SUSPENDED SEDIMENT

Based on the known volume of accumulated reservoir sediment a relationship between WSR flow and suspended sediment concentrations in the WSR was developed, which predicts the highest concentrations of sediment during the higher flows ($TSS \text{ in mg/L} = 2 \times 10^{-9} \times Q_r^3$).

The relationship between turbidity measured in NTU and suspended sediment concentration measured in mg/L was investigated by conducting a laboratory analysis and by reviewing collected data provided by the USGS. The results from the laboratory analysis did not agree well with the USGS data collected from samples on the CR. Based on USGS data collected over many years in the CR system, TSS readings in mg/L are approximately 4 times as large as turbidity readings in NTUs for the same sample for TSS values below 40 ppm and approximately $(TSS - 19.7)/1.967$ above 40 ppm. Data was taken from gage sites on the CR downstream of the confluence of the WSR and CR. TSS readings varied between 1 and 360 mg/l and turbidity varied from less than 1 NTU to over 73. Average TSS in the CR is about 25 mg/l or about 8 NTU.

6.2. SEDIMENT REMOVED

Removal of the Condit Dam on the WSR will erode sediment accumulated in the reservoir since 1913. Sediment erosion by natural river flow will cause a new river channel to form in the reservoir reach in the rock-lined channel that contained the river prior to dam construction. The eroded sediment will move downstream. Particles smaller in size than .1mm will be suspended in the water column as the river erodes a new channel. Larger particles will roll along the bed of the river as bedload.

The larger particles among the sediment will settle near the mouth of the WSR either in the WSR or the CR. Suspended sediment will settle out of the water column at various locations starting at the mouth of the WSR. The smallest of these particles, those smaller than .004 mm will remain in suspension through the entire CR system.

Between 1.6 mcy and 2.2 mcy of sediment will be eroded from the reservoir area. The amount of material eroded will be dependant on behavior of embankment slopes containing the smaller particles immediately after the dam is breached. Unknown conditions in the sediment such as buried and submerged logs will affect the extent to which the smaller particles erode and flow out of the reservoir immediately after the breach.

6.3. EFFECTS ON WATER QUALITY

Erosion of sediment will cause increased turbidity and TSS in both the CR and the WSR. Significant effects on other water quality parameters are not expected. The level of turbidity will vary with time. Initially turbidity will be very high in both rivers but will decline rapidly.

6.3.1. WATER QUALITY AFTER DAM REMOVAL

Effects on water quality in the rivers from erosion of sediment can be divided into four distinct time periods; 1) draining the reservoir which will happen for approximately 6 hours after the dam is breached, 2) formation of a new river channel in the reservoir reach, which will begin immediately and take up to a year after the dam is breached, 3) formation of a surface drainage system in the remaining sediment above the river and out of the flood plain, which will begin immediately and may take up to 5 years after the dam is breached to complete, and 4) formation of progressively wider flood plains, which will continue indefinitely.

6.3.2. DRAINING THE RESERVOIR

If no significant blockage of the outlet is encountered, in approximately 6 hours after the dam is breached the reservoir will drain and most of the small sized sediment particles immediately upstream of the dam will erode downstream. Draining the reservoir may take longer if blockages are encountered. Water draining from the reservoir will increase river flow downstream of the dam, initially to around 10,000 cfs. Normal flow will resume thereafter. Normal WSR flow is typically between 600 and 700 cfs during the autumn months of the year.

Sediment erosion during the first 6 hours will result in TSS levels in the WSR of approximately 150,000 ppm. A mixing zone of the rivers will be created for approximately 3 miles downstream of the confluence of the WSR and the CR in the CR as water from the WSR mixes with CR water. In this mixing zone concentrations of TSS will vary from the higher concentrations in the WSR to lower concentrations from dilution by the full CR flow. The average dilution ratio during the initial draining period

SEDIMENT BEHAVIOR ANALYSIS REPORT

will be approximately 23 to 1. The extent to which the suspended sediment concentrations are diluted will depend on CR flow levels.

Downstream of the mixing zone peak concentrations in the CR during the initial 6 hours will be higher due to the higher flow from the WSR during the draining of the reservoir. Peak TSS concentrations will reach approximately 3,500 ppm (1,770 NTU) during this period. TSS concentrations in the CR will decline downstream for several reasons; 1) larger suspended particles will continue to settle out of the water column in the Bonneville pool, 2) during the initial 6 hours particles will travel at different velocities causing a longitudinal spreading of the initial sediment plume, and 3) tributaries to the CR will add flow to the river and continue to dilute suspended sediment concentrations downstream of Bonneville Dam.

At Bonneville Dam, located 23 miles downstream of the WSR, settling of suspended sediment essentially ceases because larger particles have settled in the Bonneville Dam pool and water velocities increase downstream of Bonneville Dam. Peak TSS concentrations at Bonneville Dam are expected to be approximately 1,580 ppm (790 NTU). Downstream of Bonneville Dam TSS concentrations will decline slightly from dilution and longitudinal spreading of the initial plume.

6.3.3. RIVER CHANNEL FORMATION

6.3.3.1. *White Salmon River*

After the reservoir has drained, flow in the WSR downstream of the dam will return to normal, essentially the same flow as upstream of the dam. Erosion of sediment will be due to 1) failure of saturated slopes as the river starts the formation of a channel and 2) erosion of bed sediments as the river erodes the channel vertically. Due to the nature of accumulated sediment, the precise failure slope for embankments cannot be predicted. A geotechnical investigation conducted on reservoir sediments predicts embankment slopes of 30 degrees to the horizontal for newly formed surfaces. Saturated material during the period soon after the reservoir is drained may form even flatter (smaller) angles. Conditions that cannot be investigated, such as the location and quantity of buried logs, will also affect the extent to which sediment erodes as the river channel is formed.

The rock channel that defined the pre-dam river sets boundaries for the river channel. Based on the pre-dam surfaces and a variation in post dam embankment slopes from 1 to 3 (geotechnical report) to 1 to 10 (highly saturated slopes soon after the breach), a range of volume and sediment concentrations as a function of time were developed. The maximum anticipated volume that will erode is 2.2 mcy and the minimum volume is 1.6 mcy. Time required to erode the material will depend on river flow during the months after the breach and the nature of the matrix of sediment and woody debris in the reservoir.

Table 11 below shows the approximate range of *average daily* suspended sediment concentrations during the river channel formation. Because of the uncertainty of how and when embankments will form and the lack of adequate analytical tools to help determine sediment concentrations, these results are approximate. Concentrations can and will vary

as slopes fail and embankments develop. When this happens, short-term TSS concentrations will possibly increase beyond the values shown below. Sometime after sediment from these failures erodes, concentrations may be much lower than those shown in Table 11 through Table 14. Construction activities to remove blockages in the river may cause temporary short-term peaks in TSS concentrations beyond those shown in the Tables.

The concentrations are, however, based on erosion of known quantities of sediment and statistical knowledge of river flows, and represent the best information available on average values at the time periods referenced.

It is important to note that higher initial TSS concentrations are related to the lower future concentrations. In other words, the quicker the sediment erodes the less is available to erode in the future. For river flows experienced during an average year, most of the suspended sediment erosion will occur in the first 6 months. During this period TSS concentrations will be elevated most of the time, but declining steadily. After this period elevated TSS concentrations will be episodic rather than constant. The episodic nature will result from storm/high flow events around and above the reservoir.

6.3.3.2. *In-Lieu Site and Mixing Zone*

The volume of the pool at the mouth of the WSR, called the In-lieu Site, is controlled by the elevation of the Bonneville Pool. An estimated 673,500 cubic yards of eroded material will settle and remain in this site. The site will fill, mostly with silt and small sand particles within the first month, most of that within the first week. TSS concentrations of WSR water entering the CR mixing zone will be decreased, initially up to 1/3, due to settling in this area during the first week. As the mouth of the WSR fills, settling and reduction in TSS decreases. After the first week, settling in the In-lieu site will not significantly reduce TSS levels entering the CR.

6.3.3.3. *Columbia River Downstream of the Mixing Zone*

Based on average CR flows during autumn, dilution of the fully mixed WSR water and CR water should reduce TSS concentrations just downstream of the mixing zone by approximately 150 times. Larger particles in the suspended material will continue to settle in the Bonneville Pool. As discussed previously, construction activities and embankment formation may cause short-term incidents of higher TSS than shown in Table 11.

The Bonneville Pool will capture just over 1/2 of all the suspended sediment entering the CR from the WSR during this period. TSS concentrations decline steadily over the 20 miles from the mixing zone to Bonneville Dam as settling in the pool occurs to the levels shown in Table 12. Downstream of Bonneville TSS concentrations will decline slightly from dilution from the flow of tributaries to the CR.

6.3.4. UPLAND SURFACE EROSION AND CONTOUR FORMATION

A river channel will begin to form in the reservoir area immediately after the dam is breached. Sometime within the first week a well-defined channel will be apparent in the

reservoir area located along the pre-dam river alignment. Due to the depth of this channel, sediment deposited in the areas above the channel will not be exposed to river flow. Initially this area will be devoid of vegetation and will have no defined surface drainage configuration. Rain and snow events during the first year will create new drainage patterns in these areas. Surface flow from higher elevations will also create new drainages and erode pre-dam drainages.

Analysis methods used for estimating soil loss in agricultural fields and construction sites were used to estimate the volume and frequency of material eroded from these areas. Two types of surfaces, steep and flatter slopes, were identified and defined by surface slopes. A total of 60 acres of the reservoir are anticipated to be subject to this type of erosion. Approximately 1/3 of the area is relatively flat and the remaining 2/3 is relatively steep.

Approximately 19,000 cubic yards of material is anticipated to erode during the first year from formation of upland contours and surface conveyances. As vegetation and conveyances become developed after the first year, the volume of material eroded from these upland locations decreases. Estimated time for normal surface erosive behavior typical for these types of slopes and materials to return is approximately 3 years. To simulate the decrease in yearly erosion, the volume of sediment eroded in the 2nd and 3rd years after dam breach was reduced to 66% and 33%, respectively, of the erosion in the 1st year.

6.3.4.1. *Suspended Sediment Concentration in the White Salmon River*

Upland erosion will begin in the first year shortly after the dam is breached and continue for approximately three years. Suspended Sediment from this source will be episodic. Precipitation and snow melt will cause peak TSS concentrations in the WSR to be approximately 158 ppm the first year, declining with each successive year by factors discussed above until after the 3rd year sediment from upland sources will be only the volume typical of a similar terrain elsewhere in the watershed. Table 11 through Table 14 summarize anticipated TSS and NTU levels from this source.

6.3.4.2. *Suspended Sediment in the Columbia River*

Due to the extent of dilution of WSR water in the CR, suspended sediment from upland contour formation should not exceed 2 ppm or approximately .5 NTU.

6.3.5. FLOOD PLAIN FORMATION AND LONG TERM EROSION

A river channel will be established in the pre-dam channel soon after the dam is breached. After the first year, the channel bed will have eroded down to an elevation near the pre-dam thalweg elevation and a channel flood plain somewhat narrower than existed prior to dam construction will exist. Subsequent to the first year, channel widening and down cutting may occur during high flows. This type of erosion will occur primarily during flow events that exceed any experienced during this first year. The

SEDIMENT BEHAVIOR ANALYSIS REPORT

exact sequence and size of flows in any year will depend on weather conditions in that year.

Higher flows will cause higher water elevations that will access embankments that would otherwise be out of the river flow. Exposure of the embankments to river flow may cause them to fail and form a flood plain at a wider dimension than before the high flow event. For the purpose of this study, suspendable material from the failure of the embankment is assumed to be eroded during the one-day high flow event.

To simulate this type of behavior, river width was analyzed for a series of flows based on per-dam cross sections. A relationship between river width and flow was developed to analyze the incremental volume of material eroded for a flow that exceeded any previous post-dam flow. Based on this relationship and historic flow records, different sequences of flows were used to analyze suspended sediment concentrations from river widening.

This analysis shows that most of the widening events occur in the years immediately following dam removal. In general, the longer the time after dam removal, the less likely is an event that will cause embankment failure and widening. No definitive description can be given regarding the intensity of TSS concentrations and the frequency of such events. A simulation of 30 years showed only two events beyond five years after dam removal.

A worst-case analysis was conducted that assumed incrementally higher flow events in each successive year until the flow of record was reached. This showed that TSS from reservoir sediments relative to natural suspended sediment declines rapidly after a high flow event of 7,500 cfs. In general the more events that occur the smaller the TSS concentrations will be.

SEDIMENT BEHAVIOR ANALYSIS REPORT

Table 11. Summary of Suspended Sediment Concentrations in ppm

Time	WHITE SALMON RIVER							Columbia River 20 Miles Upstream of Bonneville Dam						
	River Channel Formation ^A			Upland Contour ^B Formation		Flood Plain Formation ^C		River Channel Formation ^A			Upland Contour ^B Formation		Flood Plain Formation ^C	
	High	Anticipated	Low	Peak	Average	Possible Peak	Probable Peak	High	Anticipated	Low	Peak	Average	Possible Peak	Probable Peak
6 hours	250,000	150,000	100,000					5,833	3,500	2,333				
1 day	250,000	150,000	100,000	158	22			1,667	294	196	1.1	0.1		
7 days	60,000	30,000	15,000	158	22			400	20	10	1.1	0.1		
30 days	12,000	6,000	4,000	158	22			80	3	23	1.1	0.1		
90 days	6,000	3,000	1,000	158	22			40	2	7	1.1	0.1		
6 months	3,000	200	100	158	22			20	1	1	1.1	0.1		
1 year	3,000	200	100	158	22	6,000	4,000	20	1	1	1.1	0.1	40	27
2 years				104	14	4,000	2,500				0.7	0.1	27	17
3 years				62	7	3,000	1,500				0.4	0.0	20	10
4 years ^D				62	7	3,000	1,500				0.4	0.0	20	10
5 years ^D				62	7	3,000	1,000				0.4	0.0	20	7
10 year						1,000	850						7	6
20 years						1,000	500						7	3

See Notes following Table 14

SEDIMENT BEHAVIOR ANALYSIS REPORT

Table 12. Summary of Suspended Sediment Concentrations in ppm

Time	Columbia River Immediately Upstream of Bonneville Dam							Columbia River near Quincy, Oregon						
	River Channel Formation ^A			Upland Contour ^B Formation		Flood Plain Formation ^C		River Channel Formation ^A			Upland Contour ^B Formation		Flood Plain Formation ^C	
	High	Anticipated	Low	Peak	Average	Possible Peak	Probable Peak	High	Anticipated	Low	Peak	Average	Possible Peak	Probable Peak
6 hours	2,630	1,580	1,100					2,192	1,316	917				
1 day	750	156	100	0.5	0.1			625	130	83	0.4	0.1		
3 days	330	43	20	0.5	0.1			275	36	17	0.4	0.1		
7 days	180	8	4	0.5	0.1			150	6	3	0.4	0.1		
30 days	36	1	1	0.5	0.1			30	1	1	0.4	0.1		
90 days	18	1	1	0.5	0.1			15	1	0	0.4	0.1		
6 months	9	1	0	0.5	0.1	18	12	8	1	0	0.4	0.1	15	10
1 year	9	1	0	0.5	0.1	18	12	8	1	0	0.4	0.1	15	10
2 years				0.3	0.0	12	8				0.3	0.0	10	6
3 years				0.2	0.0	9	5				0.2	0.0	8	4
4 years ^D				0.2	0.0	9	5				0.2	0.0	8	4
5 years ^D				0.2	0.0	9	3				0.2	0.0	8	3
10 year						3	3						3	2
20 years						3	2						3	1

See Notes following Table 14

SEDIMENT BEHAVIOR ANALYSIS REPORT

Table 13. Summary of Turbidity in NTU

Time	WHITE SALMON RIVER							Columbia River 20 Miles Upstream of Bonneville Dam						
	River Channel Formation ^A			Upland Contour ^B Formation		Flood Plain Formation ^C		River Channel Formation ^A			Upland Contour ^B Formation		Flood Plain Formation ^C	
	High	Anticipated	Low	Peak	Average	Possible Peak	Probable Peak	High	Anticipated	Low	Peak	Average	Possible Peak	Probable Peak
6 hours	127,090	76,250	50,830					2,960	1,770	1,180				
1 day	127,090	76,250	50,830	70	6			837	139	89	0.3	<0.1		
3 days	55,910	33,030	15,240	70	6			362	34	10	0.3	<0.1		
7 days	30,490	15,240	7,620	70	6			193	4	2	0.3	<0.1		
30 days	6,090	3,550	1,770	70	6			30	1	1	0.3	<0.1		
90 days	3,040	1,010	500	70	6			10	1	1	0.3	<0.1		
6 months	1,510	91	41	70	6	3,040	2,020	5	0.3	0.2	0.3	<0.1	10	7
1 year	1,510	15	6	70	6	3,040	2,020	5	0.3	0.2	0.3	<0.1	10	7
2 years				43	4	2,020	1,260				0.2	<0.1	7	4
3 years				21	2	1,510	750				0.1	<0.1	5	3
4 years ^D				21	2	1,510	750				0.1	<0.1	5	3
5 years ^D				21	2	1,510	500				0.1	<0.1	5	2
10 year						500	420						2	1
20 years						500	240						2	1

See Notes following Table 14

SEDIMENT BEHAVIOR ANALYSIS REPORT

Table 14. Summary of Turbidity NTU

Time	Columbia River Immediately Upstream of Bonneville Dam						Columbia River near Quincy, Oregon					
	River Channel Formation ^A			Upland Contour ^B Formation			River Channel Formation ^A			Upland Contour ^B Formation		
	High	Anticipated	Low	Peak	Average	Possible Peak	High	Anticipated	Low	Peak	Average	Possible Peak
6 hours	1,330	790	550				1,100	660	460	-	-	
1 day	370	69	41	0.1	<0.1		307	56	32	0.1	<0.1	
3 days	158	12	5	0.1	<0.1		130	9	4	0.1	<0.1	
7 days	82	2	1	0.1	<0.1		66	2	1	0.1	<0.1	
30 days	9	0.3	0.3	0.1	<0.1		8	0.2	0.2	0.1	<0.1	
90 days	5	0.2	0.1	0.1	<0.1		4	0.2	0.1	0.1	<0.1	
6 months	2	0.2	0.1	0.1	<0.1	5	2	0.1	0.1	0.1	<0.1	4
1 year	2	0.2	0.1	0.1	<0.1	5	2	0.1	0.1	0.1	<0.1	4
2 years				0.1	<0.1	3				0.1	<0.1	3
3 years				0.1	<0.1	2				<0.1	<0.1	2
4 years ^D				0.1	<0.1	2				<0.1	<0.1	2
5 years ^D				0.1	<0.1	2				<0.1	<0.1	2
10 year						1						1
20 years						1						1

See Notes following Table 14

Notes on Summary Tables.

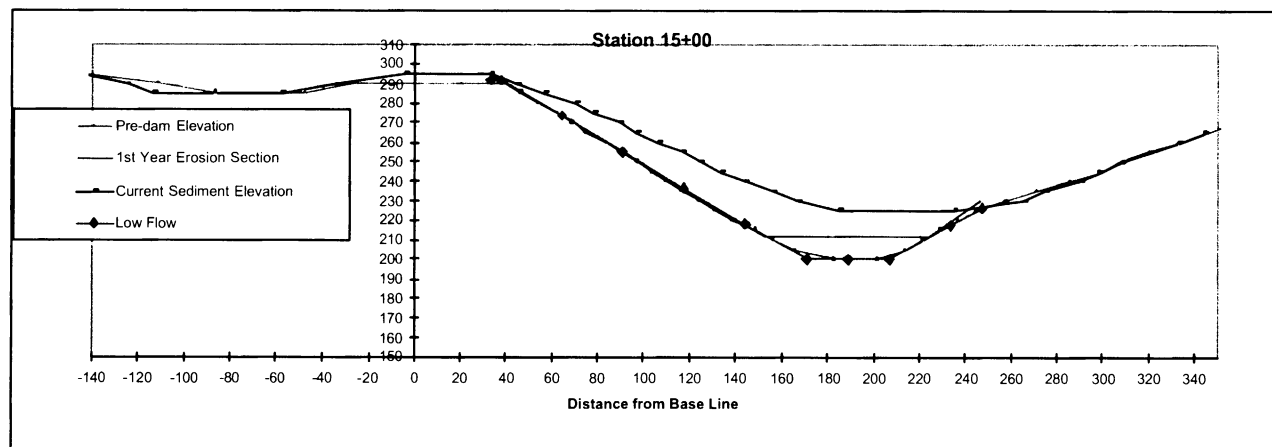
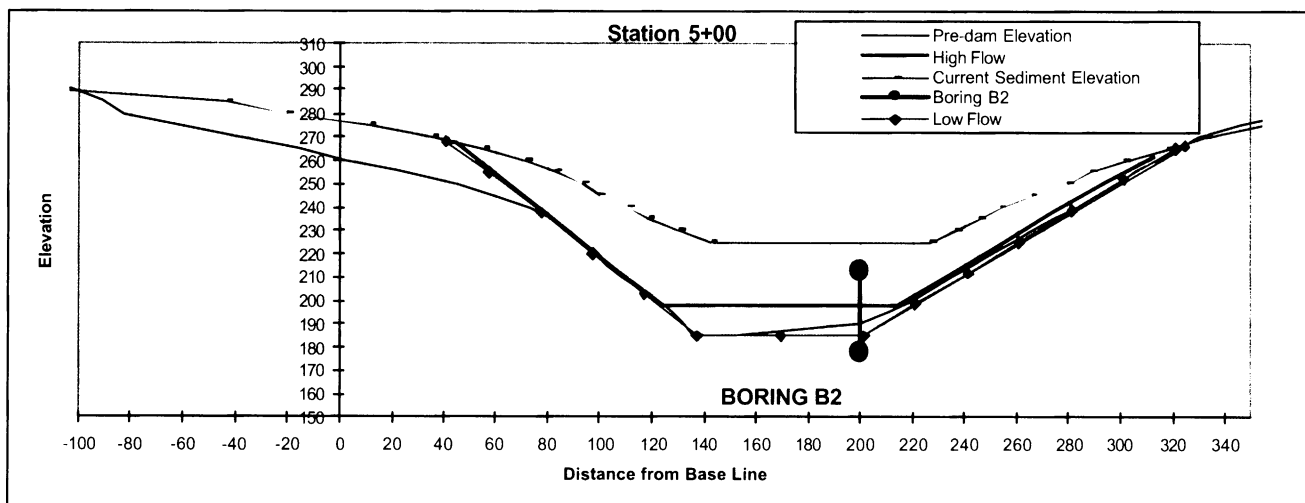
- A. River Channel formation will create TSS and turbidity levels that remain relatively high throughout the period. The values shown are one-day averages. Higher short-term concentrations, for periods less than one day, may occur as indicated by the "High" column. Periods of lower average daily concentrations will occur as indicated by the "Low" column. Anticipated concentrations represent average daily concentrations that account for removal of approximately 2.2 mcy of sediment in the first 6 months post-dam. However, depending on WSR flow conditions the process of riverbed erosion may take up to one year. Levels shown for the period 1 day to 90 days for the Anticipated column are for *sustained* average-daily concentrations. Levels shown for the period 90 days to 6 months for the Anticipated, High and Low columns are for levels that occur at intermittent periods for several days. Levels shown for the period from 6 months to one year for the Anticipated, High and Low columns represent levels associated with specific events but not sustained higher levels. Events that may occur in this period include construction activities, embankment failures, and riverbed erosion from high flows.
- B. TSS from Upland Contour Formation will occur primarily during rain and snowmelt events. Some surface erosion may occur from upland springs. Peaks represent short term, less than one day during a storm event. Average represents values based on average daily rainfall and should be considered average daily concentrations. Average daily rainfall records were used for analysis. Total sediment volume, eroded for one year, assumes some rainfall each day. Upland Contour Formation does not include sediment eroded to form major tributaries to the WSR. Major WSR tributaries will form during the River Channel formation process. Sediment eroded during tributary formation is included in River Channel Formation.
- C. TSS concentrations shown for Flood Plain Formation are assumed to occur for only one day per storm event. Values shown are one-day averages. These events will occur very infrequently, on average less than one day per year after the fifth year.
- D. Upland contour conveyance and formation will take from 3 to 5 years to complete. Weather conditions encountered after dam removal will affect time required to for completion of the process. Analysis was based on a 3-year completion but because of the inherent uncertainty associated with the process the TSS and NTU levels were extended to 5 years.

7. APPENDICES

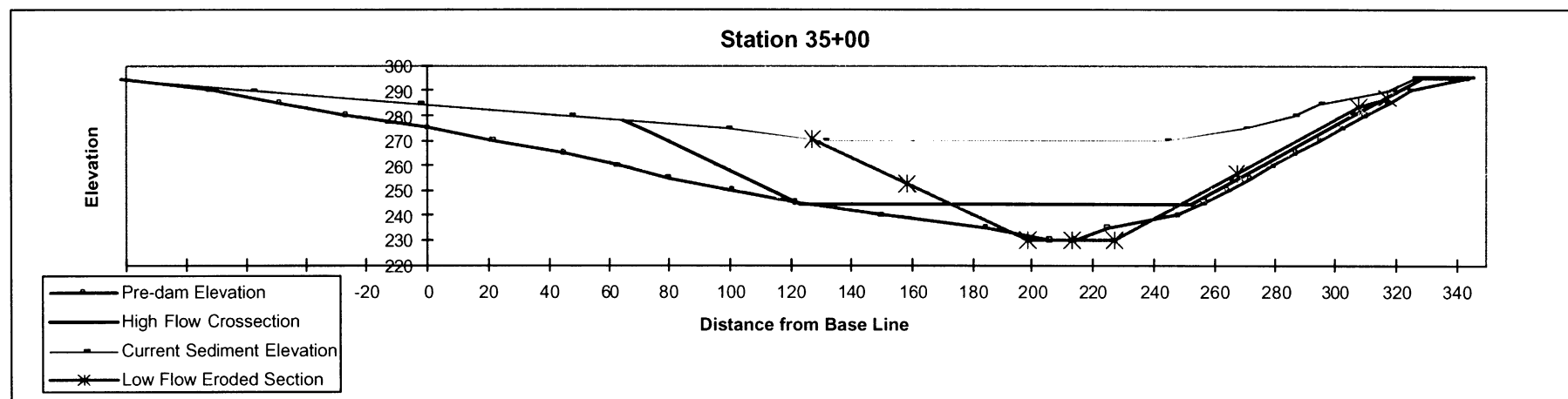
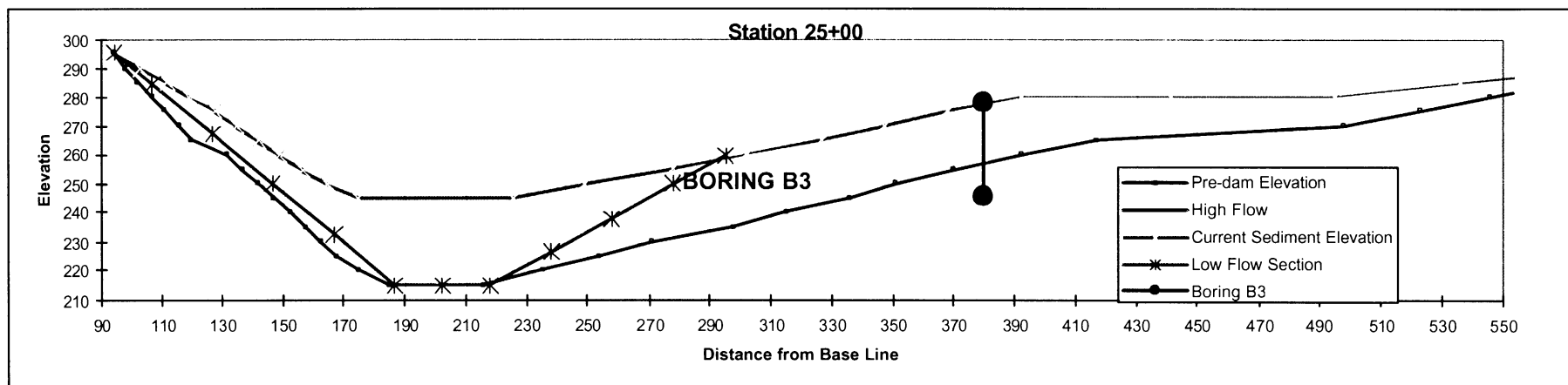
7.1. SELECTED RIVER CROSS SECTIONS SHOWING HIGH AND LOW WATER LEVELS

The following figures are based on pre-dam contours and current sediment topography data. They are graphs of the river cross sections located at intervals of 1,000 feet along the centerline of the river starting approximately 500 feet upstream of the dam. They include low and high flow water elevations and embankment surfaces based on water surface elevation. The high flow surface shown is for a flow of 8,500 cfs. The low flow surface show is for a flow of 565 cfs.

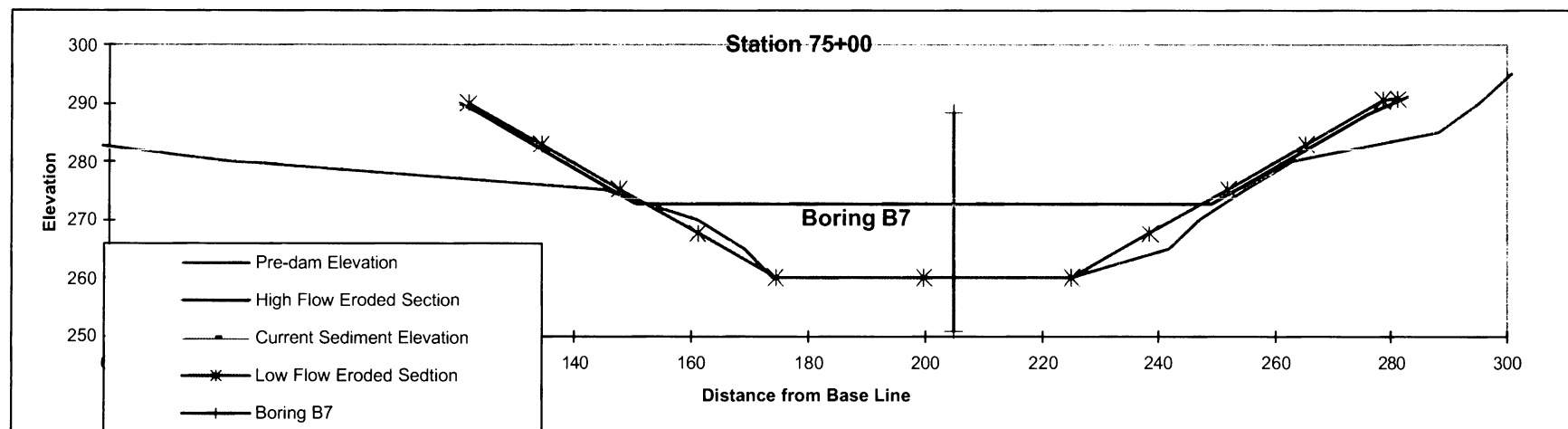
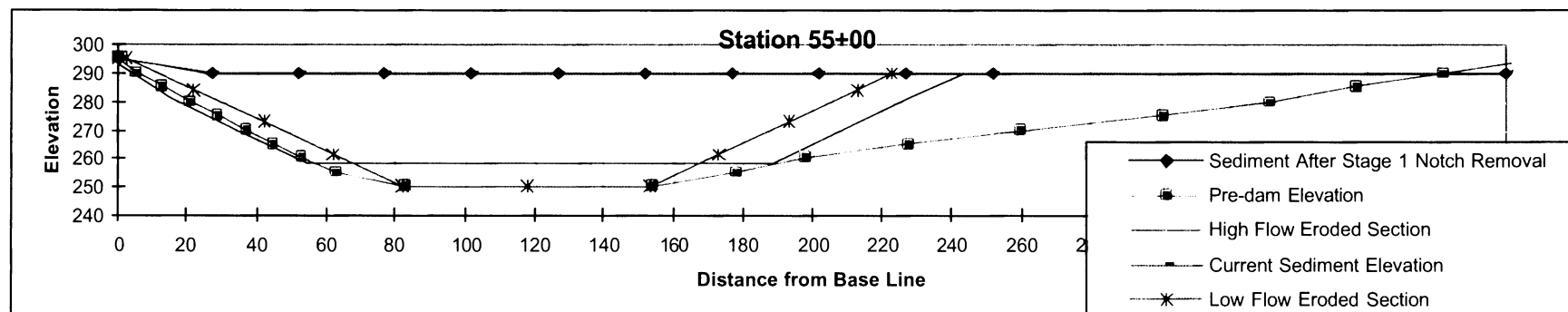
SEDIMENT BEHAVIOR ANALYSIS REPORT



SEDIMENT BEHAVIOR ANALYSIS REPORT



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7.2. EROSION ANALYSIS FOR EQUAL SUCCESSIVE INCREMENTAL FLOWS

The following tables show the “worst Case” analysis for 5,7, and 15 years of successively increasing flows.

Table 15. 5 Years of Successive Flow Increments

River Flow cfs	WSR TSS ppm	Natural WSR Suspended Sediment ppm	Increase in WSR TSS as a Percentage of Natural	CR TSS from Reservoir Sediment ppm	CR Turbidity from Reservoir Sediment NTU
3,600	5,170	236	2194%	103	48
6,200	2,456	1,204	204%	59	21
8,800	1,345	3,442	39%	35	9
11,400	741	7,483	10%	20	5
14,000	361	13,859	3%	10	3

Table 16. 7 Years of Successive Flow Increments

River Flow cfs	WSR TSS ppm	Natural WSR Suspended Sediment ppm	Increase in WSR TSS as a Percentage of Natural	CR TSS from Reservoir Sediment ppm	CR Turbidity from Reservoir Sediment NTU
2,857	4,774	118	4053%	87	38
4,714	2,527	529	478%	56	19
6,571	1,550	1,433	108%	38	9
8,429	1,003	3,024	33%	26	6
10,286	654	5,496	12%	17	4
12,143	411	9,043	5%	11	3
14,000	233	13,859	2%	7	2

SEDIMENT BEHAVIOR ANALYSIS REPORT

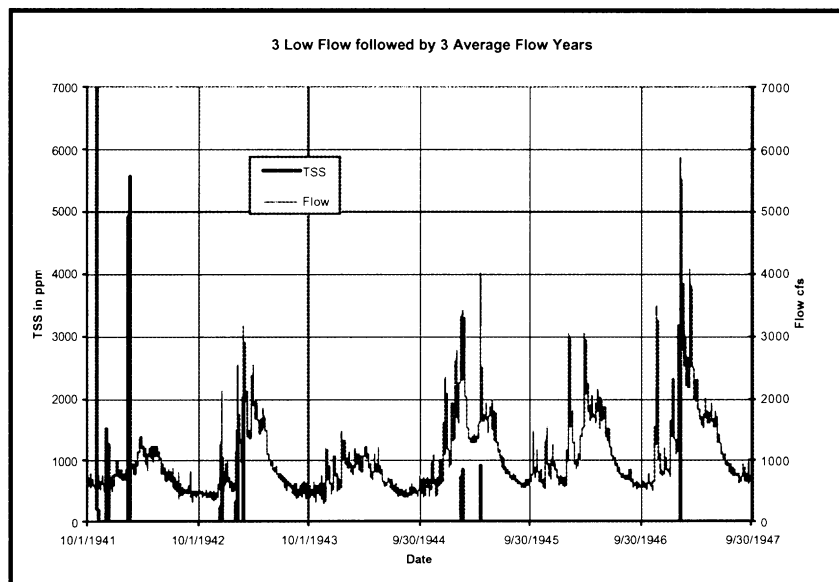
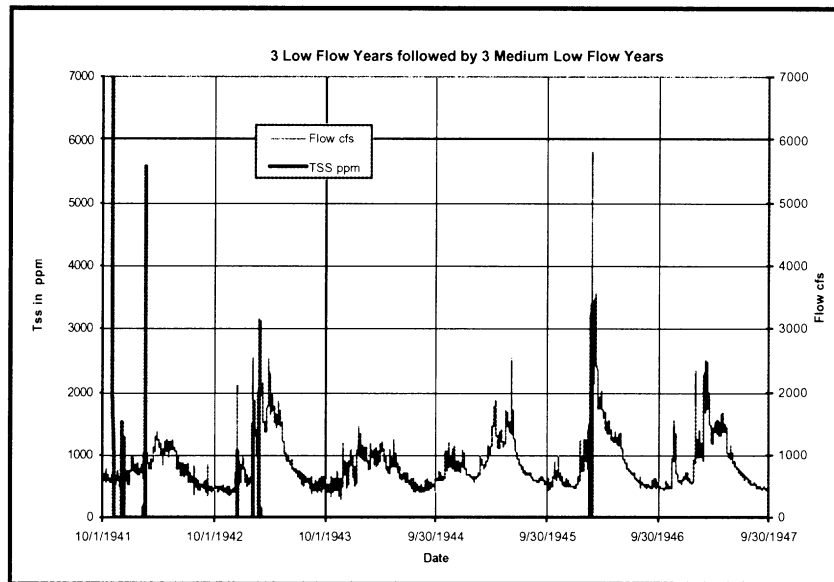
Table 17. 15 Years of Successive Flow Increments

River Flow cfs	WSR TSS ppm	Natural WSR Suspended Sediment ppm	Increase in WSR TSS as a Percentage of Natural	CR TSS from Reservoir Sediment ppm	CR Turbidity from Reservoir Sediment NTU
1,867	3,525	33	10732%	52	17
2,733	2,270	103	2201%	40	10
3,600	1,619	236	687%	32	8
4,467	1,220	450	271%	26	7
5,333	952	766	124%	22	5
6,200	758	1,204	63%	18	5
7,067	612	1,782	34%	15	4
7,933	497	2,522	20%	13	3
8,800	406	3,442	12%	10	3
9,667	330	4,562	7%	9	2
10,533	267	5,902	5%	7	2
11,400	214	7,483	3%	6	1
12,267	168	9,322	2%	5	1
13,133	128	11,441	1%	4	1
14,000	94	13,859	1%	3	1

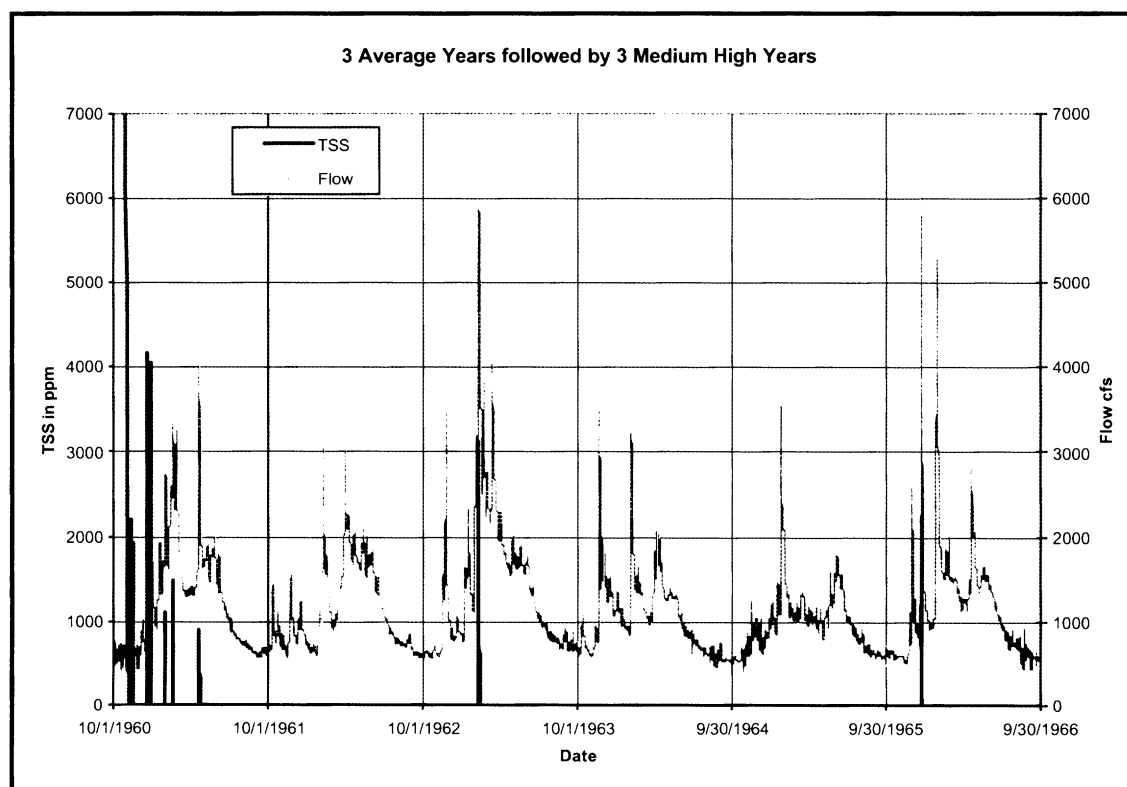
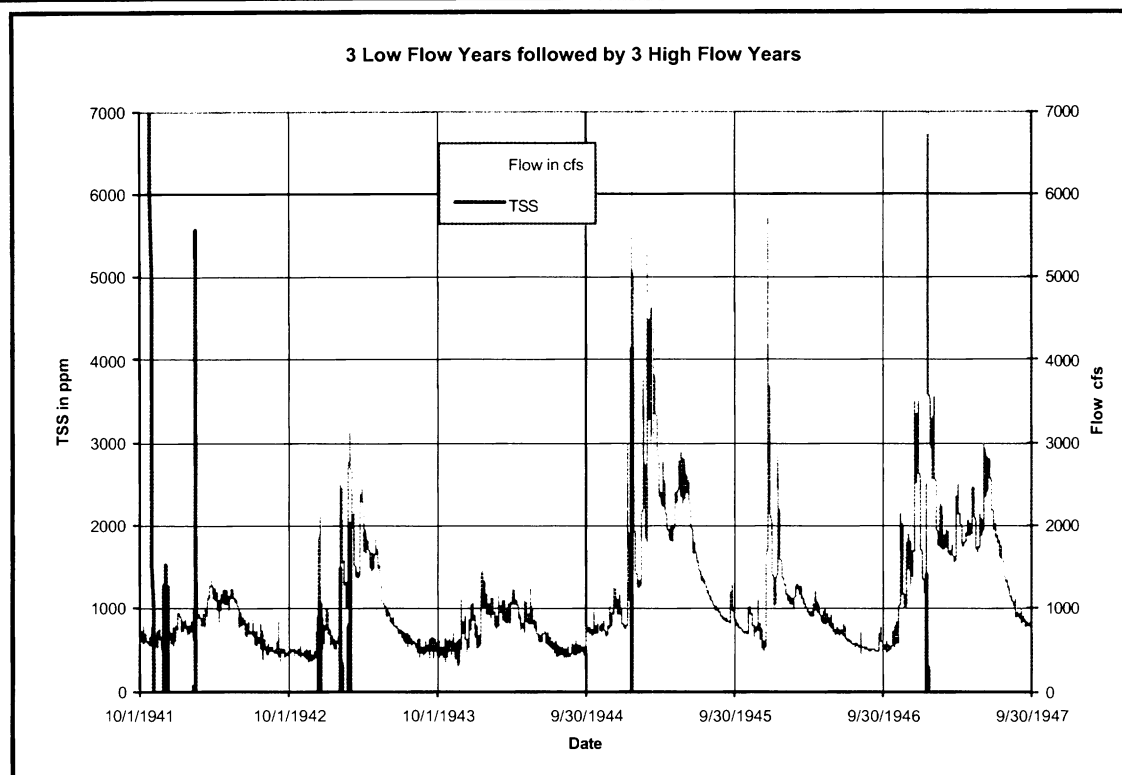
SEDIMENT BEHAVIOR ANALYSIS REPORT

7.3. RESULTS OF RIVER FLOW SEQUENCE EROSION ANALYSIS

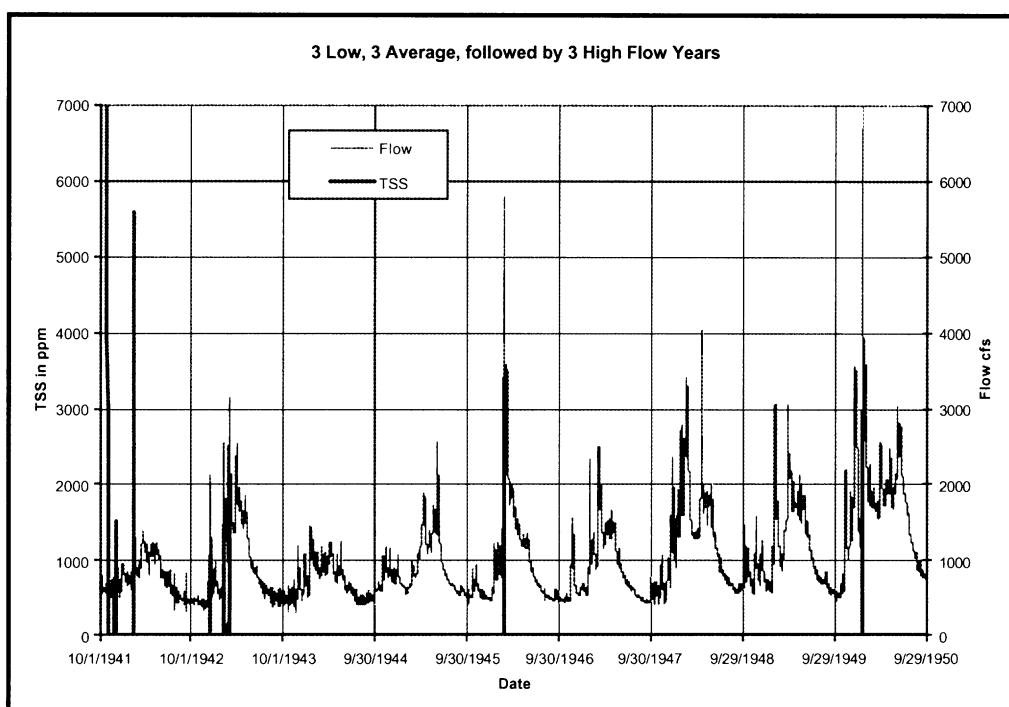
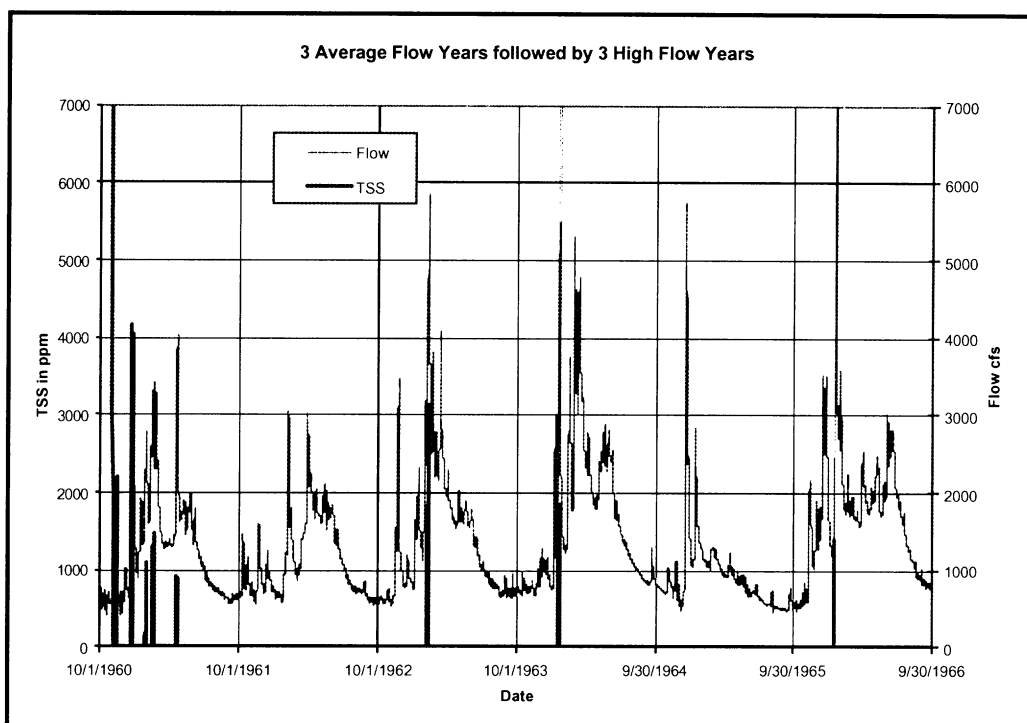
The following figures are the results of analysis of sediment erosion based on river characteristics for HEC-RAS analysis of the reservoir reach. The figures show TSS concentrations resulting from various series of past river flows recorded by the USGS near Bingen, Washington on the White Salmon River.



SEDIMENT BEHAVIOR ANALYSIS REPORT



SEDIMENT BEHAVIOR ANALYSIS REPORT



7.4. RESULTS OF HEC-RAS ANALYSIS

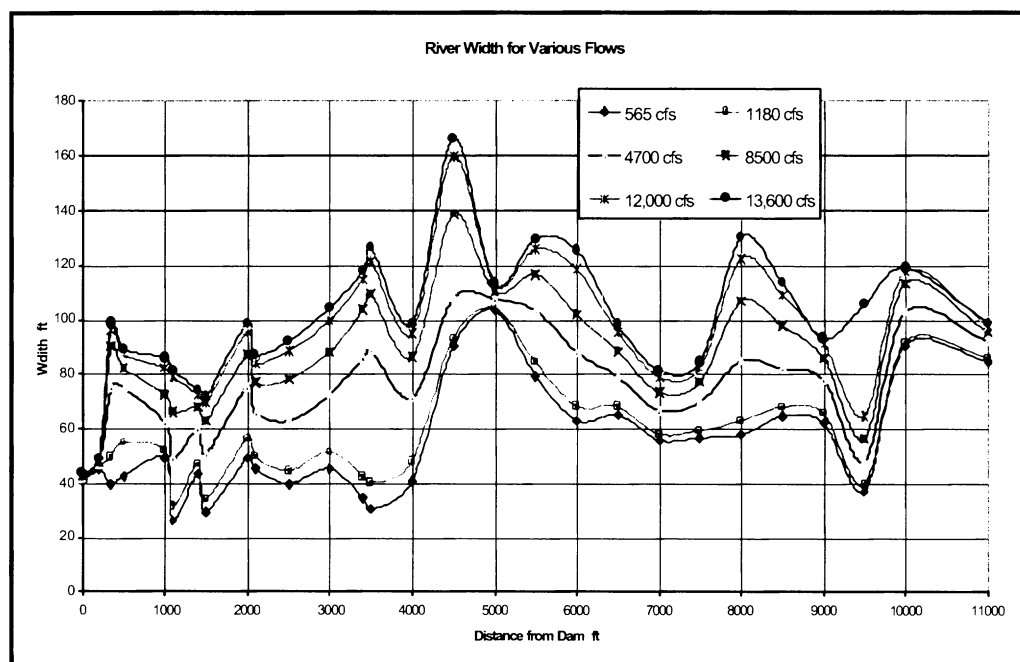


Figure 40. River Widths for Various Flows

SEDIMENT BEHAVIOR ANALYSIS REPORT

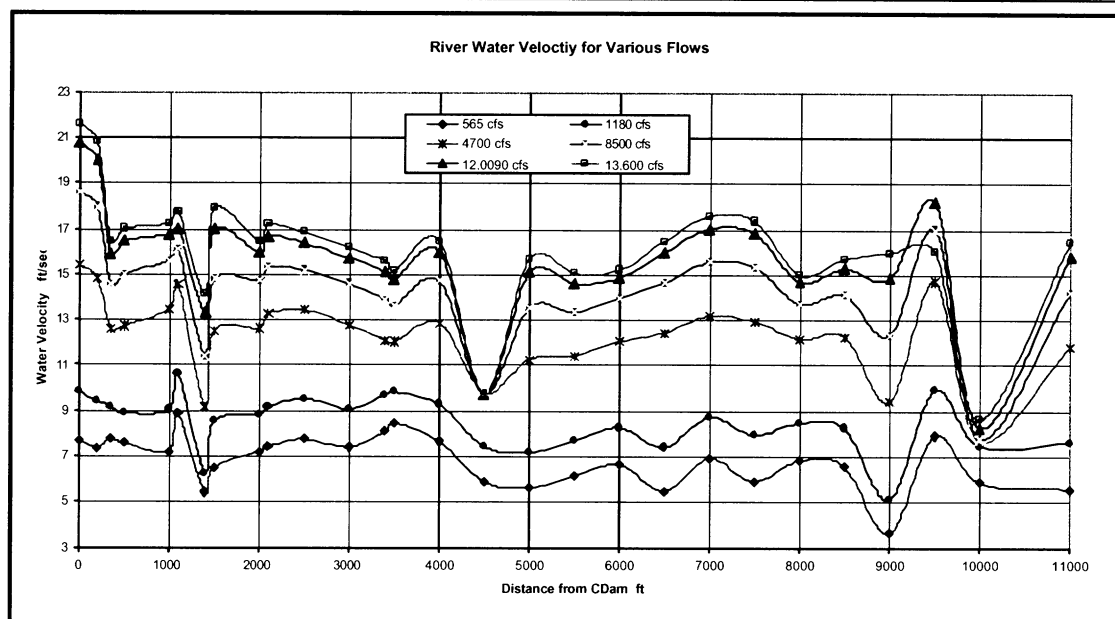


Figure 41. Water Velocities for Various Flows

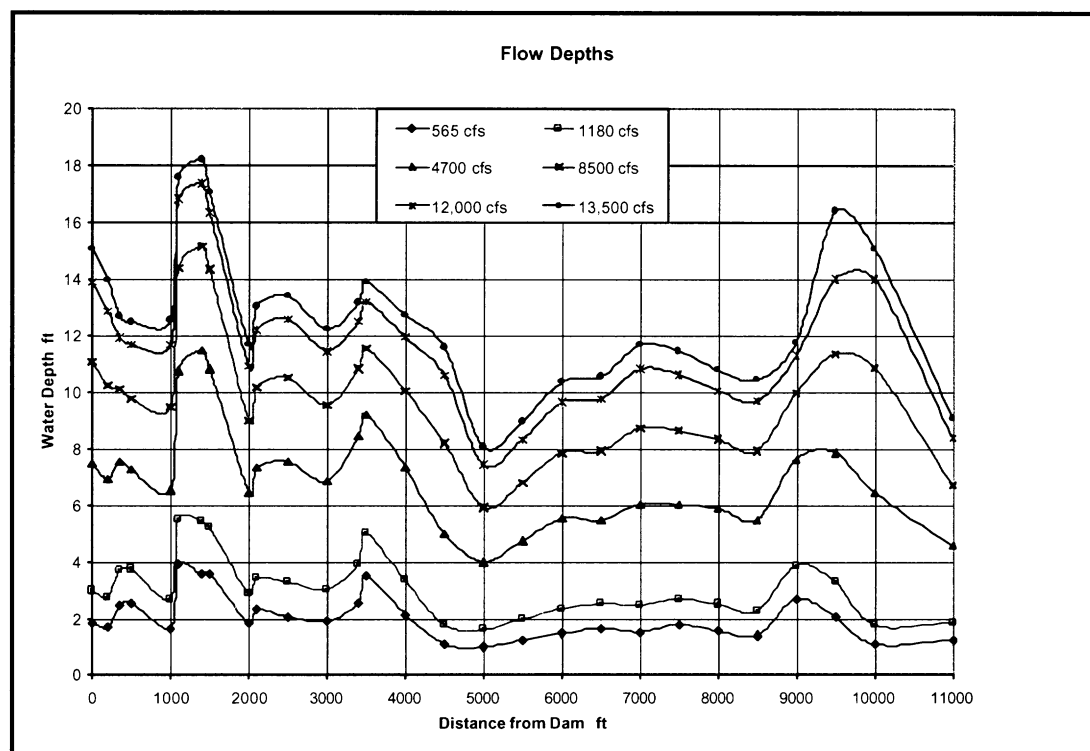


Figure 42. Water Depths for Various Flows

7.5. LABORATORY SEDIMENT ANALYSIS REPORT

(Letter from North Creek Analytical, Inc. to Brent Denham, PacifiCorp, dated March 5, 2004. Following 3 pages.)



North Creek Analytical, Inc.
Environmental Laboratory Network
10000 NE 10th Avenue, Suite 100
Portland, OR 97220
Phone: 503.281.1111
Fax: 503.281.1112
Email: info@ncalabs.com
www.ncalabs.com

March 5, 2004

Brent Denham
PacifiCorp Environmental Remediation Company
825 NE Multnomah Blvd
Portland, OR 97232

Re: Sediment/Columbia River Water Study

Dear Brent:

North Creek Analytical performed a sediment and Columbia River water study (project P4A0573) starting February 5, 2004. The purpose of the study was to correlate turbidity vs. total suspended solids (TSS) using a sediment sample obtained from the Columbia River.

All analysis was performed using EPA methods:

TSS: EPA Method 160.2

Turbidity: EPA Method 180.1

Details of the study and final results are listed below.

Analytical Procedure:

1. Sediment Preparation:

Four jars of sediment were composited yielding approximately 500 mLs. The sediment was placed in a 0.106 mm sieve, however, no sediment passed through. Next, 360 mLs of sediment was mixed with 720 mLs DI water. The diluted sediment was thoroughly mixed and allowed to settle for 5 minutes. The supernatant was decanted and poured through the sieve. This became the stock sediment solution. TSS = 1180 mg/L.

Half of the sediment solution was filtered through a Whatman #3 filter (6 microns) for a parallel study. TSS = 275 mg/L.

2. Columbia River Water Analysis:

Analysis of the Columbia River sample produced a turbidity of 0.8 NTU and TSS of <1 mg/L.

*North Creek Analytical, Inc.
Environmental Laboratory Network*

March 5, 2004

3. TSS/Turbidity Study:

Calculations were performed to determine the volume of sediment solution needed to produce TSS levels ranging from 25 -1000 mg/L (passed through the 0.1 mm sieve) and 25-250 mg/L (passed through the 6 μ filter). The sediment solutions were allowed to reach a temperature of 45-50 °F then the calculated volume was added to Columbia River samples, mixed, and tested for TSS and turbidity. Data is listed below:

Sediment: screened thru 0.1 mm sieve

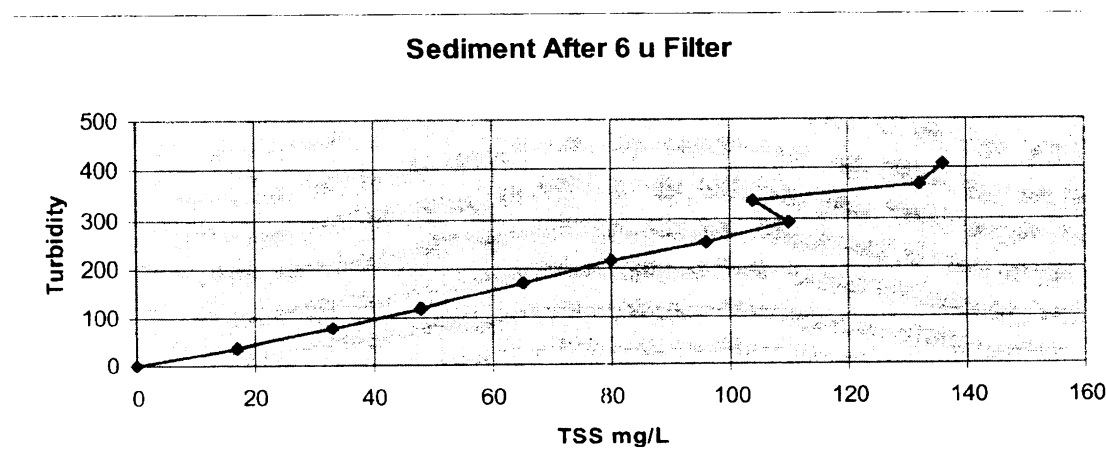
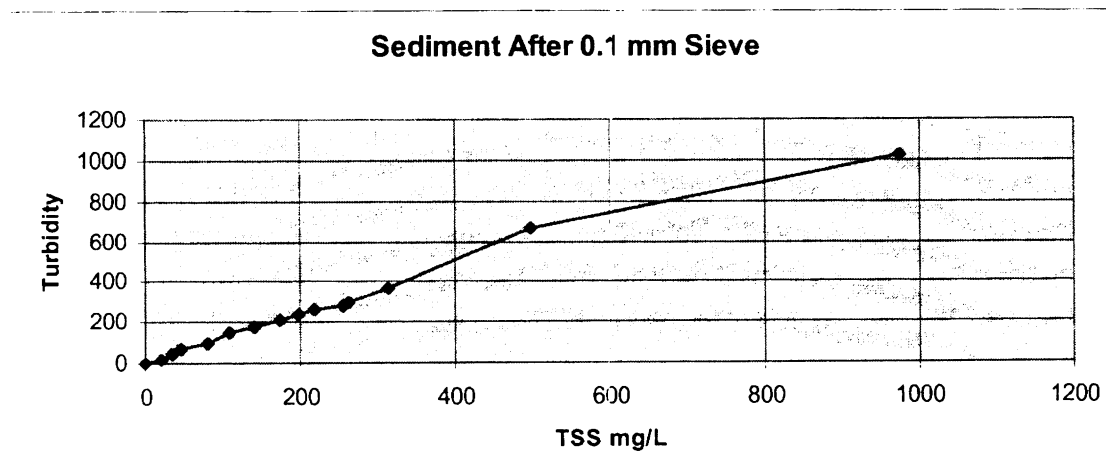
TSS	Turbidity	Temp C
0	0	
21	21.7	47.9
34	40.7	48.1
47	70.3	48.2
81	92.3	47.7
110	148	46.7
143	178	48.7
175	212	49.1
197	238	48.8
219	265	47.7
255	280	45.2
262	299	47.2
314	368	47.7
497	665	47.4
975	1026	52.6

Sediment: filtered thru 6 μ filter

TSS	Turbidity	Temp C
0	0	
17	37.8	46.6
33	77.7	45.9
48	116	45.1
65	170	46.7
80	216	45.5
96	251	46.4
110	291	46.5
104	336	48.3
132	370	47.5
136	410	48.2

4. Correlation of Results:

Results were graphed, TSS vs. turbidity for screened and filtered sediment.



5. Discussion of results:

The sieve results follow a linear progression. The filtered sediment results show an anomaly with the 104 mg/L TSS sample, otherwise, the trend is similar to the sieved sediment.

If you have any questions, call me at 503 906-9239.

Sincerely,

Brian L. Cone, CHMM
Industrial Services Manager

PROJECT DESCRIPTION

*CONDIT HYDROELECTRIC PROJECT
FERC PROJECT NO. 2342*

Appendix 10

Sediment Behavior Effects on Beneficial Uses
Prepared by G&G Associates
May 2004

CONDIT DAM HYDROELECTRIC PROJECT REMOVAL

SEDIMENT BEHAVIOR EFFECTS ON BENEFICIAL USES

PREPARED BY
G&G ASSOCIATES

FOR
PACIFICORP
PORTLAND, OREGON

MAY 2004

Table of Contents

1. <u>Executive Summary</u>	1
2. <u>Introduction</u>	3
2.1. <u>Purpose</u>	3
2.2. <u>Scope</u>	3
3. <u>Designated Beneficial Uses</u>	3
3.1. <u>Sediment Behavior and Water Quality</u>	4
3.1.1. <u>Sediment Behavior</u>	4
3.1.2. <u>Summary of Expected Turbidity Levels</u>	6
3.2. <u>Potential Effects on Designated Beneficial Uses</u>	8
3.2.1. <u>Potential Water Quality effects Categories</u>	8

Table of Tables

<u>Table 1. Material Quantities Trapped in In-lieu Site</u>	6
<u>Table 2. Material Trapped in Bonneville Pool</u>	6
<u>Table 3. Turbidity Expressed in NTU Levels in the WSR and CR after Dam Breach</u>	7
<u>Table 4. White Salmon River from Dam to Columbia River</u>	9
<u>Table 5. Columbia River 20 Miles Upstream of Bonneville Dam</u>	10
<u>Table 6. Columbia River Immediately Upstream of Bonneville Dam</u>	11
<u>Table 7. Columbia River near Quincy, Oregon</u>	12

1. EXECUTIVE SUMMARY

An investigation of the sediment erosion process associated with removal of Condit Dam, *Condit Dam Sediment Behavior Analysis Report* (Sediment Report), indicates that removal will increase sediment and turbidity in the White Salmon River (WSR) and the Columbia River (CR) downstream of the dam.

Removal of the dam will release between 1.6 and 2.2 million cubic yards (mcy) of reservoir sediment into the WSR. Approximately 673,500 cubic yards of this sediment will be trapped at the mouth of the WSR. Approximately 1.5 mcy of sediment will move into the CR as suspended sediment and bedload. Most of this, 1.2 mcy, will settle in the slack-water pool created by Bonneville Dam. The small particle sizes of the remaining 286,000 cubic yards will allow almost all this sediment to remain suspended in the water column to the mouth of the CR. Most of this small-sized sediment, however, will be eroded from the reservoir within the first few days after the dam is breached.

The amounts of sediment eroded from the reservoir will be extremely high immediately after the dam is breached. These amounts will decline rapidly throughout the following week and then more gradually thereafter. Precipitation, dam removal activities, and other events, however, will cause short-term increases in erosion. After approximately the first year, erosion will occur only intermittently during storm events, and after three to five years, erosion of reservoir sediments will occur only during rare, extremely high floods.

The water quality criterion for turbidity is 5 Nephelometric Turbidity Units (NTUs) above background, or 10 percent above background when background exceeds 50 NTUs. Turbidity levels in the WSR downstream of the dam will likely continuously exceed this criterion for approximately a year after the dam is breached, and then will occasionally exceed the criterion at a declining magnitude and frequency thereafter. Beyond three to five years after the dam is breached, the only exceedances of the criterion in the WSR would likely occur during rare, extremely high floods.

Water draining from the reservoir shortly after the dam is breached will represent nearly 6 percent of the likely flow of the CR, compared to 0.6 percent of the CR flow that the WSR would normally comprise at this time of year. Higher flows from the WSR will cause turbidity levels in the CR to be relatively high for the approximately six hours required for the reservoir to drain. Once the reservoir has drained and WSR flows return to normal, however, turbidity levels in the CR will fall dramatically (by more than 90 percent).

Downstream of Bonneville Dam, initial turbidity levels are anticipated to be 600 to 800 NTUs but will fall below 70 NTUs by the end of the first day and below the turbidity criterion within 4 to 5 days. Thereafter, relatively small, short-term exceedances of the criterion may occur during the next approximately 90 days. Within Bonneville Pool just downstream of the approximately three-mile area within which the WSR and CR mix, initial turbidity levels are anticipated to be approximately 1700 NTUs but will fall below

140 NTUs by the end of the first day and below the turbidity criterion by the end of the first week. Thereafter, relatively small, short-term exceedances of the criterion may occur with decreasing frequency for up to 3 to 5 years.

The effects on designated beneficial uses due to higher turbidity in the WSR and CR from removal of the dam were reviewed. Aquatic life uses are discussed in a separate letter attached to this document. The beneficial uses reviewed in this report are: primary contact recreation; domestic, industrial, and agricultural water supply; stock watering; wildlife habitat; fish harvesting; commerce and navigation; boating; and aesthetic values.

No permanent adverse effects on designated beneficial uses are anticipated in either the WSR or the CR. The removal of the dam, however, may result in temporary adverse effects on some uses, particularly those in the WSR.

Potential adverse effects on designated beneficial uses in the WSR may occur on a sustained basis through the first year after the dam is breached. Thereafter, the only potential adverse effects would coincide with intermittent high river flows. Beyond five years after the dam is breached, no adverse effects are anticipated because any remaining reservoir sediments would be mobilized only during rare, extremely high floods, when background suspended sediment and turbidity levels would be very high.

Potential adverse effects on designated beneficial uses in the CR might occur on a sustained basis for less than a week. Intermittent potential adverse effects on designated beneficial uses in the CR, however, may occur below Bonneville Dam for short periods during the first 90 days after the dam is breached and within the Bonneville Pool for short periods during the first two years after the dam is breached. Thereafter, no potential for adverse effects in the CR is anticipated.

2. INTRODUCTION

Condit Dam is located on the WSR 3 miles upstream of its confluence with the CR. PacifiCorp, the dam's owner, is planning to remove the dam beginning in October 2006. An investigation of the sediment erosion process associated with removal of Condit Dam, *Condit Dam Sediment Behavior Analysis Report*, (Sediment Report) by G&G Associates, May 2004, discusses changes in river water quality conditions associated with the removal of the dam.

As discussed in the Sediment Report, some temporary changes in water quality are expected as a result of dam removal. The following report discusses potential effects on designated beneficial uses in the WSR and CR.

2.1. PURPOSE

The purpose of this document is to review the potential effects that temporary changes in water quality associated with the removal of Condit Dam may have on the designated beneficial uses of the WSR and the CR downstream of Condit Dam.

2.2. SCOPE

This document discusses all beneficial uses except aquatic life uses. Biological Opinions by the US Fish & Wildlife Service and NOAA Fisheries address the potential effects of dam removal on aquatic species listed as threatened or endangered under the Federal Endangered Species Act. A separate document, developed by a PacifiCorp fisheries biologist, discusses potential effects on other aquatic life and is attached as Appendix 1. These effects are also summarized on Tables 4 through 7 of this document under the column labeled Aquatic Life.

This document also describes water quality changes in the WSR and CR downstream of the dam that may result from the removal of the dam.

3. DESIGNATED BENEFICIAL USES

The State of Washington Department of Ecology (Ecology) has designated the following beneficial uses in the WSR and CR downstream of Condit Dam (*see* WAC 173-201A-600):

- Aquatic life uses
- Primary contact recreation
- Domestic, industrial, and agricultural water supply
- Stock watering
- Wildlife habitat
- Fish harvesting
- Commerce and navigation
- Boating

- Aesthetic values

Ecology has also adopted narrative and numeric water quality criteria to protect these uses, including criteria for fecal coliform bacteria, total dissolved gas, dissolved oxygen, temperature, turbidity, aesthetic values, toxic pollutants, and pH. (WAC chapter 173-201A.)

Removal of Condit Dam would have no significant effect on levels of downstream bacteria, total dissolved gas, dissolved oxygen, toxic pollutants, or pH. Temperature in the WSR immediately after the breach may decrease slightly because of the release of cold water in the reservoir but will quickly return to normal.

The primary effects of dam removal on water quality will be from increases in total suspended sediment (TSS) and associated turbidity. Ecology's water quality criterion for turbidity is 5 NTUs over background turbidity levels when background turbidity is 50 NTUs or less, and 10 percent over background turbidity levels when background turbidity is more than 50 NTUs (WAC 173-201A-200(1)(e)). There is no water quality criterion for TSS. Nonetheless, turbidity and TSS are, in general, related. The relationship is discussed in detail in the Sediment Report. In addition, Ecology has adopted a narrative criterion in WAC 173-201A-260(2)(b) for aesthetic values, which provides that aesthetic values "must not be impaired by the presence of materials or their effects . . . which offend the senses of sight, smell, touch, or taste".

3.1. SEDIMENT BEHAVIOR AND WATER QUALITY

3.1.1. SEDIMENT BEHAVIOR

In 1997 a bathymetric survey of the Condit Dam reservoir, Northwestern Lake, indicated that approximately 2.4 mcy of sediment had accumulated there since dam construction in 1913. Removal of Condit Dam will allow between 1.6 and 2.2 mcy of this sediment to erode downstream in the WSR.

Immediately after the dam is breached, concentrations of TSS and bedload sediment concentrations in the WSR will be very high. Initial concentrations of TSS in the WSR downstream of the dam may reach 250,000 parts per million (ppm) for a very short period and are anticipated to be approximately 150,000 ppm for the first couple of days.

These initial high concentrations result from massive erosion of clay, silt, and very fine sands located in the reservoir within the first mile upstream of the dam. Silt and clay particles (fine sediment) have a very small diameter and generally erode immediately upon exposure to moving water. Because these materials are easily eroded and are small enough to remain suspended in moving water, they will cause high levels of TSS and turbidity as they erode and move downstream. The Sediment Report discusses the relationship between TSS and turbidity in detail.

It is anticipated that over 1.1 million cubic yards of sediment will erode from the reservoir area in the first 3 ½ days after the dam breach. Nearly half of this amount, approximately 500,000 cubic yards, will erode in the first day as the water in the reservoir drains.

During the first week after dam breach, TSS concentrations in the WSR will remain in the tens of thousands ppm. The reservoir contains approximately 1.45 mcy of sediment with particle diameters less than .125 mm. Most of this material will erode within a week and stay in suspension into the CR.

Some of the larger particles in this group will fall out of suspension near the mouth of the WSR in a deep pool created by Bonneville Dam (In-lieu site). The In-lieu site has the capacity to hold approximately 673,500 cubic yards of sediment. Approximately 200,000 cubic yards of silt and clay will deposit in the In-lieu site in the first week. The remaining capacity of the site will be filled with sands. Table 1 and Table 2 show the quantities of sediment captured in both the In-lieu Site and Bonneville Pool.

At the mouth, the WSR will mix with the CR, and TSS concentrations will be diluted by a factor that is equal to the ratio of CR flow to WSR flow. Breaching the dam will increase river flow downstream of the dam for approximately 6 hours, until the reservoir is drained. Based on the volume of sediment and water in the reservoir, during the 6 hours when the reservoir drains WSR suspended sediment levels will be diluted in the CR by a factor of about 23. After the reservoir drains and WSR flows return to normal, the dilution factor for suspended sediment concentrations will increase to approximately 156.

The mixing zone, where the water of the two rivers mix and dilution occurs, will extend downstream of the confluence for about 3 miles. Most particles suspended in WSR flow will settle in the CR in the pool upstream of Bonneville Dam. Both dilution and settling will cause turbidity levels to decline rapidly after the dam breach.

Table 1. Material Quantities Trapped in In-lieu Site

Material Quantities Trapped in In-lieu Site					
Type of Material	Median Particle Size mm	Incoming Volume CY	Trapped %	Trapped Volume CY	Passed Volume CY
Sand and Larger	>1	1,323,100	32%	427,565	895,535
Silt	.03	723,400	34%	245,500	477,900
Clay	.002	153,500	0%	335	153,165
Total		2,200,000		673,400	1,526,500

Table 2. Material Trapped in Bonneville Pool

Material Trapped in Bonneville Pool					
Type of Material	Median Particle Size mm	Incoming Volume CY	Trapped %	Trapped Volume CY	Passed Volume CY
Sand and Larger	>1	895,535	100%	895,535	0
Silt	.03	477,900	71%	336,920	140,981
Clay	.002	153,165	6%	8,424	144,741
Total		1,526,600		1,240,879	285,721

3.1.2. SUMMARY OF EXPECTED TURBIDITY LEVELS

The Sediment Report compiles both turbidity and suspended sediment levels for four locations downstream of the dam. The turbidity information presented in the Sediment Report is compiled in Table 3 below. Values of turbidity shown in Table 3 are based on assumed average WSR flow of 800 cfs and CR flow of 125,000 cfs, both typical flows for the time of the year when PacifiCorp intends to breach the dam. The table shows both intermittent peak values and anticipated sustained levels of turbidity. Sustained levels are the value of turbidity anticipated for that point in time. For instance, at the end of 7 days the daily average turbidity expected in the CR 20 miles upstream of Bonneville Dam is 4 NTU. Predictions of the exact timing of peak values cannot be made. Timing for peak values shown is approximate.

SEDIMENT BEHAVIOR EFFECTS ON BENEFICIAL USES

Turbidity levels shown are based on average flow values for the WSR and CR.
Sediment information is based on volumes, size gradations, and locations discussed in Condit Hydroelectric Project Removal, R W Beck, 1998.

Many simplifications and assumptions are required to compile the information shown below, such as, the nature of the relationship between TSS and turbidity, the rate at which the fine sediments erode and settle, river flows at the time of removal, lack of obstructions to reservoir drawdown, and numerous other assumptions that have smaller effects. The relationship between turbidity values and suspended sediment have been developed based on data gathered by the USGS. Details of the relationship are discussed in the Sediment Report.

Information presented here is based on professional judgment and available information. Turbidity values in the short term may vary from those shown but Table 3 provides a reasonable general description of the trends and levels expected.

Table 3. Turbidity Expressed in NTU Levels in the WSR and CR after Dam Breach

Time Period	White Salmon River		Columbia River 20 Miles Upstream of Bonneville Dam		Columbia River Immediately Upstream of Bonneville Dam		Columbia River near Quincy, Oregon	
	Intermittent Peaks	Sustained	Intermittent Peaks	Sustained	Intermittent Peaks	Sustained	Intermittent Peaks	Sustained
6 hours	127,090	76,250	2,960	1,770	1,350	800	1,120	670
1 day	127,090	76,250	837	139	370	69	307	56
3 days	55,910	33,030	362	34	158	12	130	9
7 days	30,490	15,240	193	4	82	2	66	2
30 days	6,090	3,550	30	1	9	0.3	8	0.2
90 days	3,040	1,010	10	1	5	0.2	4	0.2
6 months	3,040	91	10	0.3	5	0.2	4	0.1
1 year	3,040	15	10	0.3	5	0.2	4	0.1
2 years	2,020	<1	7	<0.1	3	<0.1	3	<0.1
3 years	1,510	<1	5	<0.1	2	<0.1	2	<0.1
4 years	1,510	<0.1	5	<0.1	2	<0.1	2	<0.1
5 years	1,510	<0.1	5	<0.1	2	<0.1	2	<0.1
10 year	500	<0.1	2	<0.1	1	<0.1	1	<0.1

3.2. POTENTIAL EFFECTS ON DESIGNATED BENEFICIAL USES

As discussed above, Washington State has designated several categories of beneficial uses in the WSR and CR downstream of the dam. Changes in water quality may have several different general results. These possible results are discussed below. Each category of beneficial use may be affected differently by water quality changes. The different potential effects are discussed below.

3.2.1. POTENTIAL WATER QUALITY EFFECTS CATEGORIES

The potential effects of water quality changes in the CR and WSR may be divided into the categories shown below. The time period in the following tables starts from the time of arrival of the first sediments at each location from dam removal.

- PE** - There is a potential for the use to be adversely affected during the period of time specified.
- TE** - There is a potential for the use to be adversely affected for brief and unpredictable intervals during the period of time specified.
- NE** - No adverse effect is anticipated during the period of time specified.

SEDIMENT BEHAVIOR EFFECTS ON BENEFICIAL USES

Table 4. White Salmon River from Dam to Columbia River

Use Time Period	Primary contact recreation	Domestic, industrial, and agricultural water supply	Stock watering	Wildlife habitat	Fish Harvesting	Commerce and navigation	Boating	Aesthetic values	Aquatic Life
6 hours	PE	PE	PE	PE	PE	PE	PE	PE	PE
1 day	PE	PE	PE	PE	PE	PE	PE	PE	PE
7 days	PE	PE	PE	PE	PE	PE	PE	PE	PE
30 days	PE	PE	PE	PE	PE	PE	PE	PE	PE
90 days	PE	PE	PE	PE	PE	PE	PE	PE	PE
6 months	TE	PE	PE	PE	PE	PE	PE	PE	PE
1 year	TE	PE	TE	TE	PE	PE	PE	PE	PE
2 years	TE	TE	TE	TE	TE	TE	TE	TE	TE
3 years	TE	TE	TE	TE	TE	TE	TE	TE	TE
4 years	TE	TE	TE	TE	TE	TE	TE	TE	TE
5 years	TE	TE	TE	TE	TE	TE	TE	TE	TE
10 year	NE	NE	NE	NE	NE	NE	NE	NE	TE

CONDIT DAM REMOVAL

MAY 2004

SEDIMENT BEHAVIOR EFFECTS ON BENEFICIAL USES

Table 5. Columbia River 20 Miles Upstream of Bonneville Dam

Use Time Period	Primary contact recreation	Domestic, industrial, and agricultural water supply	Stock watering	Wildlife habitat	Fish Harvesting	Commerce and navigation	Boating	Aesthetic values	Aquatic Life
6 hours	PE	PE	PE	PE	PE	NE	PE	PE	PE
1 day	PE	PE	PE	PE	PE	NE	PE	PE	PE
7 days	TE	TE	TE	TE	TE	NE	TE	TE	TE
30 days	TE	TE	TE	TE	TE	NE	NE	TE	TE
90 days	NE	TE	TE	TE	TE	NE	NE	NE	TE
6 months	NE	TE	TE	TE	TE	NE	NE	NE	TE
1 year	NE	TE	TE	TE	TE	NE	NE	NE	TE
2 years	NE	TE	TE	TE	TE	NE	NE	NE	TE
3 years	NE	NE	NE	NE	NE	NE	NE	NE	NE
4 years	NE	NE	NE	NE	NE	NE	NE	NE	NE
5 years	NE	NE	NE	NE	NE	NE	NE	NE	NE
10 year	NE	NE	NE	NE	NE	NE	NE	NE	NE

SEDIMENT BEHAVIOR EFFECTS ON BENEFICIAL USES

Table 6. Columbia River Immediately Upstream of Bonneville Dam

Use Time Period	Primary contact recreation	Domestic, industrial, and agricultural water supply	Stock watering	Wildlife habitat	Fish Harvesting	Commerce and navigation	Boating	Aesthetic values	Aquatic Life
6 hours	PE	PE	PE	PE	PE	NE	NE	PE	PE
1 day	PE	PE	PE	PE	PE	NE	NE	PE	PE
7 days	TE	TE	TE	TE	TE	NE	NE	TE	TE
30 days	NE	TE	TE	TE	TE	NE	NE	NE	TE
90 days	NE	NE	NE	NE	NE	NE	NE	NE	NE
6 months	NE	NE	NE	NE	NE	NE	NE	NE	NE
1 year	NE	NE	NE	NE	NE	NE	NE	NE	NE
2 years	NE	NE	NE	NE	NE	NE	NE	NE	NE
3 years	NE	NE	NE	NE	NE	NE	NE	NE	NE
4 years	NE	NE	NE	NE	NE	NE	NE	NE	NE
5 years	NE	NE	NE	NE	NE	NE	NE	NE	NE
10 year	NE	NE	NE	NE	NE	NE	NE	NE	NE

SEDIMENT BEHAVIOR EFFECTS ON BENEFICIAL USES

Table 7. Columbia River near Quincy, Oregon

Use Time Period	Primary contact recreation	Domestic, industrial, and agricultural water supply	Stock watering	Wildlife habitat	Fish Harvesting	Commerce and navigation	Boating	Aesthetic values	Aquatic Life
6 hours	PE	PE	PE	PE	PE	NE	NE	PE	NE
1 day	PE	PE	PE	PE	PE	NE	NE	PE	PE
7 days	TE	TE	TE	TE	TE	NE	NE	TE	TE
30 days	NE	TE	TE	TE	TE	NE	NE	TE	TE
90 days	NE	NE	NE	NE	NE	NE	NE	NE	NE
6 months	NE	NE	NE	NE	NE	NE	NE	NE	NE
1 year	NE	NE	NE	NE	NE	NE	NE	NE	NE
2 years	NE	NE	NE	NE	NE	NE	NE	NE	NE
3 years	NE	NE	NE	NE	NE	NE	NE	NE	NE
4 years	NE	NE	NE	NE	NE	NE	NE	NE	NE
5 years	NE	NE	NE	NE	NE	NE	NE	NE	NE
10 year	NE	NE	NE	NE	NE	NE	NE	NE	NE

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March 23, 2004

Dennis Gathard
G&G Associates
4003 1st Ave., NW
Seattle, WA 98107

RE: Condit Hydroelectric Project (FERC Project No. 2342) Assessment of Project Effects on the Aquatic Species Not described in USFWS or NOAA Biological Opinions or in the FSFEIS

Dear Mr. Gathard:

Provided herein is an assessment of the effects of the breaching and removal of Condit Dam on aquatic species other than those that are addressed in the U.S. Fish and Wildlife Service Biological Opinion (USFWS 2002) or the Final Supplemental Final Environmental Impact Statement (FSFEIS) (FERC 2002), or that will be addressed in the biological opinion to be prepared by NOAA Fisheries. These documents address or will address the potential effects of the removal of the project on anadromous salmonids and bull trout. The documents also include some discussion of resident fish species present in the White Salmon River, including Northwestern Lake. Although a final biological opinion has not been completed by NOAA Fisheries, I anticipate that the findings in the opinion will be similar to those in the USFWS Biological Opinion and the FSFEIS. I have reviewed the FSFEIS, USFWS Biological Opinion, the Project Description (PacifiCorp 2004), Sediment Behavior Analysis Report (G&G Associates 2004), and literature pertaining directly to total suspended sediment and turbidity to provide this analysis.

The only substantial adverse effects that the removal of Condit Dam may have on aquatic life would be through the erosion of sediment in the reservoir now formed by the dam. The effect of this erosion on water quality in the White Salmon and Columbia Rivers is discussed in the executive summary found in the Condit Dam Removal Beneficial Use Analysis (PacifiCorp 2004) and is the basis for the assessment provided herein. A narrative of the expected events as well as a chronological layout of the expected turbidity and TSS levels (Appendix 10, Table 3) is provided in that report.

American Shad

Shad use the Columbia River near its confluence with the White Salmon River for migration, spawning and rearing. Due to the proposed October period for commencement of dam removal, no spawning would be disrupted because the shad spawning migration is during the spring and early summer. Rearing of juvenile shad does occur in the Bonneville Pool, but shad outmigrate to the sea in the fall of their first year following hatching. It is expected that this out migration would be complete before the dam is breached, but, based on personal experience while performing sampling in the Columbia River, some juvenile shad may still be present during dam breaching. The elevated TSS levels may cause direct mortality and turbidity levels may interfere with the planktivorous feeding habits of the juvenile shad, potentially disrupting outmigration behavior. The USFWS biological opinion recognized the ability of bull trout to avoid the suspended sediment plume. Juvenile shad will be capable of this type of avoidance behavior as well. Based on the limited duration of the elevated TSS and turbidity levels, the low probability that these fish will be present during the breaching, avoidance capability, and the overall geographically limited extent of the sediment plume (5% of Bonneville Pool shoreline habitat), adverse effects on this species are expected to be minor and temporary in nature. No long-term effects on this species would be expected to occur as a result of the breaching.

White Sturgeon

White sturgeon inhabit the Columbia River in the vicinity of the mouth of the White Salmon River. White sturgeon spawning would not occur in this area of the Columbia River due to the lack of specific spawning habitat requirements, although juvenile and adult rearing take place. The elevated turbidity levels expected in this area during breaching may interfere with foraging. In addition, there is a potential for direct mortality to this species in the areas of the highest TSS concentrations. White sturgeon would be capable of avoiding this area during the initial release and may temporarily use other habitat in the Bonneville Pool until typical water quality conditions are restored. Since no spawning or migration disruptions are expected from this event, only limited effects on rearing, specifically foraging and displacement, may occur. These effects would be temporary, although periodic minor disruptions could occur for several years following the initiation of the dam removal process. No long-term effects are expected from the proposed breaching of Condit dam.

Other Aquatic Life

Elevated turbidity and TSS levels are most likely to pose a risk to aquatic invertebrates due to their limited mobility in relation to vertebrate species. It can be assumed that the initial plume of sediment and some subsequent sediment spikes that are expected to occur will cause direct mortality to an unknown quantity of aquatic invertebrates, primarily aquatic insects. This will be a temporary condition, with invertebrate re-colonization from upstream sources (drift) expected. Aquatic mollusks found in the lower White Salmon River may be forced downstream due to the high flows and a portion of some mollusk species may be covered with silt in the expected depositional areas below the confluence with the Columbia River. Some molluscan species may perish during events


that cause deposition in their associated benthic habitat, but as with the aquatic insect species, re-colonization from upstream sources should occur.

Other non-salmonid fish species could succumb to the high TSS levels that are expected. Some behavioral responses from elevated turbidity will occur, including temporary displacement, disruption in feeding/growth, and predator/prey relationship effects. Species such as dace, sculpin, redbside shiner, chislemouth, sucker sp., northern pikeminnow, smallmouth bass, walleye, and catfish may be present in the area that will be affected by the elevated TSS and turbidity. No long-term influence from this action is expected on these species due to the limited spatial and temporal extent of the elevated TSS and turbidity, the ability of these species to avoid potentially harmful water quality, and re-colonization from adjacent habitat.

Summary

In summary, the conclusions reached on aquatic effects of the breaching action in both the USFWS Biological Opinion and the FSFEIS are reasonable and could be broadened to cover other aquatic species. It should be recognized that the aquatic species that are not addressed in the biological opinions tend to be more tolerant of environmental perturbations and may not experience the same level of mortality or adverse effects. Flows that will occur in the White Salmon River resulting from this action will be high depending upon the season and the typical hydrology found at that time, although flows in excess of 45,000 cfs (over 4 times the initial expected release) did occur during the flood event of 1996. Suspended sediments may periodically affect aquatic species in the Columbia River, particularly on the north bank, for up to one year. The natural movement of bedload and sediments will be restored through the removal of the dam and the corresponding lake. This action will have short term adverse effects on aquatic life in the White Salmon River downstream of the dam and in the Columbia River for approximately three miles downstream of the mouth of the White Salmon River. Mortality could occur to some individuals of some species, but the resulting action will provide greater long-term benefits in terms of ecosystem function and aquatic habitat diversity, benefiting the overall health of the aquatic community.

Sincerely,



Ian Chane
Aquatic Biologist
PacifiCorp

Cc: File