U.S. Army Corps
of Engineers
Seattle District

Final Design Report
Green River Fish Habitat Restoration
Pilot Project – Zone 1
King County, Washington

June 20, 2003

TETRA TECH, INC.
1925 Post Alley, Seattle,
Washington 98101

GeoEngineers
600 Dupont Street, Bellingham WA 98225

Green River Fish Habitat
Restoration Pilot Project – Zone 1

King County, Washington

Draft Design Report

May 15, 2003

This page intentionally left blank.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF TECHNICAL APPENDICES

APPENDIX A – HYDROLOGY AND HYDRAULICS

APPENDIX B – SEDIMENT AND GRAVEL

APPENDIX C – ENGINEERED LOG JAMS

APPENDIX D - GEOTECHNICAL

APPENDIX E – CIVIL DESIGN (PLANS, SPECIFICATIONS, COST)

APPENDIX F – COST

APPENDIX G – REAL ESTATE

APPENDIX H – PUBLIC OUTREACH AND AGENCY COORDINATION

1. INTRODUCTION

1.1 Pilot Project Description and Location

The Green River Pilot Project involves restoration of anadromous fish habitat on the Green River in the Kanaskat-Palmer area, at two sites (named "Zone 1" and "Zone 2"). Zone 1 is at RM 60, downstream from the City of Tacoma's headworks facility, and Zone 2 is upstream of the Tacoma pipeline crossing at RM 58 (Figure 1). The project comprises design and construction of two main types of habitat enhancement features including: (a) in-stream gravel nourishment, to improve the gravel starved conditions of the river and also restore spawning conditions for salmonids; and (b) engineered log-jams (ELJ), to provide cover and resting areas utilized by a variety of salmonid species. Construction for the Zone 1 site is planned in summer, 2003 (during the fisheries construction window August 1– August 31), and construction of the Zone 2 site is planned for a similar construction window in summer, 2004. This *Design Report* focuses on Restoration
Zone 1.

Restoration Zone 1 is located in King County, at RM 60, about 3 miles upstream from Kanaskat-Palmer State Park, and about 4.5 miles downstream from the Howard Hanson Dam. The site includes a 2,300-foot section of the Green River, on property owned by Tacoma Public Utilities (TPU) and aquatic lands held in trust by the Washington Department of Natural Resources. The site is located between the Tacoma Headworks Office/Facility to just downstream of the Tacoma Watershed Office (Figure 2).

1.2 Project Authorization

The Green River Fish Habitat Restoration Pilot Project is being implemented as part of the mitigation for the loss of salmon habitat from the construction of Howard Hanson Dam (HHD), in 1962.

The Pilot Project began as an Army Corps of Engineers Section 1135 Restoration Project, as an component of the Howard Hanson Dam Additional Water Storage Project (HHD-AWSP), and was to be co-funded by the federal government and the City of Tacoma. The HHD-AWSP is a dual-purpose water supply and ecosystem restoration project currently being implemented by the Army Corps of Engineers (USACE, 1998).

Chinook salmon became listed as threatened in 1999, under the Endangered Species Act (ESA). At that time the National Marine Fisheries Service (NMFS) was in the process of issuing a Biological Opinion (BIOP) for the Green River and the HHD-AWSP. The biological opinion requires the Corps to implement fish habitat restoration in the Green River as mitigation for HHD. The effect from the resulting BIOP on the project changed the authorization from Section 1135 Restoration to “Mitigation”, and is 100 percent federally funded as part of the HHD-AWSP. Congress authorized the Green River Pilot Project in 1999.

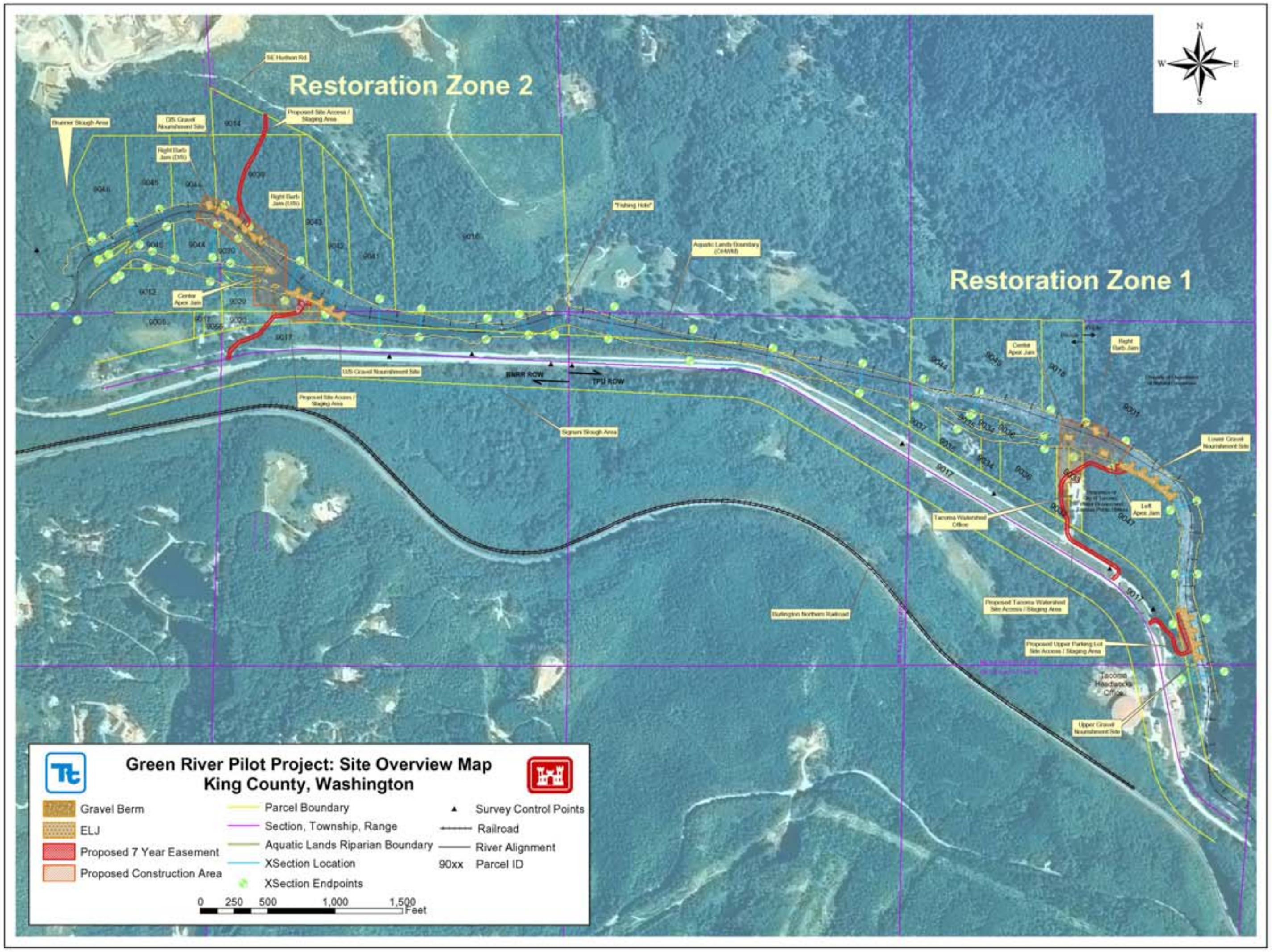

Figure 1. Restoration Zone 1 & 2 Site Map

PAGE INTENTIONALLY LEFT BLANK

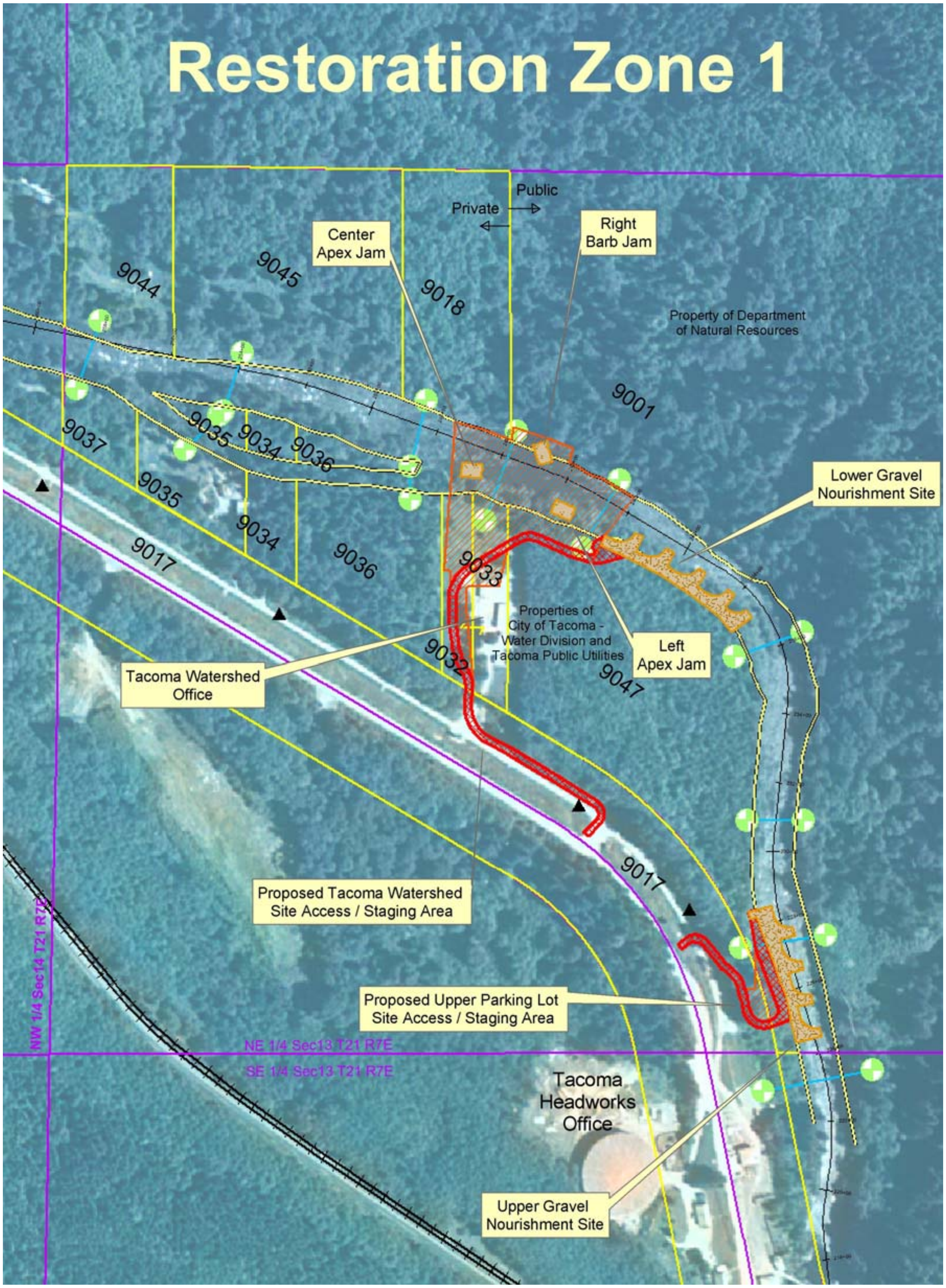

Figure 2. Green River Habitat Restoration Pilot Project, Zone 1 Site Map

This page intentionally left blank.

2. BASIS FOR DESIGN

Since the completion of the HHD in 1962, the dam has adversely affected the natural processes in the river, including interfering with the natural transport and migration of gravel and woody debris downstream of the dam. The gravel and woody debris are essential elements of natural salmonid habitat, with gravel providing spawning habitat, and woody debris - often forming natural log-jams - providing cover to a range of salmonid species. Sediment and down timber from the upstream watershed are trapped behind the HHD, and consequently, are not being transported and dispersed downstream of the dam.

2.1 Relevant Previous Studies and Actions

To mitigate for the loss of the important salmonid habitat elements due to the HHD, the Corps, as part of the *Feasibility Study and Environmental Impact Statement (EIS) for the Howard Hanson Dam, Additional Water Storage Project* (USACE 1998), evaluated a variety of fish habitat restoration methods for the Green River downstream of HHD, including spawning gravel nourishment and woody debris placement. A technical background study by Perkins on gravel placement in the Green River, completed in support of the *Feasibility Study and EIS,* estimated 12,000 tons-per-year (t/yr) are trapped behind the Dam each year (Perkins 1999a) - equivalent to about 7,800 cubic yards (yds^3) of gravel being placed in the river below the HHD. This volume estimate is the basis for design of the two gravel nourishment features in the Kanaskat-Palmer Reach.

Federal interest for fish habitat restoration in the Green River before the HHD-AWSP Environmental Impact Statement, based on the limiting factors for fish habitat (i.e., gravel and wood) was identified by King County in a limiting factors analysis published in 1996 (King County, 1996). This limiting factors analysis became the basis for the Green-Duwamish Ecosystem Restoration Project. Restoration/mitigation project descriptions were included in both Corps HHD-AWSP and the Green/Duwamish River Basin Ecosystem Restoration Study and supporting feasibility studies and analyses.

As part of the preparation of the *Feasibility Study and EIS*, consultation was required under Section 7 of the Endangered Species Act (ESA) between the Corps, the NMFS, and the U.S. Fish and Wildlife Service (USFWS). Under the requirements of Section 7, the Corps prepared a Programmatic Biological Assessment (PBA) of the potential effects of the HHD-AWSP on federally listed species. It was during this time period that the Puget Sound chinook salmon became listed as a threatened species.

The USFWS and the NMFS each issued Biological Opinions (BIOPs) on the PBA, generally endorsing the re-introduction of spawning gravel and woody debris in the Green River as mitigation for impacts on the listed bull trout and chinook salmon from the HHD. The USFWS BIOP specified that spawning gravel added to the river should be within the sediment size range of 12.7 millimeters (mm) to 101.6 mm. The NMFS BIOP stipulated that 50 percent of the wood collected from the reservoir each year should be transported downstream of the HHD. Both of the USFWS and the NMFS BIOPs stipulated that the effectiveness of the annual placement of spawning gravel and large woody debris downstream of the HHD should be monitored and evaluated.

In July 2000, the Corps completed the *Howard Hanson Dam Additional Water Storage – Phase 1 Fish and Wildlife Mitigation and Restoration Conceptual Design Report* (USACE 2000). The report provided 35% conceptual level designs for the proposed fish and wildlife habitat restoration features and measures as Phase 1 of the HHD – AWSP. This report recommended that up to 14 ELJs, comprised of LWD be constructed downstream of the HHD in the 3.5-mile Kanaskat-Palmer reach of the Green River.

In October 2000, the Corps completed the *Green/Duwamish River Basin Ecosystem Restoration Study (GD-ERP)* (USACE 2000a). The study goals included: (1) enhancing the physical nature of existing degraded habitat; (2) improving existing ecosystem functions and processes; (3) addressing limiting factors to fish and wildlife production; and (4) restoring degraded habitats for anadromous fish. The study concluded that opportunities exist and identified locations and project features in the Green/Duwamish Basin to restore ecosystem functions and processes that will create and maintain natural habitats over time.

Phase 1 Fish and Wildlife Mitigation and Restoration Conceptual Design Report (USACE 2000a). The three proposed projects identified in the *Conceptual Design Report* were (1) MSI-02, Large Woody Debris (LWD); (2) MSI-03, Engineered Log Jams (ELJ); and (3) Gravel Nourishment. Additional proposed projects in the study reach include MSI-01 Signani Slough Restoration (FP) and the GR-38, Brunner Slough Restoration, which is part of the *Green/Duwamish River Basin Ecosystem Restoration Study* (USACE, 2000a), for which the Site

Investigation did not directly assess, but considered these projects as an integral part of ecosystem restoration along the Kanaskat-Palmer reach.

An additional study and report developed by the Corps was the *Green River, Hydrologic Engineering Management Plan* (USACE, 2001). The report looks at both the HHD-AWSP and the GD-ERP and identifies the technical hydrologic, hydraulic, sediment and geomorphologic tasks necessary to evaluate, monitor and design the individual habitat restoration features. In addition, the report proposes methods and analyses for assessing the cumulative impacts of the range of projects from both of the ecosystem and habitat restoration projects.

In 2002, Tetra Tech, Inc. was contracted by the Corps to conduct *the Howard Hanson Dam, Phase I AWSP, Fish and Wildlife Mitigation and Rstoration Site Investigations and Surveys to Initiate Detailed Design* study (USACE 2003). A comprehensive site investigation of the Kanaskat-Palmer reach of the Green River, downstream of the HHD. The purpose of the site investigation was to document baseline environmental and physical conditions in the study area and collect data to support future monitoring, as well as perform engineering analysis and design of the fish habitat restoration projects proposed for this reach in the *Howard Hanson Dam Additional Water Storage Project.*

The site investigation included study areas with the following technical disciplines:

- Survey/Mapping
- Geomorphology/Geology/Geotechnical
- Biological
    - Fisheries
    - Botanicals
- Civil
    - Hydraulics/Hydrology

The Site Investigation was tasked with refining plans from the Conceptual Design Report through documenting baseline conditions and assessing locations for gravel nourishment, large woody debris placement, and engineered log jam construction. Recommendations from the *HHD Site Investigation* identified two locations (Restoration Zones 1 and 2) where there was potential to load, transport and potentially deposit gravels along a short reach "segment" of the river. In addition, both of these sites contained locations suitable for construction of ELJs. LWD placement projects were not included in the recommendation in consideration of the additional risks to boaters and landowners from "loose" wood placed along the river for transport downstream. Another concept promoted from the Site Investigation report was the integration of the gravel nourishment and ELJ features to maximize the benefits for salmonid habitat, which played into the identification of the Restoration Zones. For example, strategic locations were identified for the placement of the gravel nourishment berms and bars that would help to ensure that spawning gravels would be replenished annually, independent of the volume of flows in a given year. Also, the locations of the ELJs could be integrated with the gravel nourishment sites and channel characteristics to maximize the potential for resting pools to be developed in locations that would be of greatest benefit to migrating salmonids prior to spawning. Specifically, the Site Investigation identified locations for placement of 3,900 cubic yards (yd^3) of gravel and 3 engineered log jams in two separate locations.

2.2 Pilot Project Overview

Beyond the physical recommendations, the Site Investigation also promoted the idea of using a Pilot Project approach. The Pilot Project would provide an open forum for developing designs, monitoring project effects, apply adaptive management techniques in an interdisciplinary environment, as well as coordinate with other agencies, interest groups and the public. The Pilot Project will be a 5-year effort to design, construct, monitor, evaluate and assess the effectiveness of the fish habitat restoration efforts on the Green River in the Kanaskat-Palmer Reach. The pilot project framework gives the Corps the added flexibility to alter wood and gravel nourishment techniques from evaluation of project success during the 5-year period.

The specific goals of the Pilot Project are:

- Return the Green River to a more natural state by restoring natural sediment and wood functions within the river.
- Restore historical salmon habitat to the river including mainstem spawning habitat for chinook and side channel rearing habitat.
- Utilize an "adaptive management" approach, for the benefit of ongoing and future habitat restoration projects.

3. DESIGN APPROACH

The approach for developing the details for the construction designs of the gravel nourishment and engineered log jams utilized engineering analyses of hydrologic, hydraulic and sediment transport conditions for Restoration Zones 1 and 2. Previously, geomorphic, sediment transport and biological considerations were employed in determining the need, location and general configuration of these features.

Hydrologic analysis included review of USGS gage summary statistics, flow duration analysis, flood frequency analysis, identification of representative low, typical and high flow hydrographs, and identification of the construction period design discharge criteria. The hydrologic analysis evaluated data for water years 1964 through 2001, which is considered the post-dam era. Design of the habitat restoration features evaluated a range of flow conditions including the low, typical and high flow events. Construction period, low flow analysis focused on the expected flow rates during the month of August. Results of the hydrologic analyses were used as input to the hydraulic and sediment transport models.

The hydraulic analysis utilized the development and evaluation of river hydraulics using a HEC-RAS model. The hydraulic model was comprised of data collected in the field including a series of cross sections, water surface elevations, and flows representative of the existing topography of the Green River. The model was calibrated to a water surface profile performed during the April 15, 2002 flood event. Output from the model utilized in design of the habitat restoration features included shear stress, channel velocity, energy slope, flow area, hydraulic depth, and hydraulic radius. These parameters were evaluated in developing gravel nourishment, ELJ and water control designs.

Engineered log jams (ELJs) were designed using supporting engineering analyses that included a qualitative planform stability assessment, force balance stability analysis, scour analysis and an assessment of encroachment criteria for establishing ELJ features. Additional analyses were performed to evaluate existing and future conditions related to the design the ELJ features. These include planform, scour and stability analyses. Planform analysis included a qualitative assessment of channel configuration and stability. Scour and stability analyses were performed using a series of assumptions and equations for assessing existing and future conditions in the ELJ feature reach.

The approach for performing sediment analyses for evaluation and design of the gravel nourishment features was to review existing gravel nourishment projects, identify the gravel nourishment size specifications and evaluate the sediment transport characteristics of the existing river and the future conditions with the gravel nourishment features. The analysis was focused on determining the appropriate gravel sizes for the project, ability of the Green Rive to entrain the intended gravel loading and a suitable configuration for placing the gravel. The review of other gravel nourishment projects for salmon habitat restoration was performed to evaluate the success and identify limitations encountered on other gravel nourishment projects. In developing the proposed gravel nourishment size distribution specifications several design criteria were evaluated taking into account spawning gravel size distributions, construction issues, and water quality regulations. The final step was the sediment transport analyses including incipient motion and sediment transport capacity analysis that was used to verify the sediment transport characteristics of the river for existing and future conditions.

3.1 Hydrology

Hydrologic data were compiled from the Green River at Purification Plant Near Palmer, Washington (USGS gage #12106700). The gage is located on the left bank of the Green River at the City of Tacoma water purification plant, 0.4 miles downstream from the diversion dam at river mile (RM) 60.5. Information from the gage includes average daily flows from July 1st 1963 to September 30th, 2001 as well as annual peak flows for the same time period. The construction of HHD was completed in 1962, and the hydrologic analysis is for the post-dam era from 1964 on. Summary statistics for this gage, referred to as the Palmer Gage, are found in Table 1, Appendix A. Figure 3 represents the mean daily discharge for the period of record and Figure 4 displays the average annual hydrograph (based on mean daily discharges averaged for each day of the year over the period of record). The maximum flood event on record was 12,500 cfs on February 12, 1981.

Flow Duration Analysis

Flow duration curves for mean daily flows on both an annual basis and a monthly basis were developed. The results of the annual flow duration analysis are shown in Figure 5. The 90%, 50% and 10% probability exceedance flows are 130cfs, 600cfs and 2,000cfs, respectively. Evaluation of the monthly flow duration curves reveals that during the month of August (construction period), the 90%, 50% and 10% probability exceedance flow rates are 111cfs, 136cfs, 230cfs, respectively (Table 2 - Appendix A).

Flood Frequency Analysis

Flood frequency analysis is particularly important in evaluating the stability of the ELJ features. The ELJ features must be able to resist the hydraulic forces created by the design flood as well as accommodate the resulting bed scour without adversely impacting adjacent areas of the river. The performance of gravel nourishment features is also influenced by flood hydraulics, but concerns regarding flood influence are different being that the gravel nourishment berms are designed to erode during flood events. Section 3.3 discusses how the gravel nourishment features are designed to erode at flows much less than the 100-year flood event.

Prior to the presence of the HHD, the estimated 100-year peak discharge in the Green River downstream of RM 64 was approximately 28,000 cfs (USGS, 1996). With the HHD in place, the maximum regulated release from the reservoir is 10,000 cfs and the maximum spillway capacity release is 12,000 cfs. Typically a flood frequency analysis, assuming Log Pearson Type III statistical distribution of the data, would be performed to support engineering analysis and design However, the flood flow frequency approach outlined in Bulletin 17B is not wholly appropriate for "watersheds where flood flows are appreciably altered by reservoir regulation, or where the possibility of unusual events such as dam failures must be considered" (USWRC, 1981). Understanding that the Green River flow regime is highly regulated, flood design hydrology for high recurrence interval floods (i.e. Q_{20}-Q_{100}) were selected from maximum dam release rates published in the Howard Hanson Dam Water Control Manual (USACE, 2001). However, a flood frequency analysis was utilized to evaluate lower recurrence interval statistics, the results of which are shown in Table 1. Further details on flood frequency analysis are included in Appendix A.

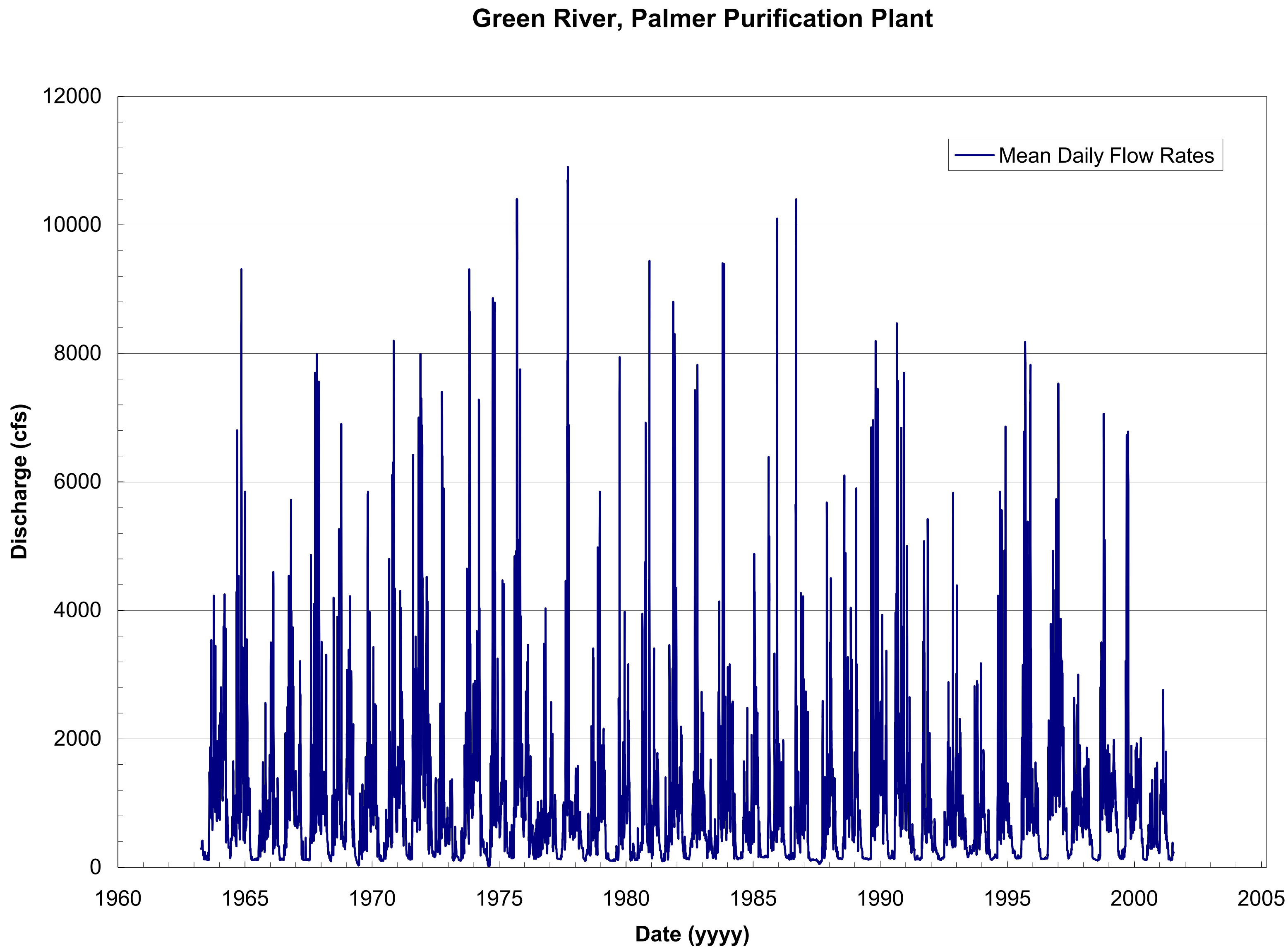

Figure 3. Green River Mean Daily Discharge

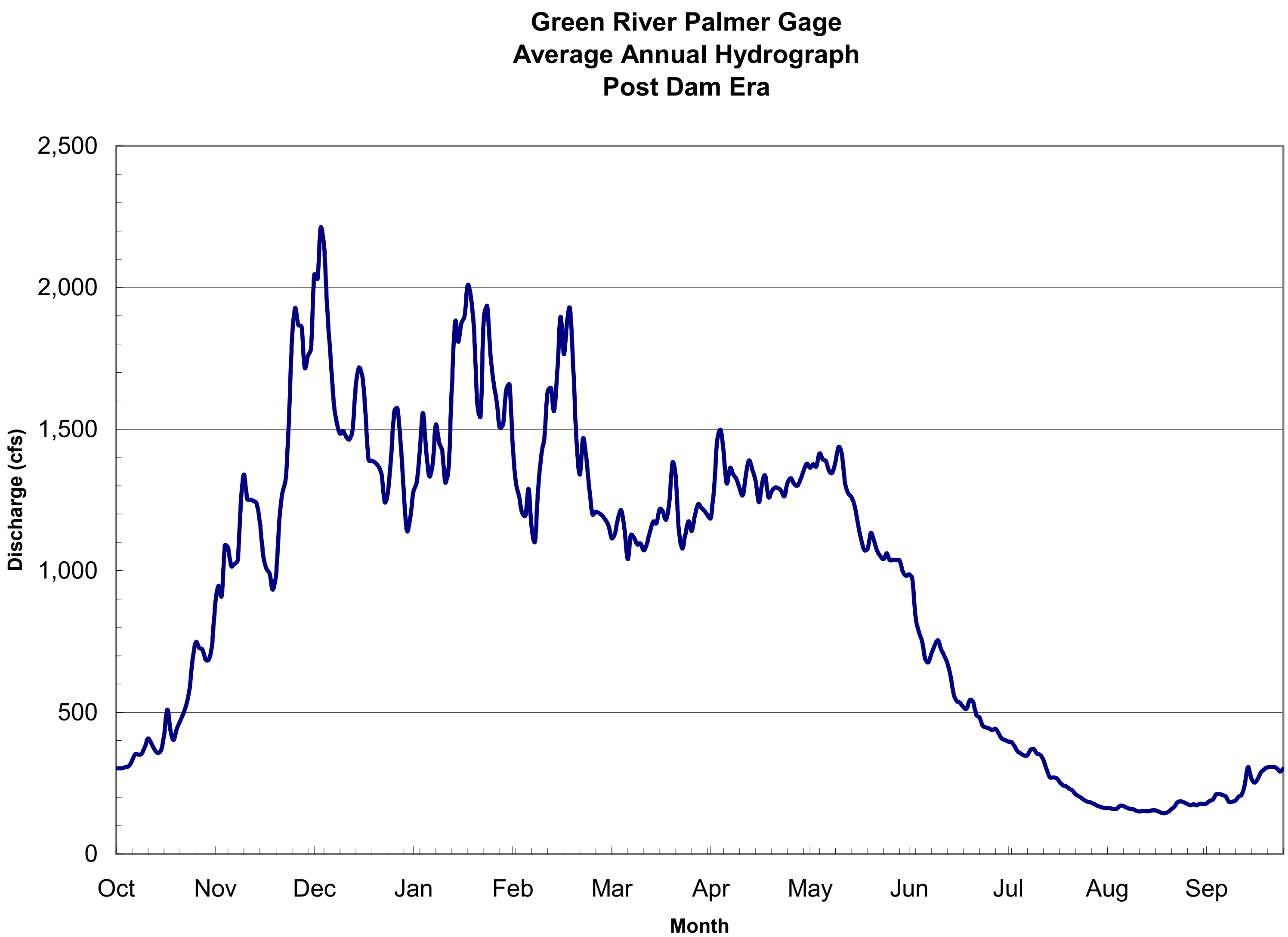

Figure 4. Green River Average Annual Hydrograph

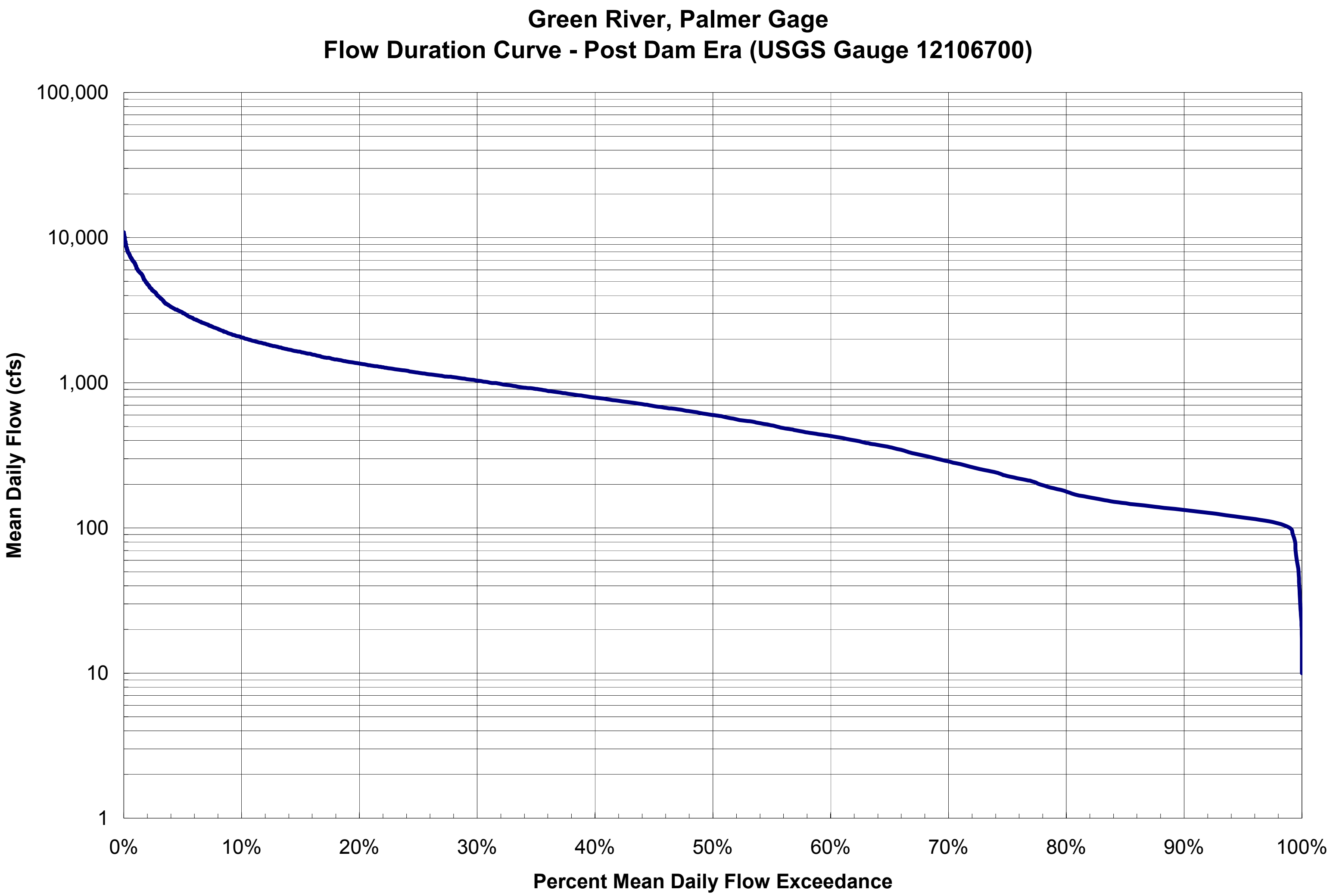

Figure 5. Green River Annual Flow Duration Curve

It was postulated by Dunne and Dietrich (1978) that 12,000 cfs was the pre-dam bankfull discharge with a recurrence interval of 1.87 years. Prior to 1962, when the HHD was completed, 12,000 cfs was exceeded 14 times during the 25-year period from 1937 to 1961 (Madsen and Beck, 1997). Post-dam, 12,000 cfs is estimated to be a 25-year flood event and the bankfull event is now on the order of 6,900 cfs to 7,720 cfs (Q1.5 – Q2). The current bankfull event is just greater than 50% of the historical flow rate. The historical event of 12,000cfs had the capacity to transport up to 6 inch material on average, using the existing hydraulic model. This event would mobilize approximately 60% of the current, armored bed material composition, and theoretically 80% to 90% of the historical bed material. Evaluation of the 1.5-year event reveals transport mobility of 4-inch material on average through the study reach which is between 70% and 85% of the gravel berm bed material specifications.

Table 1. Flood Frequency Recurrence Intervals

Annual Recurrence Interval (yr)	Annual Exceedance Probability (%)	Peak Discharge (12106700) (cfs)	Peak Discharge (12105900) (cfs)
1.05	95	4,360	4,030
1.25	80	5,950	5,670
1.5	67	6,870	6620
2	50	7,920	7,720
2.5	40	8,580	8,390
3.33	30	9,300	9,130
5	20	10,200	10,000
10	10	11,400	11,300
20-100	5	12,500	12,500

Low Flow Analysis

Low flow analysis of the Green River at the Palmer Gage was performed primarily to evaluate river hydraulics and water surface elevations during the construction period. The following is a list of relevant low flow characteristics of the Palmer Gage. Construction of the Engineered Log Jams requires building either water control berms or cofferdam structures to isolate water from excavation areas. Several construction methods were evaluated in relation to the following low flow information. The 10% exceedance flow for the month of August was selected as a target low flow condition for installation of the cofferdam and pipe by-pass system. Using two 48" pipes through the site passes approximately 180 to 200 cfs which is less than the selected design criteria of 10% exceedance for the month of August of 230cfs. This does not meet the 10% exceedance criteria, but the cost of installing a third pipe is expensive and therefore the project team is in discussions with water management personnel for controlling flows to remain below the 180cfs level for a period of 2-weeks during the month of August, 2003.

- The instream low flow augmentation requirement for the Green is 113 cfs
- The average daily flow rate for the month of August is 162 cfs
- The 90% exceedance flow for the month of August is 111 cfs
- The 50% exceedance flow for the month of August is 136 cfs
- The 10% exceedance flow for the month of August is 230 cfs
- The selected construction low flow is 180cfs with a 20% exceedance probability and coordination with dam and diversion operations.

Representative Flow Hydrographs

Representative flow hydrographs were developed to support sediment transport analysis of the gravel nourishment features. The purpose of this effort was to identify annual hydrographs for three representative conditions: a typical low flow year, a typical average flow year, and a typical high flow year. These three representative annual conditions were then used to evaluate gravel entrainment and sediment transport characteristics of the existing and proposed conditions for the gravel nourishment sites (Appendix A). Using the methods outlined in Appendix A the low, typical and high flow hydrographs were selected as 1992, 1999 and 1996, respectively (Figures 6-8). For the low flow year, four water years fit the criteria very well, although water year 1992 appeared to meet the criteria the best and had a peak flow near the 1.25-year recurrence interval. For the typical year, the timing of the peaks in water year 1999 most closely matched the timing of the peaks in the average annual hydrograph, and the recurrence interval for the highest peak was approximately the 2-years recurrence interval. The representative high water year was identified as 1996 with a recurrence interval flood on the order of the 5 to 10-year event and a large number of occurrences of peaks greater than the 1.5-year recurrence interval.

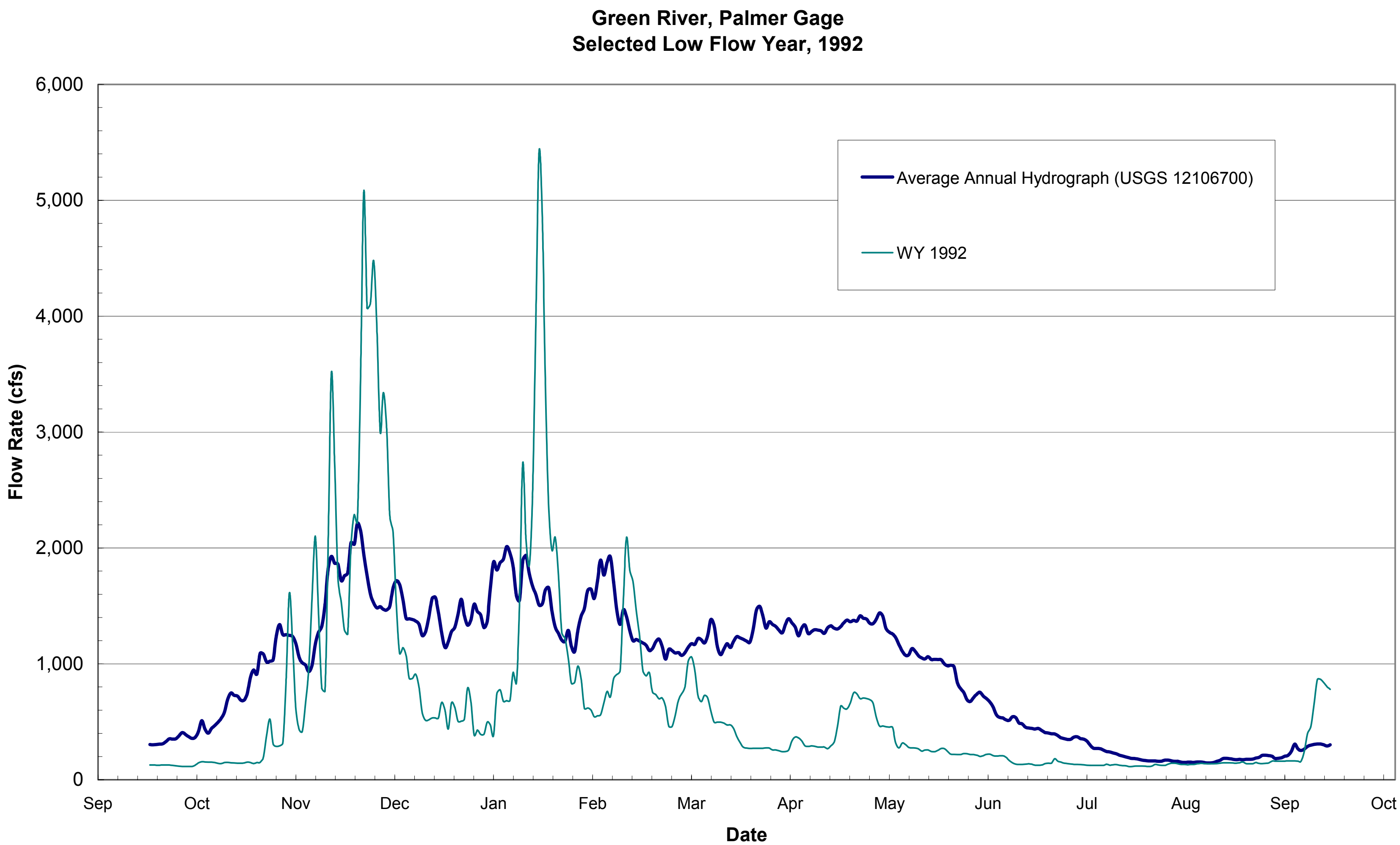

Figure 6. Green River Low Flow Hydrograph

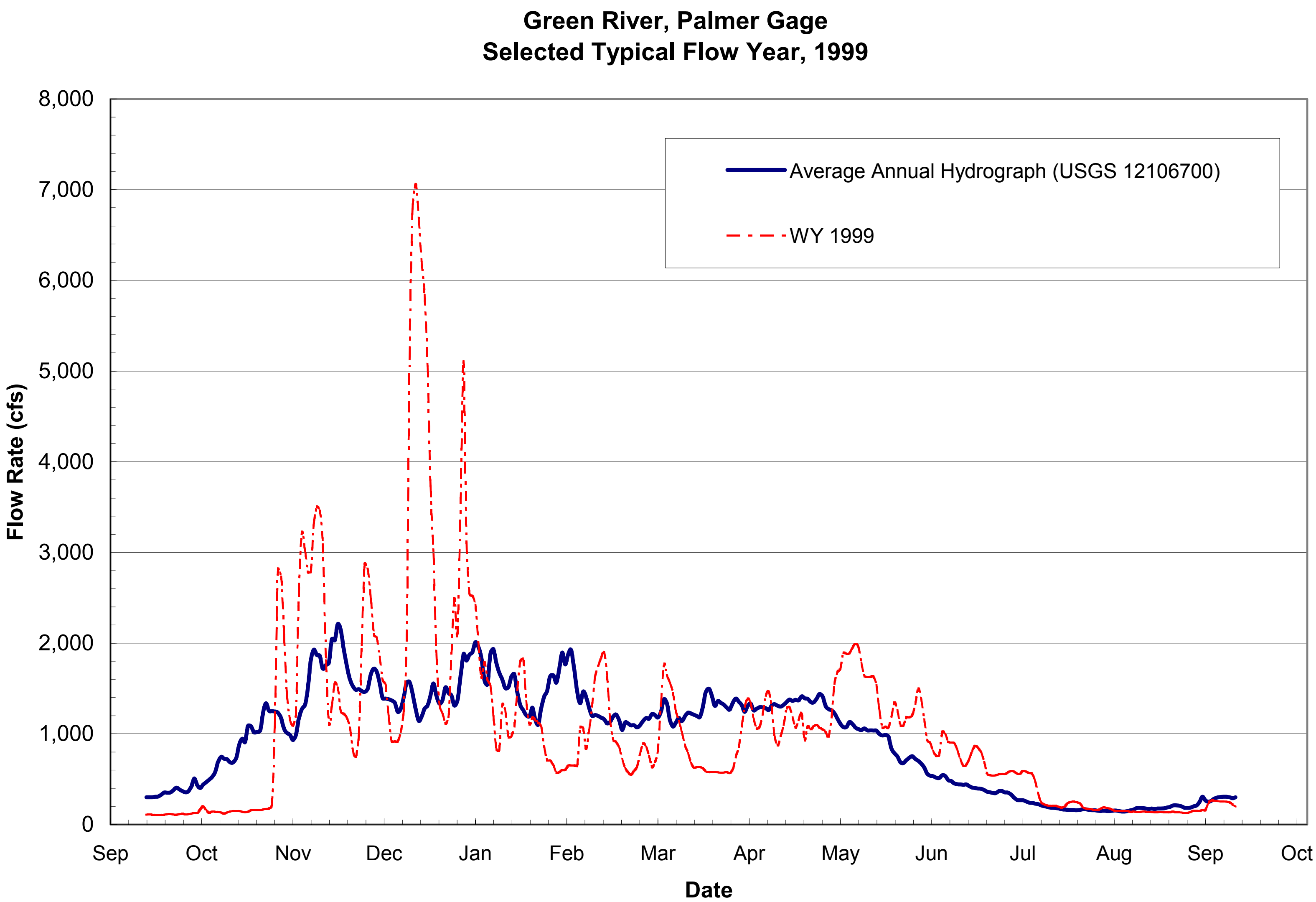

Figure 7. Green River Typical Flow Hydrograph

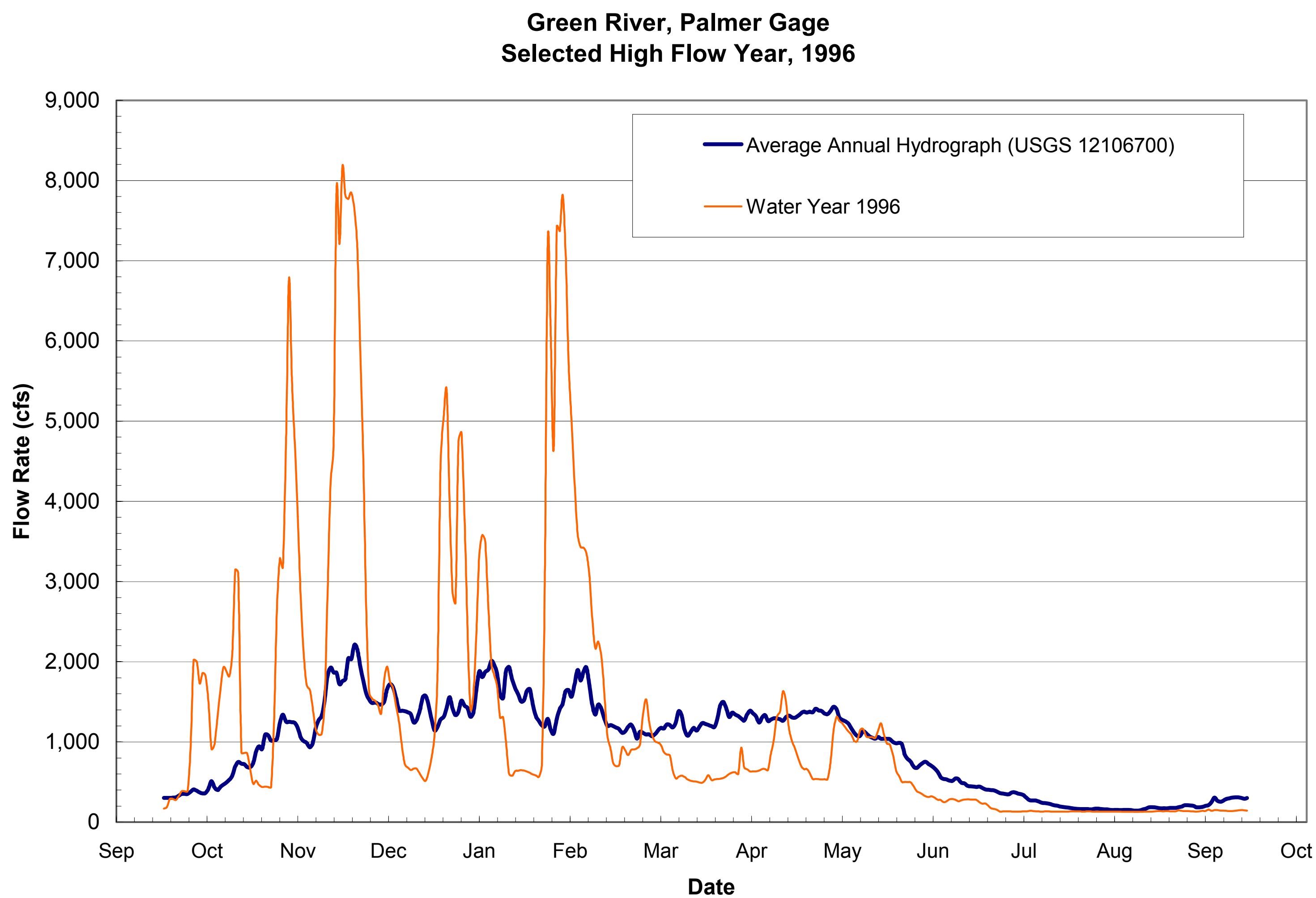

Figure 8. Green River High Flow Hydrograph

3.2 Hydraulics

An HEC-RAS model was developed for the Green River as a tool to determine specific hydraulic parameters for input to the design elements and the habitat evaluation of the project alternatives (Appendix B). The hydraulic model was comprised of a series of cross sections, water surface elevations, and flows representative of the existing topography of the Green River. The model extends from KP-1.0 (Tacoma Headworks Office, RM 60) to KP-9.0 (Tacoma Pipeline Crossing, RM 58.0). The focus of the hydraulic analysis was in the segment of the river that travels through Restoration Zone 1 (Figure 9).

The existing conditions model was developed using a variety of sources. Geometric inputs included data generated from hydrographic survey cross sections and intermediate cross section data cut from DTM sections developed from bankline topographic surveys. Hydrologic inputs were taken from the design hydrology. Calibration of the model used water surface profiling survey information. The range of flows modeled include the construction period low flow (Q=200 cfs), increments of 1000 cfs up to 10,000 cfs, the approximate bank-full discharge of (Q1.5 = 5,500 cfs), and the maximum event on record of 12,500 cfs. Plots of model outputs are shown in Appendix A.

Three basic modeling scenarios were evaluated to support engineering analysis and design of the project. These include 1) existing conditions, 2) changes in hydraulics from "short-term" future conditions evaluation of the gravel nourishment and ELJ features and 3) water control design, cofferdam and pipe by-pass during construction. Outputs from the model, including water surface elevations, shear stress, channel velocity, energy slope, flow area, hydraulic depth, and hydraulic radius, were used in the sediment analysis and design of site features (Appendix A). Specifically, shear stress, energy slope and hydraulic radius information were used for the sediment transport and scour analyses for the gravel nourishment and ELJ features. Water surface profile elevations were used to identify/verify gravel nourishment berm elevations, identify the height of ELJ structures, and determine the elevation for the water control cofferdam elevations for head requirements and the size pipe for construction flows.

Modeling scenarios were run to evaluate changes in flood hydraulics resulting from the short term future conditions after installation of the ELJ and gravel nourishment features. The features generally create more roughness, constrict flow and create backwater areas upstream from the construction locations. The most notable change in flood hydraulics is the water surface profile.

Figure 10. shows comparisons of existing and short term increases in flood water surface elevations. Further analysis related to the individual features is included in the following sections of the report. Although water surface elevations increase, this condition is short term and will likely subside once scour holes develop around the ELJ features. Also, there is no private property that will be damaged from the increase in water surface elevations during flood conditions.

Figure 9. Green River HEC-RAS Restoration Zone 1, Site Overview Map

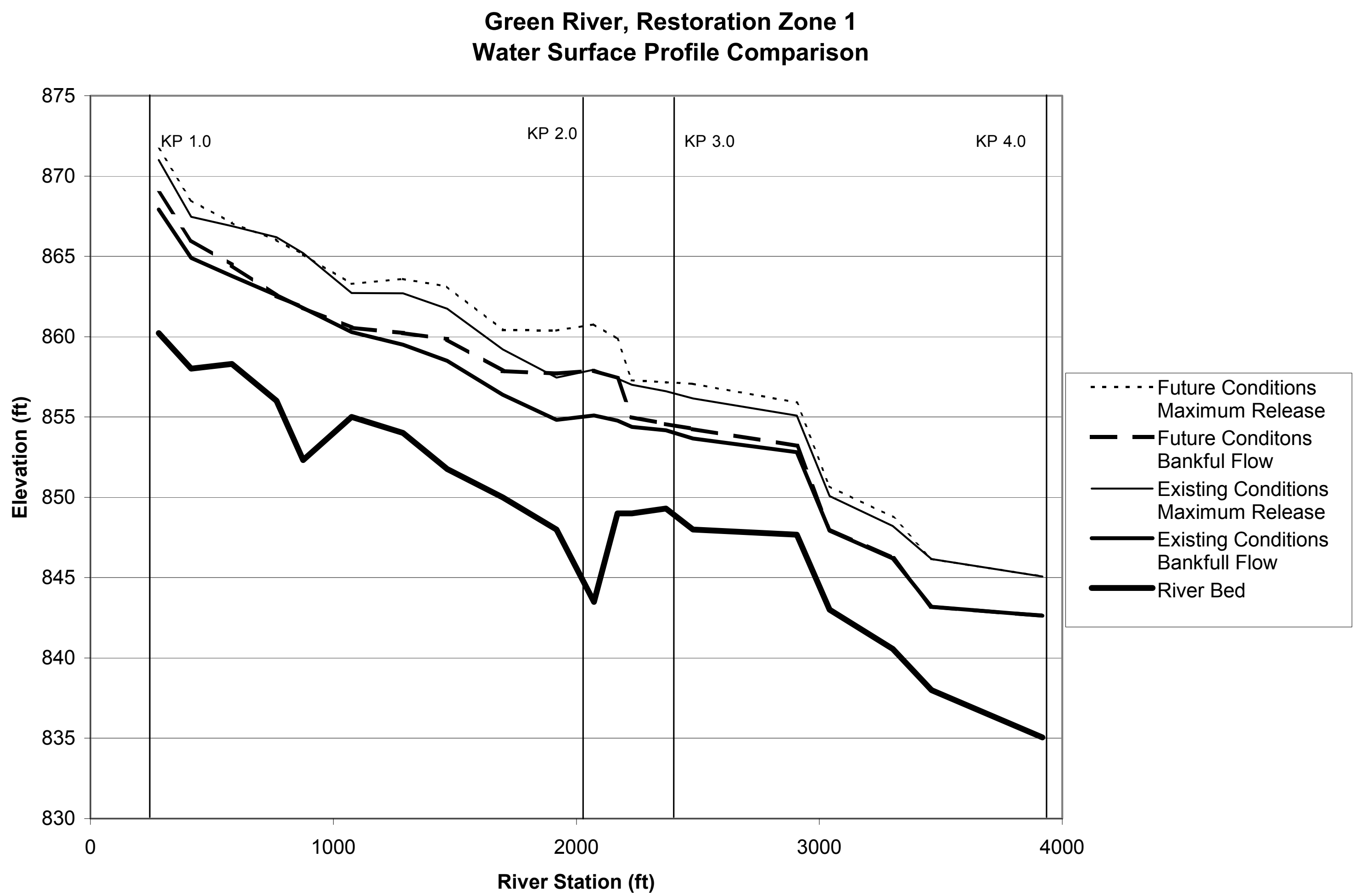

Figure 10. Green River HEC-RAS Restoration Zone 1, Existing and Short-Term Future Water Surface Elevations

3.3 Sediment and Gravel Nourishment

The approach for evaluation and design of the gravel nourishment features entailed review of existing gravel nourishment projects, identification of the gravel nourishment size specifications and evaluation of the potential performance of the gravel nourishment features. First, reviews of existing gravel nourishment projects for salmon habitat restoration were performed to evaluate the success and identify limitations encountered on other similar projects. Second, identification of the proposed gravel nourishment size distribution specification was performed taking into account design criteria associated with spawning gravel size distributions, construction issues, and water quality regulations. Thirdly, sediment transport analyses were performed to evaluate the potential performance of the proposed gravel nourishment plans.

Gravel Nourishment Review

A review of other gravel nourishment projects was performed to help identify successes and issues facing similar programs. The projects include the Cedar River in Washington, and the Trinity, Merced, and Sacramento (below Red Bluff Diversion) rivers, in California. The projects use a variety of gravel nourishment techniques, which have had varying degrees of success and issues related to gravel loading. Some projects have loaded gravel by dumping during large events and have had success mobilizing material at the loading site, but problems with excessive deposition in downstream areas. Other projects spread materials across the channel bed that were too large in diameter and had trouble transporting material. Also, another project had built a long berm parallel to river flow patterns and was having difficulty entraining material. Overall, the application methods for these projects vary and the success of the projects also varies. Overall, the review of the gravel nourishment projects indicates that sediment entrainment is limited at times because of the application method.

In consideration of the findings from the gravel nourishment project review, two distinct application methods were proposed to improve the ability of the river to entrain, mix and distribute sediments. The proposed application methods are 1) gravel berms with ribs that protrude significantly into the flow path and are either perpendicular or angled upstream with the direction of flow and 2) semi-circular wedges or bars (1/2 teardrop) that protrude out into the flow line. Construction of only berms that parallel the flow path were eliminated due to the limited success identified in the other gravel nourishment projects.

Gravel Specifications

The task of developing gravel specifications for the gravel nourishment berms addresses several issues related to size distribution of salmon spawning gravels, identification of construction methods and design criteria and evaluating the potential effects on water quality. The difficulty in developing a gravel specification is that there are competing interests. For example, spawning gravel distributions are composed of gap graded gravel materials and do not have the amount of fines and sands needed to establish a competent driving surface for dump trucks and heavy equipment. The berms must function for the latter purpose to allow construction access for placement of both the berms and the ELJs.

A review of spawning gravel distributions was performed to assist in analysis and design of the gravel nourishment features, specifically the development of a gravel nourishment gradation specification. The biological opinion issued by the National Marine Fisheries Service (NMFS, 2000) identifies the preferred size distribution of gravel substrates ranging from 12.7 mm (1/2 in) to 101.6 mm (4 in) materials. In Figure 11, the Bi-Op specification is identified. Additional work was done regarding salmon spawning gravels that examined historical spawning material data sets and sediment samples from known spawning sites on the Green River (Appendix B.) This evaluation shows that the Bi-Op specification is lacking sands and fines that are found in other known spawning samples. Due to permitting restrictions, the Pilot Project has minimized the use of this material, but further investigation into the role of sands and fines in alluvial substrate composition in relation to habitat viability for salmon is warranted.

One important consideration for the gravel distribution is the suitability of the berms for travel using heavy construction equipment and dump trucks. The Bi-Op gravel specification does not have the binding capacity to for driving heavy equipment and an additional specification is required to support heavy equipment. This material is identified as the "structural backfill" material, that will be used along the riverward bankline along the edge of the ordinary high water mark (Figure 12). The structural backfill specification was developed by the Seattle District, Corps that meets the needs of supporting heavy construction equipment on the water control berms (USACE, 2003b)The gradation of materials proposed for the backfill and driving areas are identified in Figure 12.

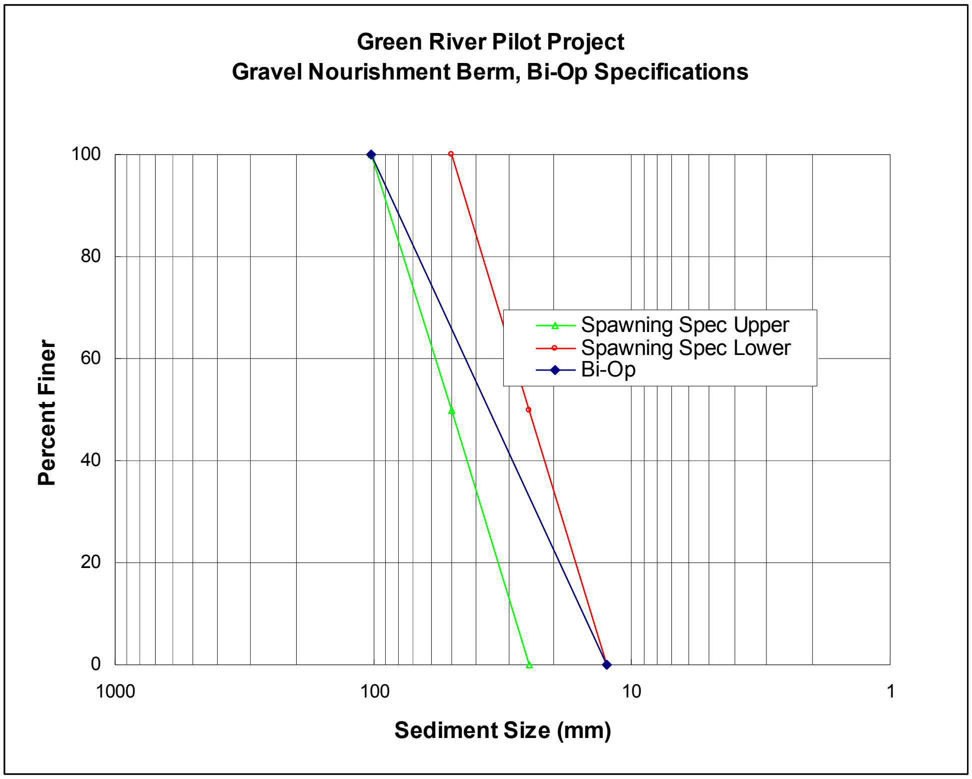

Figure 11. Biological Opinion Salmon Spawning Gravel Gradations

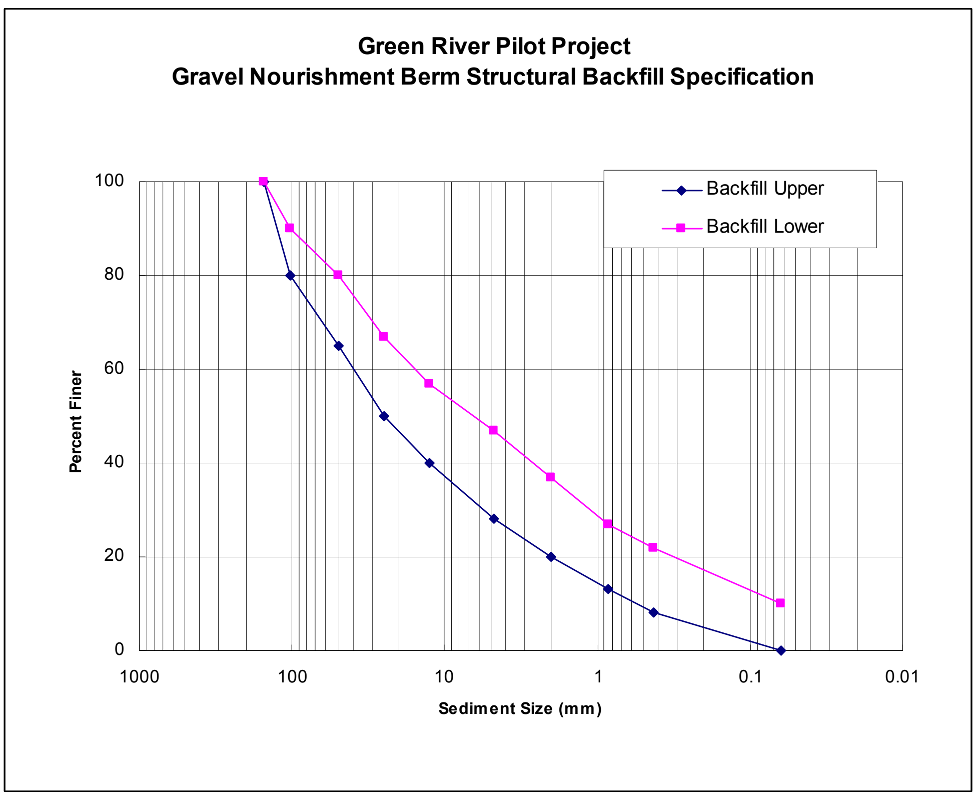

Figure 12. Structural Backfill Specification

Water Quality

Water quality is a significant issue that limits the amount and placement technique of the gravel nourishment berms and also is a driving factor behind the water control design. The water quality regulations on the project are identified in the Washington State, Water Quality Standards (WAC, 173-201). The turbidity standard is not to exceed 5 NTU over background turbidity when the background turbidity is 50 NTU or less or not more than a 10 percent increase in turbidity when the background turbidity is more than 50 NTU at a point 300-feet downstream from the project site. Typical NTU levels during the month of August range between 0.5 and 2.0 NTUs for the Green River (WDOE, 2003). The likely effects from construction of the gravel nourishment berms is short periods of increased turbidity resulting from placement of gravel in wet conditions during the low flow period. In addition, the gravel nourishment berms will also contribute a fraction of fine materials during larger flood events when they are eroding into the river. However, it is unlikely that this will create increases in turbidity levels above background levels, unlike the potential increases during low flow periods. There is also a potential to effect turbidity during the low flow period with the construction of the ELJs. Construction of these features requires isolation of the area from water to excavate a pit for placing wood foundation layers beneath the existing channel bed. Water infiltrating to the pit will be extremely turbid and will be pumped to upland trickle or infiltration areas. The limiting factor in controlling turbidity is the method of water control for isolating the pits. The methods are discussed herein.

In consideration of the turbidity regulations several options were examined for limiting turbidity in the areas of construction. For the gravel nourishment features, these included using the screened Bi-Op specification in combination with the structural backfill specification, washed gravel protective toes with structural backfill, sediment fencing, ecology block deflectors and gravel bag protection. The two methods evaluated for controlling turbidity for constructing the ELJ features were use of a cofferdam and pipe by-pass system or a series of water control berms with a temporary bridge crossing. Each of the methods have varying levels of the potential to effect turbidity as well as construction limitations and cost and are discussed in further detail in the supporting technical appendices and site design section of the report.

The primary feasibility criteria were turbidity control, cost, fisheries issues related to diverting the river, and safety concerns. It was determined that the most feasible solution that met project objectives for the gravel nourishment features was the use of a combination of a structural backfill construction pad from which the spawning gravel (Bi-Op) berm would be built by pushing into the river using a bulldozer shown in Figure 13. The construction of the gravel nourishment berms themselves will create turbidity even using limited structural backfill material and a majority of the Bi-Op specification. An additional measure is proposed to place ecology block deflectors at the upstream edge of the gravel nourishment berm to create a hydraulic shadow for constructing the berm feature. It is unknown the exact level of turbidity that will be created using this method, and construction activities will be monitored regularly. Section 4.5 discusses the amount of gravels for each of the two specifications that will be used in constructing the project. Figure 13. Washed Gravel Toe Section View

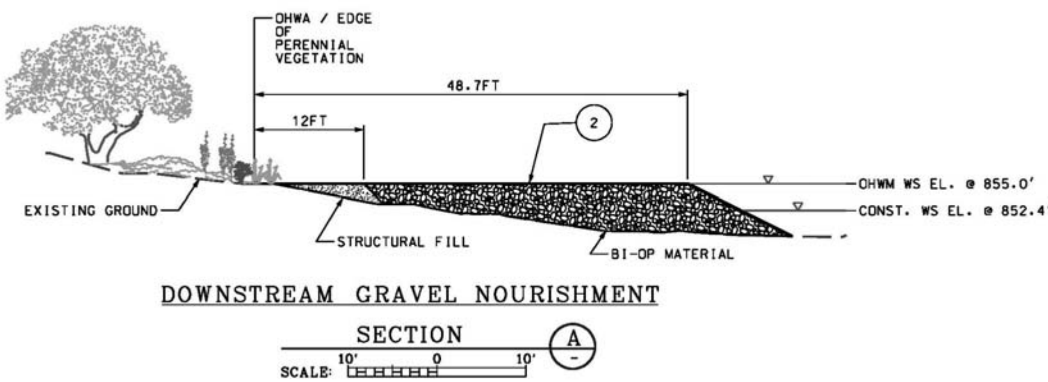

Figure 13. Gravel Nourishment Section View

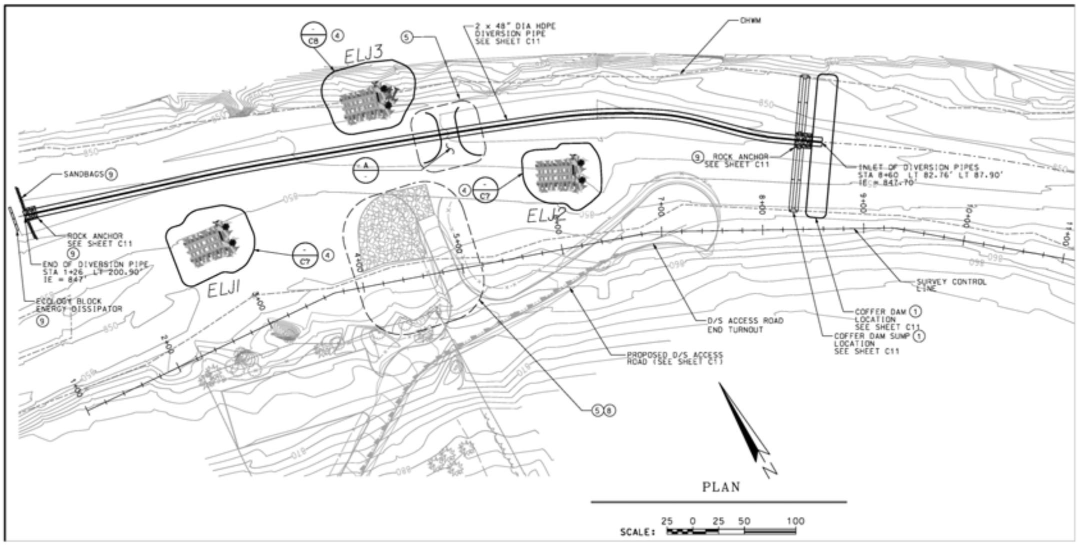

Figure 14. Cofferdam and Pipe By-Pass Plan

The cofferdam and pipe by-pass system are designed so that construction crews can work in the riverbed in a controlled flow environment (Figure 14). The site will be dewatered and infiltration flow pumped to upland trickle and infiltration areas. The proposed approach is the most effective measure in providing turbidity control.

Sediment Transport Analysis

There are three main purposes to the sediment transport analysis associated with gravel nourishment. These are to evaluate the river's ability (existing and future conditions) to entrain gravel, evaluate the river's ability transport gravel, and to utilize the sediment transport analysis results in refining gravel nourishment berm designs (Appendix B). Incipient motion analysis was performed by determining the critical grain size diameter using the Shield's equation. Sediment transport capacity analyses were performed using the Meyer-Peter Müller bedload and Yang's suspended load formulas. The sediment transport calculations were then used to identify and modify the gravel nourishment design configurations.

General results of the incipient motion analysis reveal that flow hydraulics are sufficient to entrain 1.5 inch to 3.5 inch materials for the 2,000 cfs event, 2.5 inch to 7.0 inch material for the

5,500 bank-full flow rate, and 4.0 to 11.0 inch material for the 12,500 cfs maximum release event. The low end of the incipient motion range was typically found near the downstream end of the restoration area, where plans were to have material deposit to improve spawning habitat. The sections with larger critical diameters were at the locations selected for the gravel nourishment berm loading sites (Table 1, Appendix B).

In addition, a comparison of critical grain sizes to bed material distributions were performed. Results of the comparisons reveal that 57% of the bed material at KP-1.0 is potentially mobilized at the 2,000 cfs event, whereas approximately 12%-16% is mobilized at KP-2.0 and KP-3.0. The hydraulic gradient near KP-1.0 is steeper than that of KP-2.0 and KP-3.0 and KP-1.0 also has a finer bed material gradation. This appears contradictory, but the finer bed material distribution is a function of two morphologic controls. First, KP-1.0 is located near the mouth of the canyon downstream from HHD, where gravels naturally deposit. The second is that KP-1.0 is near the alluvial deposits of a recent landslide.

Future conditions comparisons show a slight upward shift in critical grain size diameters for lower flow conditions resulting from changes in channel hydraulics associated with the changes in channel geometry from construction of the gravel nourishment berms. For the future conditions it is seen that the critical grain diameter is larger than the Bi-Op material maximum grain size of 4 inches in diameter at approximately 3,000cfs for both the Upstream and Downstream Gravel Nourishment Sites. This implies that the entire surface layer of the berm could be mobilized at events slightly less than the bankfull event of 5,500 cfs (Figures 15 & 16).

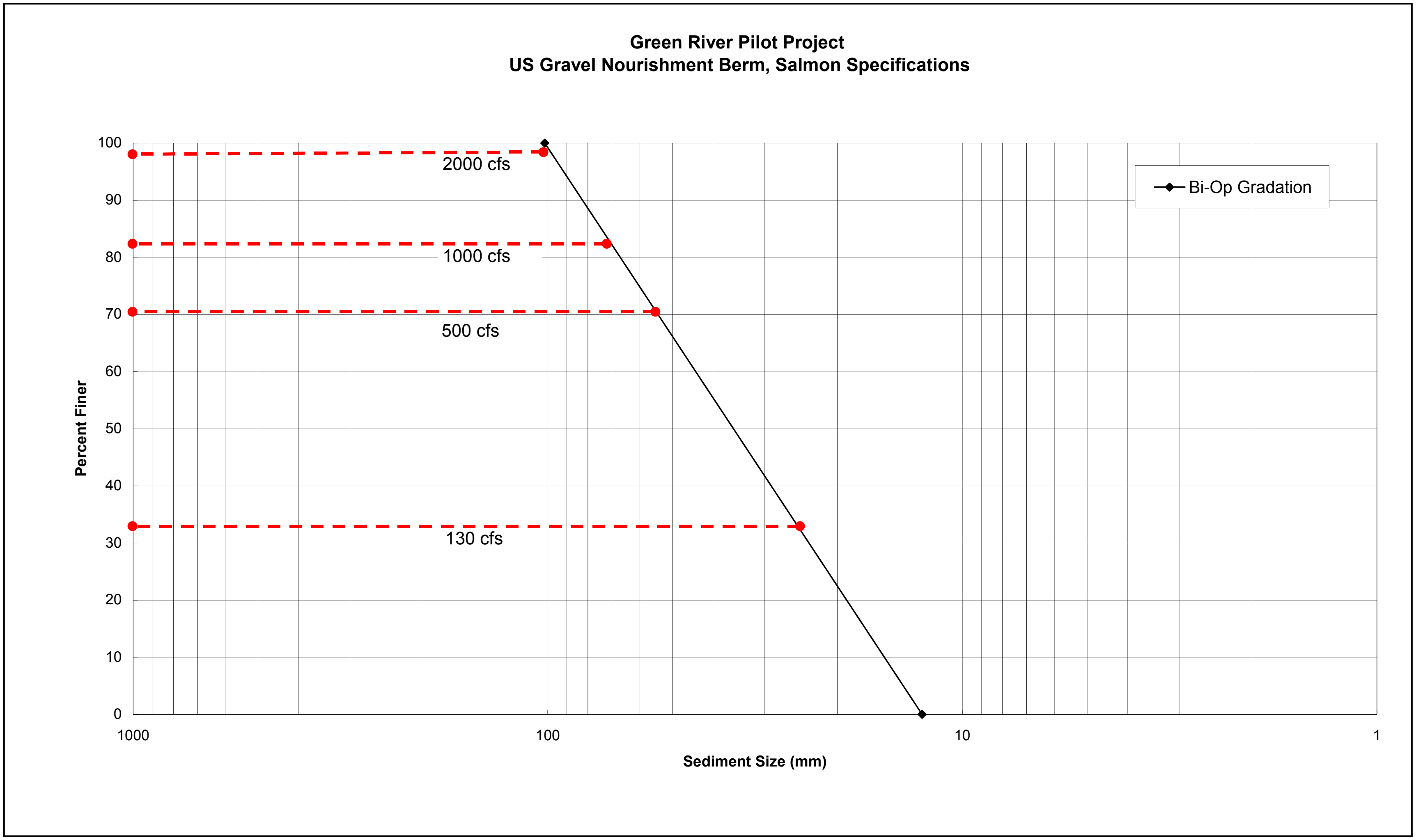

Figure 15. Upstream Gravel Nourishment Berm Incipient Motion Characteristics

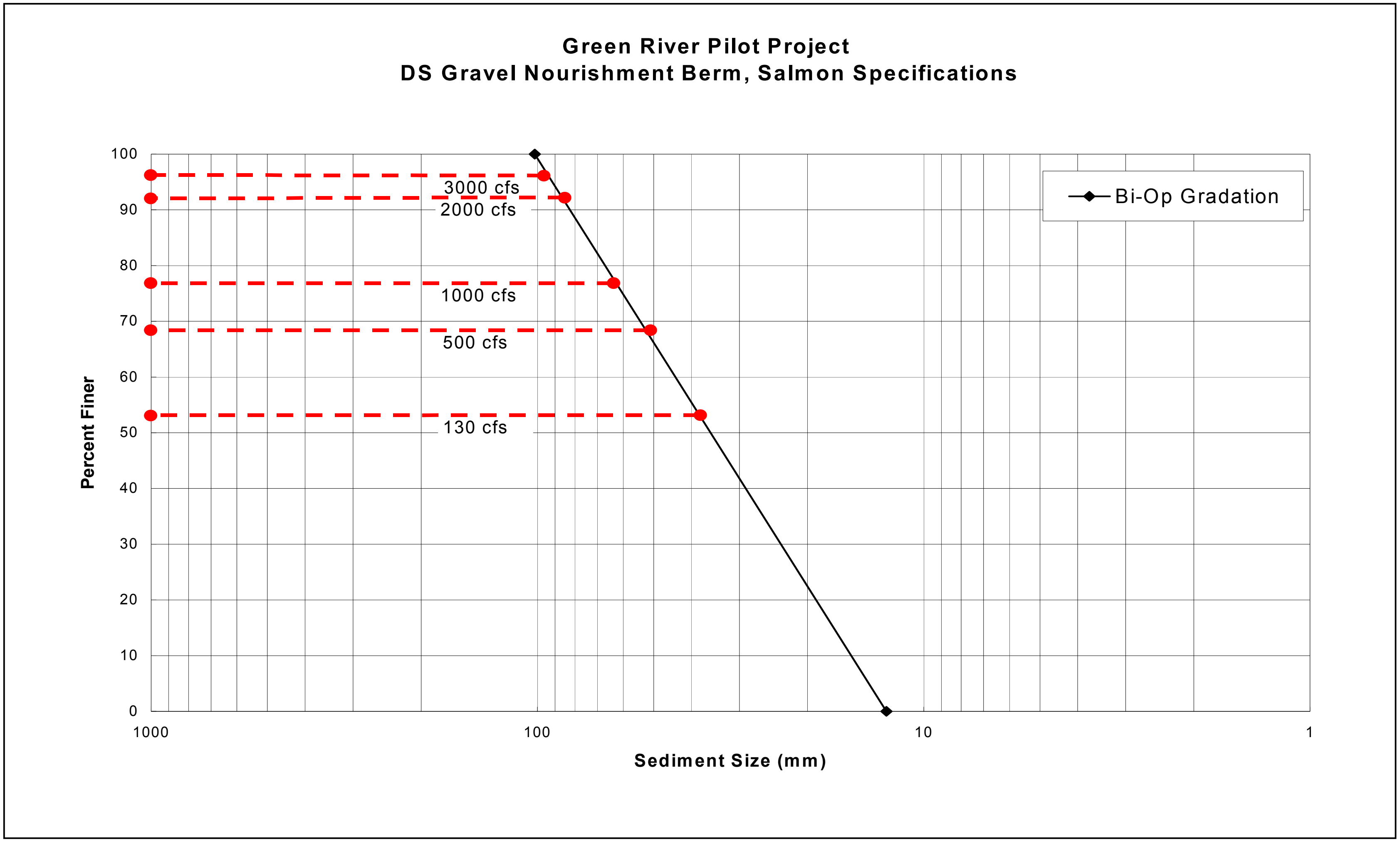

Figure 16. Downstream Gravel Nourishment Berm Incipient Motion Characteristics

The next level of analysis performed for the sediment investigations was to evaluate the sediment transport capacity and estimate the total annual sediment load through Restoration Zone 1. The Meyer-Peter Müller (MPM) (Meyer-Peter, Müller, 1948) bed load equation is used for this analysis. This equation is often used for streams with large amounts of gravel and cobble, can be utilized in supply limited situations, and was used to compute the bed material transport of the gravel and cobble grain fractions through Restoration Zone 1. Yang's dimensionless equation for sand transport (Thorne, C.R., et al, 1987) was used to compute the suspended sediment transport of the finer grain sizes. The total load estimates can vary by a factor of two, but the results match well with other sediment transport capacity estimates performed on the Green River (Madsen, 1997 and Perkins, 1999).

Total load estimates through the study reach were then computed by combining the separately computed bed load and suspended load components and developed into total load rating curves (Appendix B). The curves were then integrated with the design hydrology to develop annual total load estimates. Table 2 displays the results of the sediment transport capacity analysis for the low, typical, high flow and period of record hydrographs. The results of the analysis show that changes in channel geometry and decreases in bed material size distribution contribute to increases in sediment transport capacity. The reach average for the typical flow year shows an increase from 6,272 tons/yr to 9,924 tons/yr and an increase from 10,413 tons/year to 15,286 tons/year for the high flow hydrograph. The hydrograph averages match well with the total load estimates of 12,000 tons/year identified in previous feasibility studies.

Table 2. Annual Total Load Estimates

	Low Flow Year		Typical Flow Year		High Flow Year		Period of Record	
	Hydrograph Method		Hydrograph Method		Hydrograph Method		Flow Duration Method	
	Existing	Future	Existing	Future	Existing	Future	Existing	Future
	(tons/year)	(tons/year)	(tons/year)	(tons/year)	(tons/year)	(tons/year)	(tons/year)	(tons/year)
KP 1.0	8,491	9,630	15,810	16,621	28,524	26,073	22,800	19,900
RAS 27.1	3,717	3,025	7,451	5,812	12,618	12,083	9,400	8,100
KP 1.3	6,580	19,092	12,337	33,811	18,860	48,851	15,800	41,900
RAS 26.1	2,706	4,152	4,847	7,517	8,015	11,175	16,400	28,800
KP 1.5	4,696	8,741	8,026	15,871	12,554	20,646	10,400	20,200
KP 1.7	2,748	960	4,618	1,742	6,490	2,930	4,900	1,400
RAS 24.2	2,700	4,085	5,020	6,597	8,691	10,695	6,600	8,500
RAS 24.1	1,803	4,556	3,494	7,970	6,311	11,963	5,200	9,400
KP 2.0	77	333	77	479	222	1,511	400	1,300
KP 3.0	541	1,417	1,042	2,819	1,849	6,933	1,500	4,100
Average	**3,406**	**5,599**	**6,272**	**9,924**	**10,413**	**15,286**	**9,340**	**14,360**

Overall, the sediment studies indicate that the Green River has the ability to mobilize gravel sized sediments in the proposed gravel nourishment locations at flows less than the bankfull condition. Segments at the low end of the incipient motion were typically found near the downstream end of the restoration area, near the ELJ features, where plans were to have material deposit to improve spawning habitat. The sections with larger critical diameters were at the locations selected for the gravel nourishment berm loading sites (Table 1, Appendix B). The analysis supports the overall scheme adopted for the gravel nourishment of scour from the initial loading zone and then transport of the material to spawning areas where portions of the gravel load will deposit and counteract the historic influence of HHD on the bed material sizes.

However, issues remain regarding the sediment transport rates of the gravel nourishment project under the current flow regime and the historical annual loading deficit estimate of 12,000 tons per year. The modeling effort shows that 15,000 tons per year at the upper end of the gravel nourishment transport capacity scenario for the high flow. In order for the program to be effective, the loading rate will need to exceed the capacity initially to fill in sediment voids and dead spaces in the short term. Verification of gravel nourishment project performance will need to utilize information from project performance monitoring. Monitoring plans for the pilot project include baseline and future conditions monitoring to aid in adaptive management of gravel nourishment operations. Sediment monitoring techniques include bed material sampling, cross section and topographic surveys, and geomorphologic and habitat assessments of segments of the river within the pilot project reach.

Over time gravel nourishment loading rates should be similar to the annual sediment transport capacity of the river with future flow conditions. Further examination of Table 2 indicates that the average sediment transport capacity of the reach for the proposed gravel nourishment project is approximately 9,000 tons per year to 15,000 tons per year, which on average is equal to the annual total load identified by Perkins, 1999. This is nearly double the amount of sediment being loaded in Restoration Zone 1, but similar to the amount of sediment loading proposed for both Restoration Zone 1 and 2. In areas near the berms, transport rates exceed the volumes of gravel being loaded indicating the potential for erosion and in downstream areas the amount of gravel loading (from upstream) exceeds the sediment transport capacity indicating the potential for deposition. Future monitoring including cross section surveys, topographic surveys of the gravel nourishment berms, sediment sampling and photographs of the site will be beneficial in evaluating the actual sediment transport conditions through Restoration Zone 1.

3.4 Engineered Log Jams

This discussion is for use in planning and designs with respect to the Howard Hanson Dam Engineered Log Jam and Gravel Nourishment Pilot Project. This discussion typifies analyses related to Engineered Log Jam (ELJ) design and implementation. ELJs are instream hydraulic structures comprised primarily of large woody debris (LWD) that can be used to solve common river engineering problems involving grade control, flow manipulation, and channel training. The design premise of ELJs is to emulate naturally occurring structures and processes found in fluvial environments. Wood debris accumulations have been identified as the primary feature affecting geomorphic change in natural systems. A properly designed and constructed ELJ can perform as a revetment or groin, with the additional benefits of introducing significantly more habitat complexity to the channel and blending effortlessly into the natural environment. ELJs have been used to redirect flow approaching bridges, provide reach scale bank protection for roads and hillslopes, and decreasing the likelihood of avulsion. Logjams have also been used primarily for the creation of fish habitat through pool creation and the development of complex hydraulic conditions desirable for anadromous fishes. Furthermore, ELJs can be placed such that they diversify channel networks by splitting flows and creating secondary channels.

There are three proposed engineered log jams (ELJs) in Restoration Zone 1. Two are apex jams located toward the center of the active channel and one is a barb jam along the right channel margin. The general placement location was identified initially in the *Howard Hanson Dam Additional Water Storage – Phase 1 Fish and Wildlife Mitigation and Restoration Conceptual Design Report* (USACE 2000). Two preliminary locations were identified in the report along the split flow reach near the Tacoma Watershed office. The subsequent HHD Site Investigation report further evaluated the placement of ELJ structures along the reach and identified similar placements as well as several other installation locations.

The conceptual restoration design put forth in the HHD Site Investigation was to integrate the ELJ structures with the Gravel Nourishment plans in order to maximize the habitat benefits for salmonid habitat. The physical character of the conceptual designs was to place gravel in upstream locations where it will be eroded and transported downstream. ELJ structures would be located downstream where they would create pools near potential gravel depositional areas, resulting in holding habitat in close proximity to potential spawning areas. An additional goal of the conceptual design for ELJ locations was to help promote sorting and distribution of gravels along the main channel and side channel areas. Currently, side channel habitats in the Kanaskat-

Palmer reach are composed of large cobble substrate and little gravel material (Figure 17). As such, this reach provides little area for spawning opportunity.

Figure 17. Splitflow Side Channel (low flow)

The selected site near the Tacoma Watershed Office is a long, low energy run with high potential for gravel deposition. The ELJ features will act as localized roughness elements creating complex local hydraulics. This will help trap, store, and mix gravel material and potentially distribute gravel to both the mainstem and splitflow side channel areas.

Determining the location, type, and size of ELJ placements is done through a series of qualitative and quantitative analyses. ELJ locations are typically determined by considering the overall objectives of the project and evaluating site specific conditions, such as local geology, hydrology, geomorphology, etc. Final siteing is highly dependent upon the expected future conditions at the site and how well ELJ location(s) are expected to meet these objectives. The structure type is highly dependent on the final jam location, but is also linked to the objectives of the project. The specific architecture (size and configuration) is determined through a more quantitative process evaluating the structural stability and potential scour of the proposed structures. For this project, we also conducted an encroachment analysis where we considered various ELJ configurations and evaluated the potential effects of these configurations. This evaluation provides support for the design and expected future conditions. An overview of the general assumptions and engineering analyses are provided in the following sections.

Planform

The planform along this segment of the river is a relatively straight reach where the river is transitioning away from the Lemolo fault hillslope towards the broad valley downstream near Signani and Brunner Sloughs. The river is partially confined and has little floodplain connectivity because of the reduction of peak flood flows. The elimination of sediment supply from the headwaters has resulted in degradation and incision of the channel bed, and the floodplain is currently limited to the interior benches of the historical channel. The objectives of placing ELJs in this reach were to diversify the existing planebed conditions resulting in more complex local hydraulics and flow distribution. This would in turn lead to the sorting, distribution, and temporary storage of sediments introduced upstream. The sediments stored in this reach would become available to adult salmonids for spawning. The conceptual layout for the three ELJs is displayed in Figure 18.

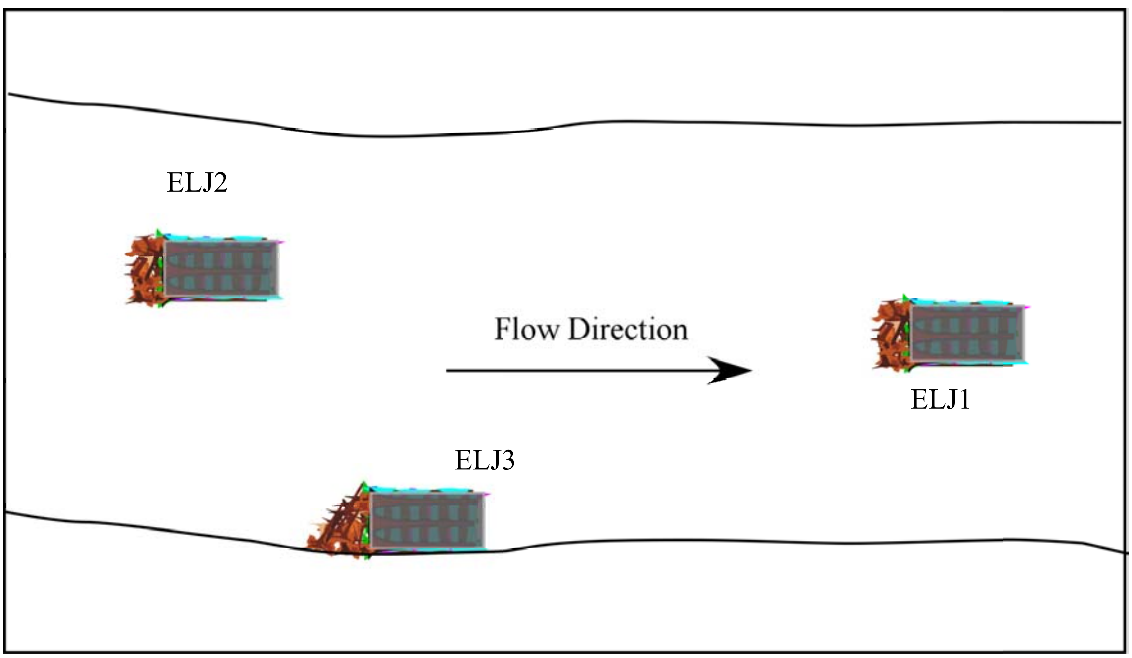

Figure 18. Conceptual Layout for ELJ Structures

ELJ1 and 2 are bar apex jams that will be constructed in the middle of the active channel. ELJ1 will be placed at the head of an existing island and will promote the stability, growth and maturation of the island. ELJ2 will likely form an island as well. This island may link up with the lower island to form one large island during some future time period or they may remain separate features. At any rate, mature forested islands are seen as a positive step in improving ecological conditions in the project reach. ELJ3 is a barb jam that will be constructed adjacent to the right bank. This structure will function much like a rock groin, although the pool scour local to the structure and deposition in the lee are likely to be more extensive than with a similar sized rock structure.

Short term impacts from ELJ placements

The expected impacts of the ELJ placement include alterations to the riverbed and local hydraulic parameters such as water surface elevation. These impacts are typically limited to the immediate area adjacent to the ELJ. However, when logjams are situated in close enough proximity to one another they can function together to impose larger, possibly reach scale, channel and hydraulic alterations.

Riverbed Changes

Local changes in the riverbed associated with ELJ placement include scour pool creation in front of and along side of the ELJ and sediment deposition in the lee of the structure. Typical post installation conditions are shown in Figure 19.

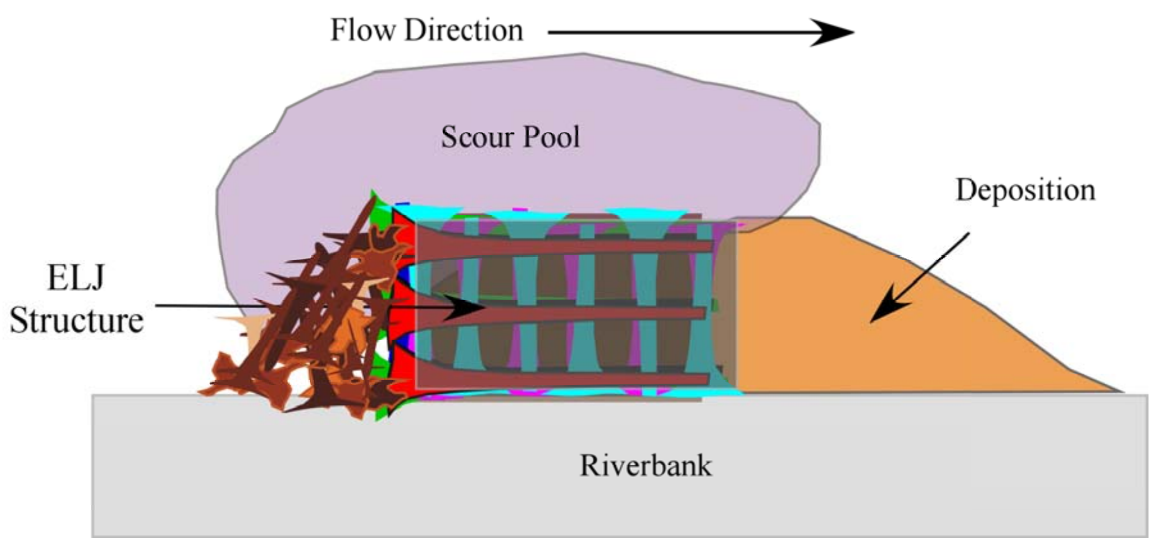

Figure 19: Typical Riverbed Alteration Associated with an ELJ Structure.

Pools created by ELJs provide vital instream habitat for holding adult salmonids. In addition, the structural complexity provides ideal cover for juveniles during feeding and resting periods. Typical cross sectional effects are displayed in Figure 20.

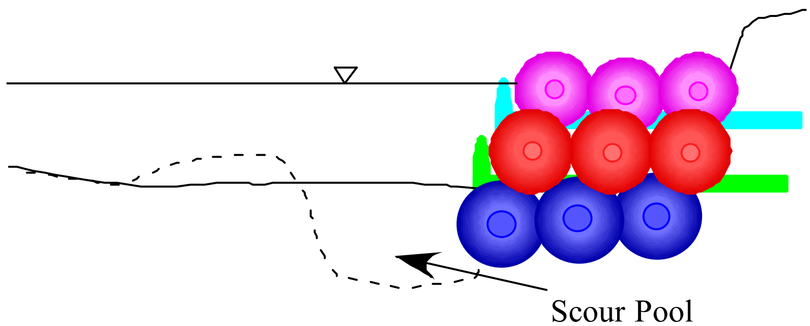

Figure 20: Typical Scour Associated with ELJ Placements.

The anticipated depth of scour for the proposed ELJ designs was evaluated and is included in the scour analysis portion of this report. Scour depths are predicted to be approximately 12 feet local to each ELJ, although the actual depth is likely to vary both spatially and temporally, depending upon site specific river dynamics and changes in those dynamics through time.

When several ELJs are used collectively in a river system, local changes in bedform can collectively result in reach scale alterations in channel type. For example, in the South Fork Nooksack River a series of ELJs were constructed in a planebed channel. Subsequent high flows scoured pools associated with each ELJ and the planebed channel was converted to a pool-riffle system. This project enhanced the ecological conditions through pool development and sorting of sediments creating spawning areas in a reach that was severely degraded. A conceptual view of the expected scour and deposition associated with the pilot project is displayed in Figure 21. Both ELJ1 and ELJ2 will likely experience some degree of horseshoe scour around the upstream face of the feature. ELJ3 will develop a scour along the side of the feature. ELJ3 has the greatest potential to increase habitat benefits. This is because the feature is located in a deeper portion of the stream, that remains wetted during the lowest flow periods. In addition, the hydraulics associated ELJ3 are such that the scour pool and depositional area may well be larger and longer than that of its counterparts on the left side of the channel.

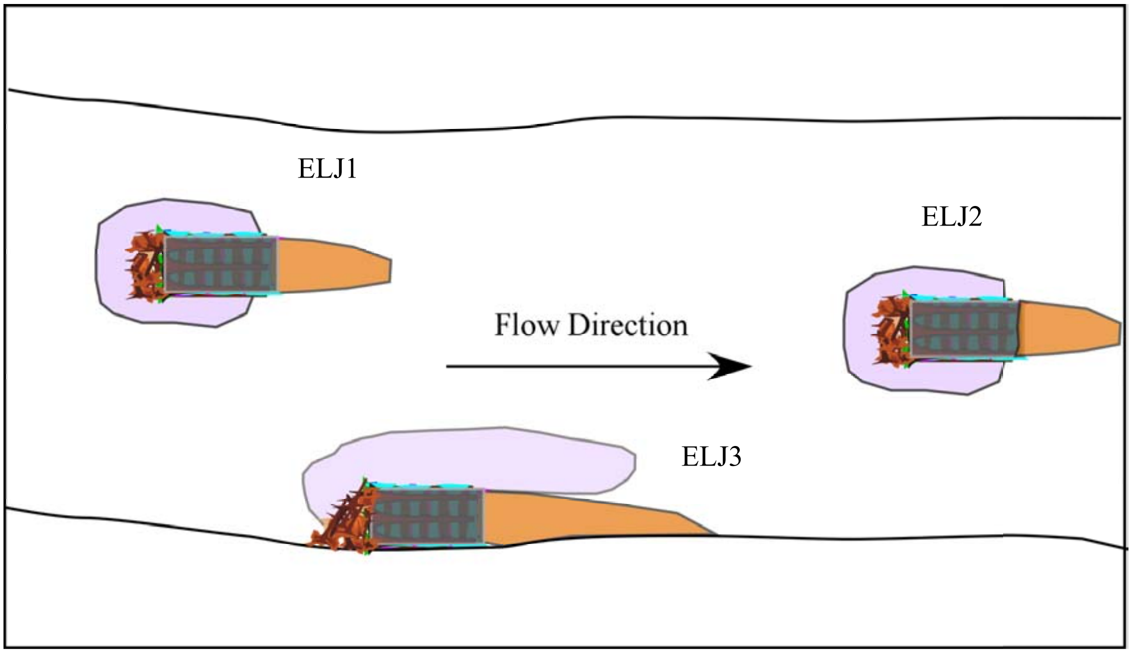

Figure 21: Expected Scour and Deposition Associated with ELJs.

As discussed, logjams create pool habitat with cover and complex hydraulic conditions desirable for anadromous and stream fishes. Logjams have also been used to help diversify channel networks by splitting flows and creating secondary channels (Figure 22).

Figure 22: ELJ Constructed as Part of the South Fork Nooksack, Larson's Bridge Project.

The example logjam in Figure 22 splits flow and promotes the creation of approximately two thousand feet of new side channel habitat. This side channel habitat is used by juvenile salmonids year round and adult fishes were found holding in these areas during higher flow conditions.

Changes in water surface elevation

It is reasonable to suspect that placement of ELJs will have an impact on local hydraulic parameters. These impacts are displayed in detail in the encroachment analysis (Appendix C), but will be discussed briefly here.

The effect the proposed ELJ design will have on the local water surface elevation is displayed in Figure 23. These data are from evaluation of cross section KP 3.0.

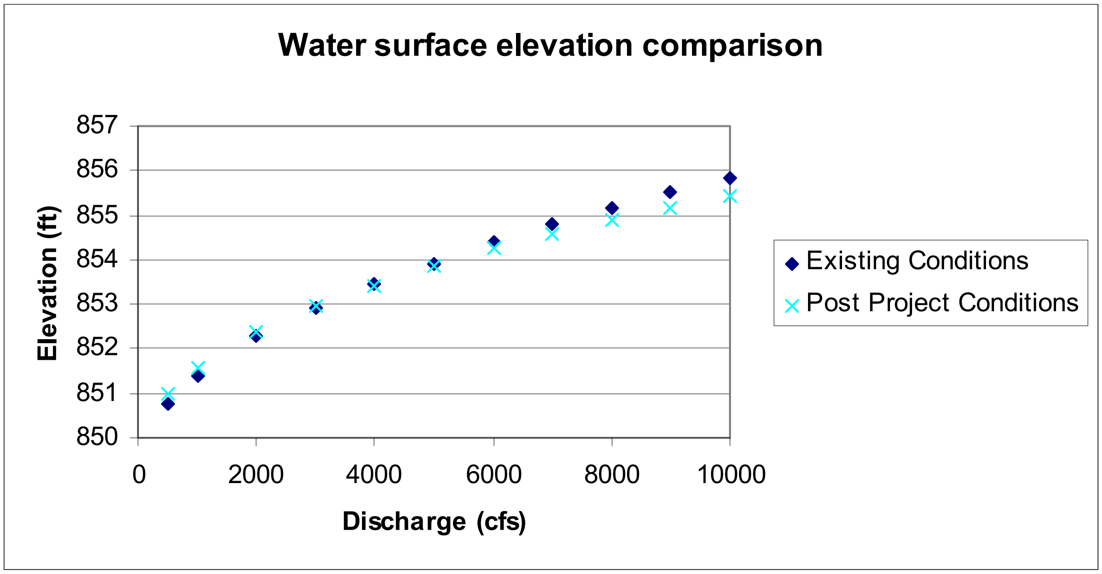

Figure 23: Water Surface Elevation Under Existing Conditions and Proposed Project Conditions.

Figure 23 indicates that the proposed project will increase water surface elevation during low to moderate flow conditions (approximately 3000 cfs), but that water surface elevation will be reduced for discharge values of 4000 cfs and above. The expected changes in water surface elevations induced by the proposed project are minimal, however changes to other parameters are more significant. Perhaps more important to notice is that the proposed project will affect hydraulic parameters differently dependent upon discharge conditions (Appendix C). Therefore, it is important to consider the entire flow regime when evaluating the impacts of project placement.

It is also important to consider the upstream and downstream impacts of a proposed project. Figure 24 displays the longitudinal profile of the reach under baseline conditions and the proposed projected conditions. It can be seen that near cross section KP 2.0, the water surface elevation is raised approximately two feet under maximum flow conditions (12,500 cfs). The lineal extent of change in water surface elevation is approximately eight hundred fifty feet. The increase in water surface elevation under the typical discharge regime is less significant and is not expected to affect public or private property and/or infrastructure.

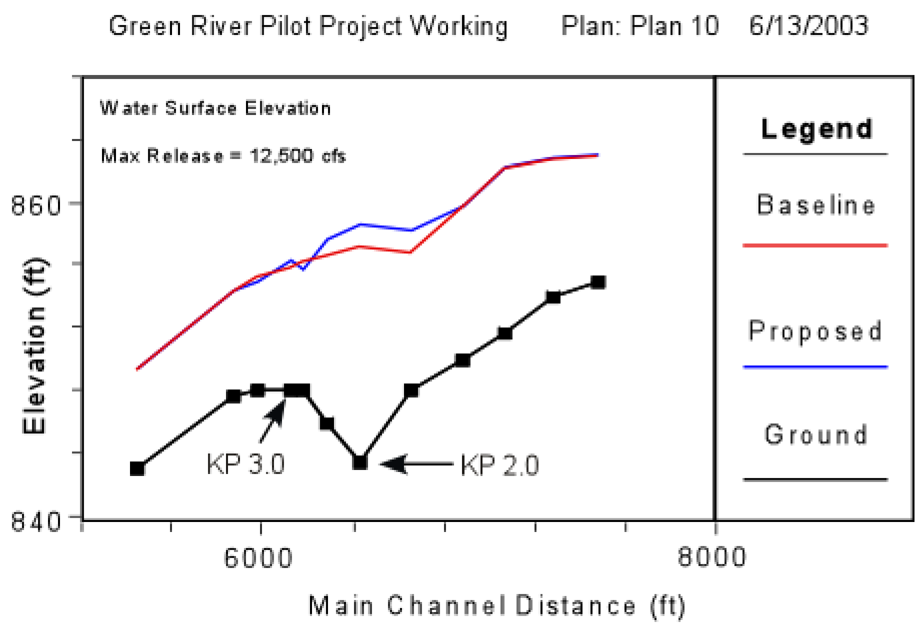

Figure 24: Baseline and Proposed Water Surface Elevation Under Maximum Discharge.

Expected Longterm Impacts From ELJ Placements

The long term influences of the logjam placement include the influence that the structure itself has on the local environment as well as the impact that the structure may have on reach scale channel processes and sediment movement in conjunction with gravel nourishment activities.

Logjam influence local to the structures

As described earlier, the placement of ELJs will promote the development of scour pools that are used by anadromous salmonids prior to spawning. These pools are typically maintained by hydraulic forces during high flow events. While the area where the logjams will be placed is heavily armored and likely more resistant to erosion than conditions prior to the installation of Howard Hanson Dam, construction activities will create the initial pool conditions, and we anticipate that hydraulic conditions in the river are capable of maintaining these pool formations under clear water conditions.

Placement of logjams will create areas within the active channel that are protected from erosion. This enables the establishment and development of riparian vegetation adjacent to salmonid holding areas. Over time this vegetation will mature and provide additional shading benefits that will promote thermal stratification of these pools and additional cover for juveniles and stream fishes. The development of the riparian areas will promote the long-term development of forested islands within the active channel. This doubles the channel margin habitat per linear length of river channel that is used year round by juveniles.

In the lee of the structures, sediment deposition occurs resulting in temporary sediment storage local to the logjams. In addition, the interaction of hydraulic forces and the logjam tends to sort sediments that are deposited in the lee of the structure. This results in areas with different grain size distributions that can be used for spawning by different salmonid species with respect to their species preference.

Channel patterns

As described above and displayed in Figure 18, ELJs can be placed such that they promote secondary flow conditions creating habitat length, volume, and diversity. The proposed ELJ placements will promote secondary flow paths and enhance the frequency and magnitude of flow moving through the secondary channels. This diversification of flow also diversifies habitat conditions available within the project reach and will increase the local juvenile carrying capacity of the river.

Pools created and maintained by the logjam structures alter riverbed conditions and can affect reach scale channel patterns. We anticipate that the proposed ELJs will create bedforms that result in a pool riffle channel unit sequence through the treatment reach. This will diversify the habitat units by creating holding habitat in close proximity to available spawning areas. Over time, this reach will likely be converted to an anastomozed channel pattern more typical of a historic condition.

ELJ influence on gravel nourishment

The proposed ELJ placements will promote the distribution of gravel moving through the reach. ELJs constructed in the middle of the active channel will help distribute sediment down the secondary channel located along the left bank downstream of the structures. This side channel is heavily armored with large cobbles and we expect that gravel moving into the side channel could potentially be stored along the bed of the side channel. This will likely lead to aggradation in the side channel. This aggradation will result in a fining of the riverbed substrate material likely resulting in improved habitat during high flow conditions. However, the current slope of the side channel is steep enough to remove historic deposits of gravels, and bed roughness alone may not be enough to store gravels along the side channel. Therefore, monitoring of gravel transport through the side channel is recommended and future evaluations of placing additional roughness elements in the side channel to increase gravel deposition are recommended.

The barb jam along the right bank, ELJ3, will likely scour the largest pool because of the existing hydraulic conditions near the placement location. This should also result in the largest pool tailout in the project area. We anticipate that sediment moving through this area will be distributed broadly across the right hand side of the mainstem riverbed downstream of this ELJ. The tailout area will likely aggrade and will be comprised primarily of materials imported from the gravel nourishment project. Downstream of the tailout, the riverbed elevation will likely grade back toward existing conditions, although it is expected that gravel nourishment materials will fill void spaces in the existing bed material essentially blanketing the current riverbed over time. These materials will provide suitable spawning areas for salmonids and will dramatically increase the area available for spawning in the project reach. The areas in the lee of the logjams have the greatest localized potential for spawning gravel deposition.

Encroachment

An encroachment analysis was conducted to evaluate the expected effects of channel blocking features on several hydraulic parameters in the project reach. The purpose of the encroachment analysis was to quantify impacts of potential ELJ design configurations in the project area and to determine at what blockage percentages the greatest impacts were realized. In addition, the results of this evaluation were used in conjunction with actual ELJ design parameters to help evaluate the expected results of the proposed ELJ placement in the project reach.

The blockage percentages evaluated were the five, ten, twenty, thirty, forty, and fifty percent. These conditions represent an ELJ of a size that results in a cross sectional blockage of five to fifty percent. The configurations were evaluated under one thousand cfs discharge increments beginning at one thousand cfs and ending at ten thousand cfs. The parameters evaluated included shear stress, water surface elevation, stream power, velocity, channel width, hydraulic radius, and Froude number. A sample of this output is displayed in Figure 25.

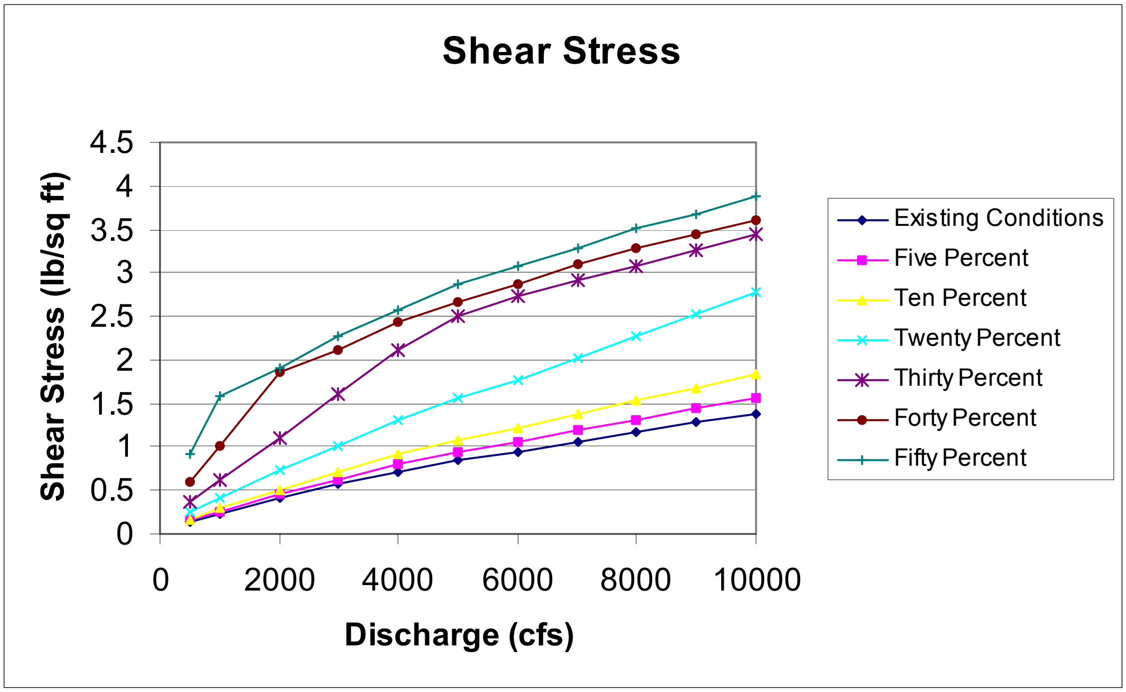

Figure 25. Shear Stress values in Relation to Blockage Percentages.

Figure 25 displays the affects of channel blockage on shear stress in the main channel. Notice in Figure 25 that there is an increasing trend in shear stress as blockage percentage increases. This stands to reason because flow is increasingly concentrated as blockage increases. Perhaps most informative is the level of encroachment that results in the greatest incremental changes in hydraulic parameters. Figure 26 displays the changes in shear stress from existing conditions to changed conditions with respect to blockage percentages.

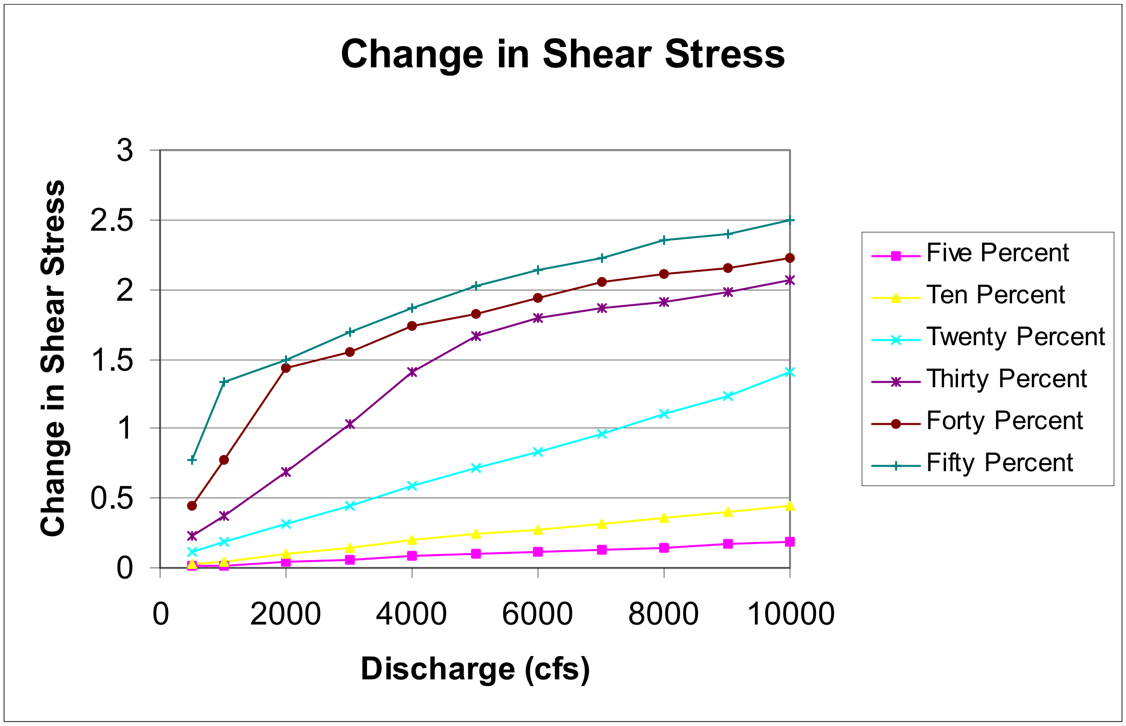

Figure 26. Changes in Shear Stress Relative to Existing Conditions.

What can be seen in Figures 25 and 26 is that the incremental change in shear stress is relatively low for the five and ten percent blockage conditions, but is quite high for twenty and thirty percent blockage. The incremental effects are then lessened as blockage becomes forty and fifty percent. Therefore, significant impacts to shear stress are seen under design conditions when blockage is twenty percent of the channel width.

Shear stress was used to illustrate the effects of blockage through the range of discharges. While not all results are identical, there is a general trend through the hydraulic parameters evaluated that significant impacts are first seen at twenty percent blockage and that the greatest incremental effects are found for blockage values of twenty and thirty percent.

The proposed ELJ design results in a blockage percentage of approximately twenty percent. This design is expected to influence all hydraulic parameters evaluated. While increases in water surface elevations are expected, these increases are not expected to cause any local flooding issues.

Stability of ELJ structures

Conducting stability analysis for an ELJ begins with the identification of forces acting on a composite ELJ structure. A typical free body diagram is shown in Figure 27 displaying forces and the directions in which these forces act.

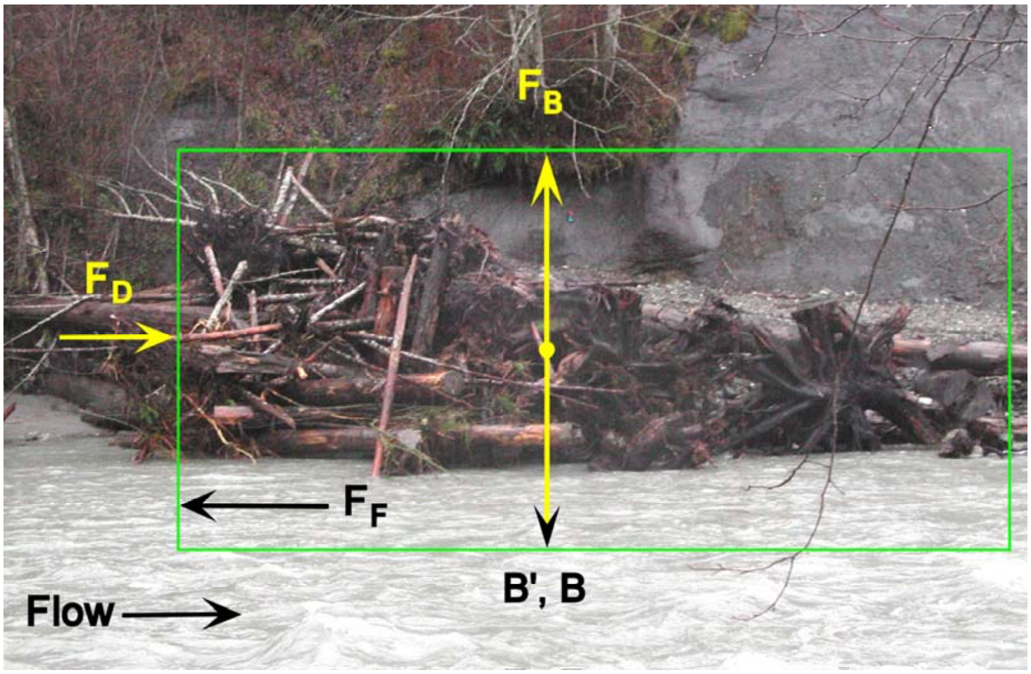

Figure 27. Typical Free Body Diagram for an ELJ Structure

Where:

F_B is the buoyancy force of submerged wood:

$$F_B = V_W \rho g \left(1 - \gamma_W\right)$$

F_D is the drag force:

$$F_D = C_D \left(\frac{1}{2} \rho V^2 A\right)$$

B' is the weight of submerged ballast

$$B' = \rho g \left(\gamma_S - 1\right) V_B$$

B is the weight of non-submerged ballast

$$B = \rho g \left(V_B + V_W \gamma_W \right)$$

The frictional force (F_F) is:

$$F_F = \left(B' + B - F_B \right) \tan \phi$$

Variables in the above equations are defined as: V_w is the volume of wood, ρ is the density of water at 20 C, g is the gravitational constant, γ_w is the specific gravity of wood, C_D is the Drag coefficient for the ELJ, V is the cross-sectional averaged velocity, A is the area normal to the flow, γ_s is the specific gravity of ballast material, V_B is the volume of ballast materials, ϕ is the friction angle. Using these equations, factors of safety are calculated for both the vertical and horizontal directions by taking the ratios of forces acting in opposite directions as shown below:

Vertical factor of safety (V_{FS}):

$$V_{FS} = \left(B' + B \right) / F_B$$

Horizontal factor of safety (H_{FS}):

$$H_{FS} = F_F \; / \; F_D$$

Using this methodology, forces acting on the structure were calculated and factors of safety were determined. Based upon successful project designs in other river systems, factors of safety greater than or equal to 3.0 were targeted for stable ELJ design. A summary of forces calculated and the resultant factors of safety for this specific ELJ design are displayed in Table 3. This analysis was conducted using data for cross section KP 3.0. The design flow for this evaluation was 12,500 cfs resulting in a predicted water surface elevation of 856.58. The elevation of the ELJ design is 856.08, hence forces from non-submerged ballast was not present in the analysis.

Table 3. Total Forces and Factors of Safety for ELJs.

Total Buoyancy Force	Ballast from backfilling	Drag Force	Friction Force	Total Vertical Force	Total Horizontal Force	Vertical Factor of Safety	Horizontal Factor of Safety
F_B	B'	F_D	F_F	$B'-F_B$	F_F-F_D	V_{FS}	H_{FS}
(kN)	(kN)	(kN)	(kN)	(kN)	(kN)		
756	2698	405	1630	1943	1224	3.6	4.0

These results indicate that the proposed ELJ design configuration will be stable in this portion of the Green River.

Scour associated with ELJ placement

When discussing local scour depth associated with a flow deflection structure, the depth of scour (d_s) is the difference between bed elevation before and after placing an obstruction (Figure 28). These evaluations have typically been undertaken in association with spur-dikes or rock groins.

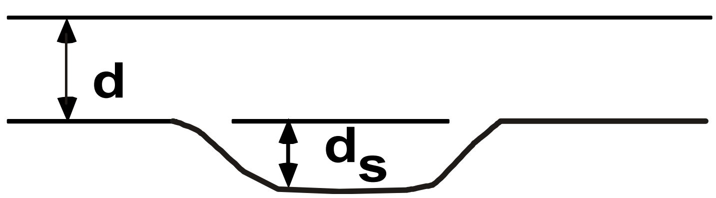

Figure 28: Depth of Approach Flow (d) and Local Scour Depth (d_s).

Dimensional reasoning can lead one to deduce that the depth of scour, d_s, at a flow deflection structure is a function of the parameters displayed in Figure 29.

$$\frac{d_s}{d} = f\left(\frac{u_*}{u_{*c}}, \frac{L}{d}, \frac{d_{50}}{d}, \sigma, K_s, \beta \right)$$

Figure 29. Hydraulic Parameters Affecting Scour Depth.

Variables in Figure 29 are as follows: d_s is the depth of scour, d is the flow depth, u_* is shear velocity, u_{*c} is the critical shear velocity, L is the effective length of protrusion of the obstruction into the flow, d_{50} is the mean grain size, σ is the standard deviation of the sediment grading, K_s is a shape factor, and β is the angle of the obstruction to the flow.

In Drury 1999, eight scour equations using various combinations of these parameters were evaluated for their respective applicability to scour associated with ELJs. The purpose of that study was to identify scour equations used for rock structures that accurately predicted scour associated with ELJs. For the purposes of Drury's study β, the angle of the obstruction to the flow was 90 degrees and not considered a variable (each ELJ designed in this project is also situated approximately 90 degrees to the flow). Similarly, K_s the shape factor, did not represent a variable because each structure design had similar plan view characteristics. In addition, the ratio of shear velocity to critical shear velocity (u_*/u_{*c}) was replaced by U/U_c the average flow velocity over the critical flow velocity for a given grain size (d_{50}). This reduced the equation in Figure 30 to:

$$\frac{ds}{d} = f\left(\frac{U}{U_c}, \frac{L}{d}, \frac{d_{50}}{d}, \sigma \right)$$

Figure 30. Factors Affecting Scour Depth for the ELJs.

These factors were investigated under laboratory conditions where it was found that clear-water scour conditions result in maximum scour depths. In addition, scour initiation and pool maintenance local to flow obstruction structures occurs at flows below those inducing live-bed scour. Scour initiation around a flow deflection structure after installation occurs at flows below live-bed condition because an alteration in local hydraulics is induced by placement of the structure. One could attempt to design the expected geomorphic effects into the construction sequence, but the effectiveness is questionable because of the complexity and variability of reach scale channel dynamics; and the river will certainly influence the outcome of any design. Pool maintenance occurs below live-bed conditions since during live-bed scour conditions sediment is being supplied to the scour hole and the transport capacity of the flow is diminished because of particle entrainment in the flow. As flows decrease, a situation occurs just below live-bed conditions where sediment is no longer supplied to the scour hole and transport capacity increases because of the decrease in particle entrainment. Under these brief conditions, maximum scour depth occurs. Therefore, clear-water equations appear to be most appropriate for predicting local scour.

In Drury 1999, eight scour equations using various combinations of the parameters shown in Figure 29 were evaluated for their respective applicability to scour associated with ELJs. The results of this evaluation found two equations that best predicted measured values. Of these two equations, Karaki's equation was chosen for this evaluation because of its independence from sediment grain size inputs. This decision was based upon site specific conditions and our professional judgment.

Karaki offers two equations depending on the ratio of length of groin over depth of approach flow (a/h) (Figure 31). These methods were developed by laboratory tests in a flume with prototype features and was verified by field measurements. The relationships are for groins placed perpendicular to the flow. Evaluation of these equations indicates that the contraction ratio and approach flow depths are critical parameters in scour prediction. The first equation is recommended when a/h < 25. The second for values of a/h > 25.

$$d_s = 1.1 \left(\frac{a}{h}\right)^{.4} F^{.33}$$

$$d_s = 4\, F^{.33}$$

Figure 31. Karaki's Scour Prediction Equations.

In Figure 31, d_s is the depth of scour, a is the length of protrusion of the structure into the flow, h is the depth of the approach flow, and F is the Froude number.

For this project, a/h is approximately equal to 6.1. Therefore the first equation was used. The predicted scour depth and resultant footprint elevation for ELJ placement is displayed in Table 4.

Table 4. Scour Prediction and ELJ Footprint Elevations.

Width of ELJ	Average Depth of Flow	Froude Number	Predicted Depth of Scour	ELJ Footprint Elevation
a	h		d_s	
(ft)	(ft)		(ft)	(ft)
37.5	6.07	0.63	11.99	840.5

Because of the close proximity and relationships between values of hydraulic parameters at specific ELJ placement locations, the recommended footprint elevation for all three ELJs in the PILOT project is 840.5.

4. SITE DESIGN

The following section of the report provides description of features and activities, details and notes regarding construction, and quantities and specialty specifications for construction elements in Restoration Zone 1. The project has been delineated into six general construction elements, based on the overall project sequence.

- Site Preparation
- Access Route / Staging Areas
- Water Control Features
- Engineered Log Jams
- Gravel Nourishment Features
- Revegetation / Site Reclamation

The primary driver for the construction schedule is that all in water activities must be performed from Aug. 1 to Aug. 31, which is identified as the fisheries construction window. In water construction activities include water control features, engineered log jams and gravel nourishment features. Construction activities for other project elements will occur outside of the river's wetted areas.

4.1 Site Preparation

Site preparation activities include construction survey layouts, fence removal, gate installation and silt fence installation.

Construction survey layouts will need to identify existing project control, and identify and locate City of Tacoma and Washington Department of Natural Resources property corners. In addition, surveyors will need to establish construction control and roadway alignments.

In addition to survey layout work, fence removal at the Tacoma Watershed office is required. The two locations that need fence removal are the proposed access entryway to the Tacoma Watershed office property (just east of existing gate) and near the northeast corner of the property fence. This activity will only move a section of the fence wide enough for roadway construction. The width of the fence removal is approximately 25 feet. In addition to fence removal, installation of roadway access gates is required at the proposed entrance to the Tacoma Watershed Office and the U/S gravel nourishment entryway.

Silt fence installation will be performed as a BMP for erosion and turbidity control, especially for access route and staging area features. Silt fencing will be installed in areas peripheral to construction sites, staging areas, and transport routes where disturbance activities have the potential to initiate or promote sediment delivery to the active river channel. Use of a sediment fence reduces the transport of coarse sediment from a construction site by providing a temporary physical barrier to sediment and reducing the runoff velocities of overland flow. Silt fence installation is required at both the downstream (Tacoma Watershed Office) and upstream (Tacoma Headworks Office) sites. Approximately 1,500 linear feet of silt fence will be installed using the specifications identified in the specifications report.

4.2 Access Route / Staging Areas

Access route construction is proposed at both the U/S Gravel Nourishment site, from the gravel parking lot to the river's edge, and the D/S gravel nourishment/ELJ site to the west of the Tacoma Watershed Office. Specific activities involved in construction of the access route include clearing and grubbing, cut/fill/compaction of roadway surface and subsurface, and disposal of additional topsoil and cleared vegetation and materials.

U/S Gravel Nourishment Access Route

The U/S Gravel Nourishment Site access route is 450 feet long and requires clearing and grubbing for the entire length of the route between the Tacoma Pipeline Access Road and the edge of the river. This site will be cut into a steep bank near the gravel parking lot (contractor lot) just downstream from the Tacoma Headworks Office (Figure 32). Cut/fill/compaction activities are required for the section of the access road along the steep embankment (Figure 33). The amount of cut/fill materials are estimated at 1,448 cubic yards and 553 cubic yards of material, respectively. Cut materials are composed of duff material that needs to be disposed and fine topsoils that can be used as fill material if they meet environmental and water content conditions specified in the Geotechnical Section of Appendix D. Fill materials are composed of a 12 inch layer of gravel sub base overlain by a 4 inch layer of crushed rock for the running surface. Additional features of the access route include an interior drainage ditch on the cut side of the embankment, a rock drain at the bottom of the access route, and seed mulch and geotextile fabrics along cut/fill embankments to prevent erosion.

Figure 32. U/S Access Route Entrance

Figure 33. U/S Access Route Entrance

D/S Gravel Nourishment and ELJ Permanent Access Route

The D/S Gravel Nourishment and ELJ Access Route is 900 feet long and requires clearing and grubbing for the entire length of the route. The alignment enters the Tacoma Watershed Office Property from the Tacoma Pipeline Access Road crossing the fenceline approximately 50 feet from the centerline of the Watershed Office driveway at the gate (Figure 34). The route travels to the west, heading north, of the watershed office and then turns towards the northeast down the hillslope (Figure 35 & 36). At the edge of the river, the route has an elevated turnaround where dump trucks, bulldozers and excavators can access the Water Control Stage 1 berm and the D/S Gravel Nourishment Site (Figures 37 & 38). The amount of cut/fill materials are estimated at 946 cubic yards and 875 cubic yards of material, respectively. Cut materials are composed of duff material that needs to be disposed and fine topsoils that can be used as fill material if they meet environmental and water content conditions specified in the Geotechnical Section of Appendix D. Fill materials are composed of a 12 inch layer of gravel sub base overlain by a 4 inch layer of crushed rock for the running surface. Additional features of the access route include an interior drainage ditch on the cut side of the embankment, a rock drain at the bottom of the access route (Sta. 9+10), and seed mulch and geotextile fabris along cut/fill embankments to prevent erosion.

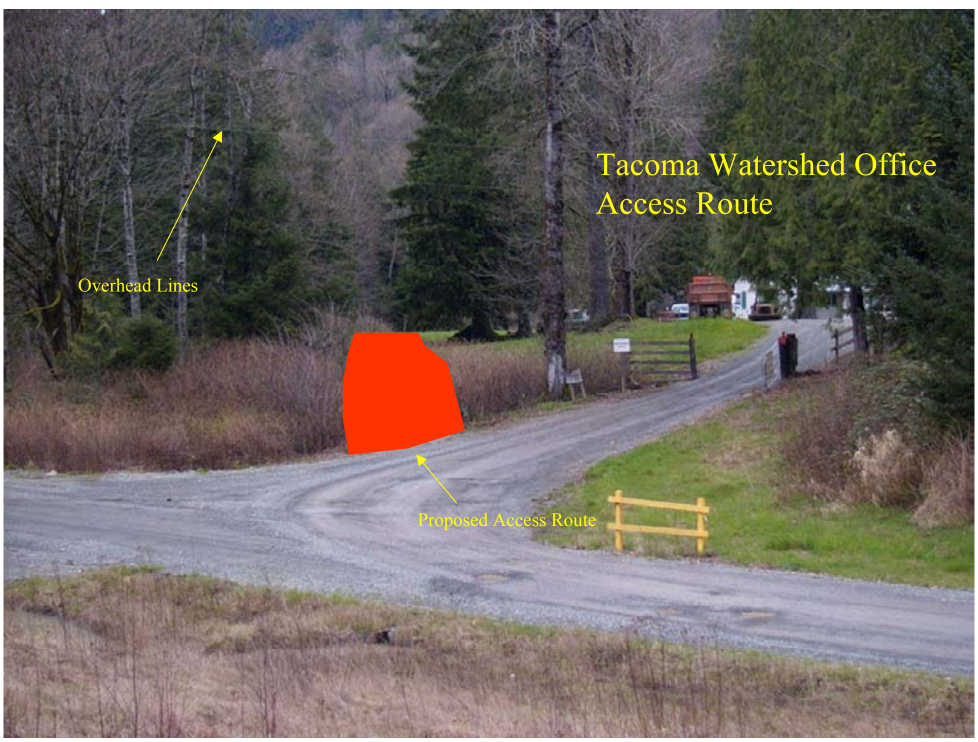

Figure 34. D/S Access Route (Sta. 1+50 to 3+50)

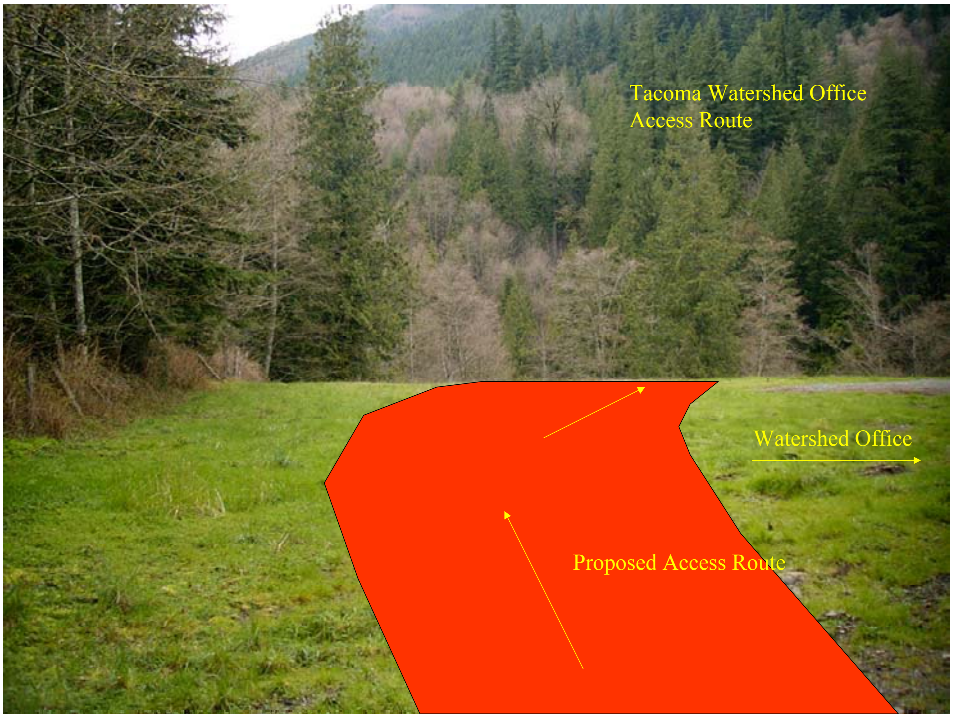

Figure 35. D/S Access Route (Sta. 3+50 to 5+50)

Figure 36. D/S Access Route (Sta. 5+50 to 7+50)

Figure 37. D/S Access Route (Sta. 7+50 to 10+00)

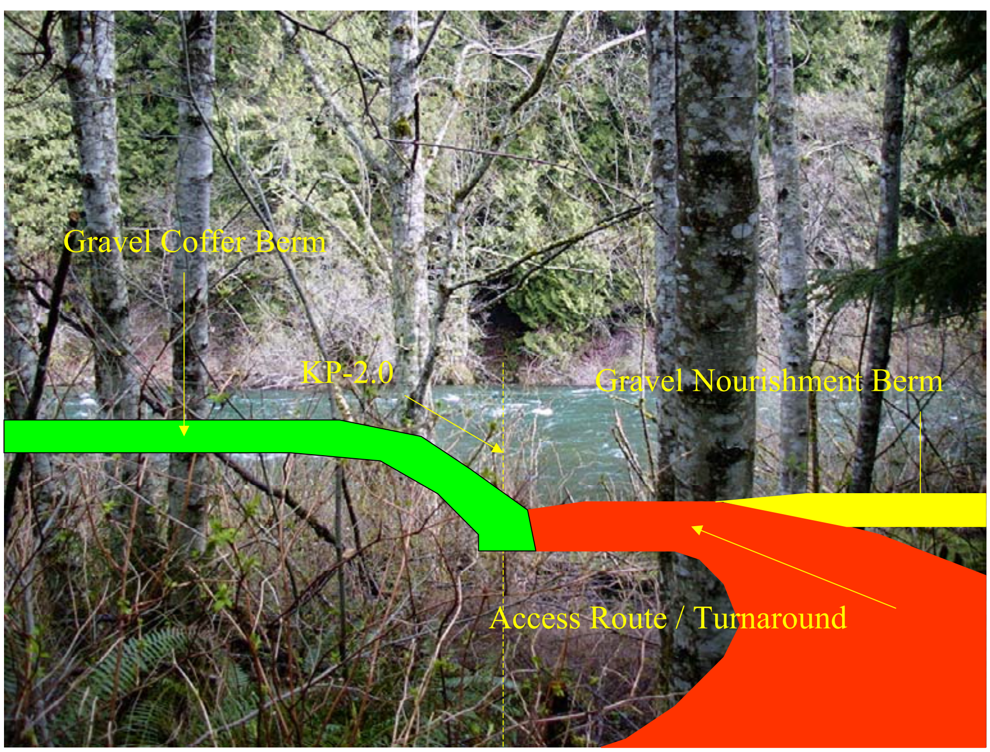

Figure 38. D/S Access Route (Sta. 5+50 to 7+50)

D/S Log Loading Temporary Spur Access Route

The D/S Log Loading Temporary Access Route connects with the D/S Gravel Nourishment and ELJ Permanent Access Route at approximately 7+80, just beyond the fenced line, with an alignment heading directly towards the river. The alignment will be filled using backfill down to the channel bed of the river with approximately 175 cubic yards of material. At the end of the alignment, additional fill of approximately 165 cubic yards of material will be required in the log loading staging area to fill in cobble and boulder substrate and provide a working area platform for the log loading truck. Log trucks will travel down the D/S Gravel Nourishment and ELJ Access Route just past the Log Loading Route. Trucks will then back down this route, unload the logs and then pull out forwards. 40-foot turning radii were used on both sides of the spur access route. During the Water Control Stage 2 this route will be raised in the channel to provide access to a temporary crossing, which will access the right side of the river (See Section 4.3).

4.3 Water and Turbidity Control

The preferred method of water control for constructing ELJs on the site has changed from a series of water control berms with a temporary crossing to a cofferdam and pipe by-pass system. The cofferdam and pipe by-pass system will be constructed using a temporary cofferdam and 1500 feet of 48-inch diameter HDPE pipe. Two primary diversion pipes will be used to divert flows through the construction site up to 180cfs. It is recommended that the COE coordinate HHD operations during the month of August to not exceed this flow rate. The predicted amount of freeboard is less than 1-foot when flows exceed this amount. In addition to the two primary diversion pipes, two emergency spill pipes with sliding gates will be installed in the cofferdam that are design to pass approximately 530 cfs with all pipes open. This will allow for emergency spilling of water if a flood event happens during the period of construction. Other elements associate with the water control system are rock anchoring that is placed around and over the pipe at several locations, as well as a series of ecology blocks at the downstream end of the pipe to dissipate energy and prevent channel scouring.

4.4 Engineered Log Jams

The ELJ features will be located in the downstream segment of Zone 1 in an area immediately upstream from a split flow area between river station 241+00 and 246+00. An apex jam is planned to be located at the tip of the island near the Tacoma Watershed office (Figure 1). Figures 39 through 41 show where the ELJs are located at the site.

During the construction of the ELJs, the footprint of the structure will need to be isolated from the river to prevent entrainment of fine sediments into the river's current. This will entail water diversion and sediment control. The cofferdam and pipe by-pass system will isolate excavation areas from flowing water. Infiltration to the excavation pits and local seepage will remain and require pumping and upland trickle or infiltration treatment of turbid water. This can be done using two or more 4-inch diameter portable pumps, or one larger pump. As logs are placed, previously excavated riverbed materials will be backfilled into the structure and pumping requirements will cease. Water control berms will be dismantled and materials will be used as final backfill for the ELJs.

The following is the sequence of construction activities for the ELJ features.

- Isolate excavation area
- Excavation construction pit
- Dewater pit during excavation and installation
- Construct interior pad
- Place logs in a series of backfilled lifts
- Reclaim water control berm for use as final backfill
- Slowly rewater construction area

The equipment needed for constructing the ELJs are a 400 series excavator and log loader, a bulldozer, and wood delivery trucks. The log loader will be staged in the area near the Tacoma Watershed Office. The bulldozer will be utilized to construct cofferdam berms and begin the first excavations. The excavator, with a bucket and claw, will then be used to transport logs up to 48 inches (dbh) with intact rootwads, and finish excavation of the pit. Additional equipment is required for dealing with turbid water from the excavation pit that includes a sump pump, piping and or hosing.

Figure 39. Restoration Zone-1 Center Apex Jam Location, looking downstream at the splitflow area near Tacoma Watershed Office.

Figure 40. Restoration Zone-1 Left Apex Jam Location, looking from right bank to the left bank.

Figure 41. Restoration Zone-1 Right Barb Jam Location, looking from left bank to the right bank.

Table 5 Final ELJ #1 Specifications

Specifications						
Logjam #	ELJ1					
Type	Bar Apex					
Cross Section	22.1					
Section Station Offset	155.0ft					
Control Line Station Offset	96.0ft					
Length	50-60ft (dependent upon supplied materials)					
Width	37.5ft (Based on placement of key members at 12.5 foot centers)					
Footprint Elevation	841.0ft					
Wood Requirements						
Diameter Breast Height (inches)	**48+**	**42-48**	**36-42**	**30-36**	**24-30**	Rack logs **<24**
# of Logs with rootwads	0	3	4	9	3	25
# of Logs without rootwads	0	0	4	4	0	25
Total # of Logs / Size Category	**0**	**3**	**8**	**13**	**3**	**50**
Total # of Logs	**77**					

Table 6 Final ELJ #2 Specifications

Specifications						
Logjam #	ELJ2					
Type	Bar Apex					
Cross Section	23.2					
Section Station Offset	116.0ft					
Control Line Station Offset	48.0ft					
Length	50-60ft (dependent upon supplied materials)					
Width	37.5ft (Based on placement of key members at 12.5 foot centers)					
Footprint Elevation	841.0ft					
Wood Requirements						
Diameter Breast Height (inches)	**48+**	**42-48**	**36-42**	**30-36**	**24-30**	Rack logs **<24**
# of Logs with rootwads	0	3	4	9	3	25
# of Logs without rootwads	0	0	4	4	0	25
Total # of Logs / Size Category	**0**	**3**	**8**	**13**	**3**	**50**
Total # of Logs	**77**					

Table 7 Final ELJ #3 Specifications

Specifications						
Logjam #	ELJ3					
Type	Barb					
Cross Section	23.1					
Section Station Offset	250.0ft					
Control Line Station Offset	168.0ft					
Length	50-60ft (dependent upon supplied materials)					
Width	37.5ft (Based on placement of key members at 12.5 foot centers)					
Footprint Elevation	841.0ft					
Wood Requirements						
Diameter Breast Height (inches)	**48+**	**42-48**	**36-42**	**30-36**	**24-30**	Rack logs **<24**
# of Logs with rootwads	0	3	4	8	3	25
# of Logs without rootwads	0	0	4	4	0	25
Total # of Logs / Size Category	**0**	**3**	**8**	**12**	**3**	**50**
Total # of Logs	**76**					

4.5 Gravel Nourishment

Gravel nourishment features are berms or bars constructed of a composition of materials. The gravel materials will be eroded and entrained in river flows and will provide sediments in spawning beds for chinook salmon. Restoration goals for the gravel nourishment projects are to re-introduce 3,900 cubic yards of gravel sediments into the river to improve chinook spawning beds, which is approximately equivalent to ½ the mean annual sediment load in this reach of the Green River (Perkins, 1999). The designs are such that sediments will be entrained or eroded during storm flow events. A majority of the features will be constructed within the boundaries and at elevations matching surveys of the ordinary high water mark (OHWM). Figures 42 through 43 show the locations of the proposed gravel nourishment features.

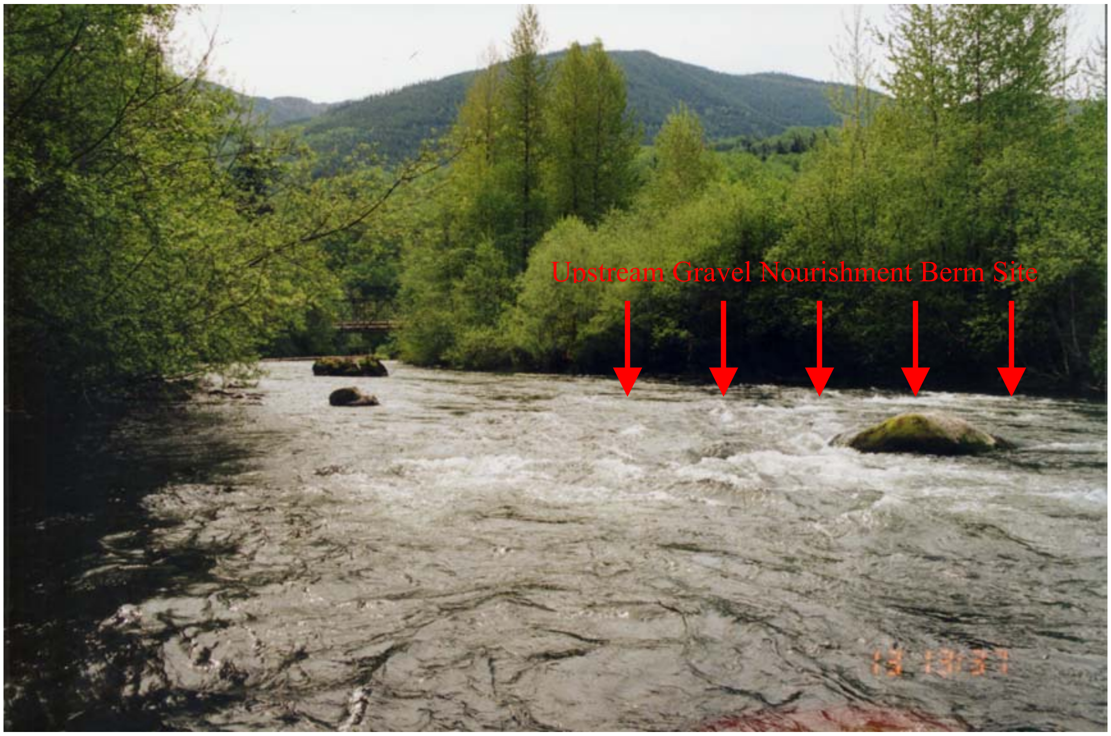

Figure 42. Restoration Zone-1 Upper End of the Upstream Gravel Nourishment Berm Site, looking upstream.

Figure 43. Restoration Zone-1 Downstream Gravel Nourishment Berm Site, looking upstream.

The gravel nourishment features will be constructed using a series of dump truck deliveries from a local quarry to the site. The gravel specifications of round river rock for constructing the gravel nourishment features is shown in Table 8. The gravel nourishment berms will be constructed by building a thin construction pad (12-feet wide) along the extent of the nourishment berm. This will allow dump trucks to back down the pad and end dump bi-op materials, which will then be pushed into place by a bulldozer. At the downstream gravel nourishment site the trucks will drive down to the access turnaround area and back down the gravel berm and dump materials at the end of the berm. A bulldozer will then be used to grade out the gravel teardrop berms. At the upstream site the trucks will drive down the access route immediately to the turnaround and can then back to the edge of the river and end dump their load of material.

Table 8. Gravel Specifications of Round River Rock

Sieve Size	Percent Finer	
	Bi-Op Material (Screened Gravel) % Finer	Structural Backfill Material % Finer
152.4mm (6.0in)		100
101.6mm (4.0in)	100	80-90
50mm (2.0in)	50-100	65-80
25mm (1.0in)	0-50	50-67
12.5mm (0.5in)	-	40-57
4.75mm (No.4)	-	28-47
2.0mm (No.10)	-	22-37
0.85mm (No.20)	-	13-27
0.0625mm (No.200)	-	0-10

In order to meet the restoration measures identified in the NMFS Biological Opinion, a design goal of 85% spawning material was set to help minimize the amount of fine materials being introduced to the river. Table 9. displays the volumes of material that will be utilized in constructing the gravel nourishment features.

Table 9. Gravel Specifications of Round River Rock

		Gravel Nourishment Berms					
		Downstream		Upstream		Total	% Total
		Structural Fill	Bi-Op Gravel	Structural Fill	Bi-Op Gravel		
	SIEVE SIZE	(CY)	(CY)	(CY)	(CY)	(CY)	
Gravels	101.6mm (4.0in)	21.8	-	44.9	-	66.6	1.7%
	50mm (2.0in)	18.1	480.3	37.4	392.8	928.5	23.6%
	25mm (1.0in)	20.3	960.5	41.9	785.5	1808.2	45.9%
	12.5mm (0.5in)	14.5	480.3	29.9	392.8	917.4	23.3%
Sands	4.75mm (No.4)	16.0	-	32.9	-	48.8	1.2%
	2.0mm (No.10)	11.6	-	23.9	-	35.5	0.9%
	0.85mm (No.20)	13.8	-	28.4	-	42.2	1.1%
	0.0625mm (No.200)	21.8	-	44.9	-	66.6	1.7%
Silts/Clays	<0.0625mm (No.200)	7.3	-	15.0	-	22.2	0.6%
	Total Material (CY)	145.0	1921.0	299.0	1571.0	3936.0	
	Percent Bi-Op Material	95.5%		89.8%			92.8%

Note: Total gravel (structual and washed) required = 3,936 CY

Total spawning gravel = 3,720CY

Total sand volume = 193CY

Total silt/clay volume = 22CY

D/S Gravel Nourishment Berm

Configuration: 2 teardrop berms

Total Length: 200 ft/teardrop

Height: Varies (2.0-3.5 ft). Equal to OHWM.

Topwidth: Varies from 0 to 50 ft

Sideslope: Assumed 2:1 (angle of repose gravel materials)

Total volume: 2066 yd^3

Truck Haul Trips: 10 yd^3 dump truck, 210 trips

Table 10. D/S Gravel Nourishment Berm Station-Offset-Profile Table

	Station GNDS Alignment	Elevation (ft-msl)	Offset	Control Reference
POB	7+51.98	853.17	LT 38.91	Survey Control Line
PVI	8+29.40	853.50	LT 61.38	Survey Control Line
PVI	8+78.36	853.70	LT 59.73	Survey Control Line
PVI	9+20.00	854.00	LT 8.03	Survey Control Line
PVI	10+22.03	854.94	LT 66.58	Survey Control Line
PVI	10+71.48	855.32	LT 68.27	Survey Control Line
POE	11+20.37	856.00	LT 10.98	Survey Control Line

U/S Gravel Nourishment Berm

Configuration: 6 rib sections

Total Length: 100 ft/rib section

Height: Varies (1.0-2.5 ft). Equal to OHWM.

Topwidth: Varies from 30 to 50 ft

Sideslope: Assumed 2:1 (angle of repose gravel materials)

Total volume: 1870 yd^3

Truck Haul Trips: 10 yd^3 dump truck, 190 trips

Table 11. U/S Gravel Nourishment Berm Station-Offset-Profile Table

	Station GNUS Alignment	Elevation (ft-msl)	Offset	Control Reference
POB	1+00.00	859.50	LT 9.96	Survey Control Line
PVI	1+08.96	859.57	LT 39.49	Survey Control Line
PVI	1+68.13	859.71	LT 40.32	Survey Control Line
PVI	1+73.35	859.74	LT 58.07	Survey Control Line
PVI	1+99.87	859.81	LT 58.64	Survey Control Line
PVI	2+05.24	859.86	LT 41.46	Survey Control Line
PVI	2+82.77	859.95	LT 44.28	Survey Control Line
PVI	2+88.50	860.00	LT 60.60	Survey Control Line
PVI	3+10.56	860.22	LT 58.79	Survey Control Line
PVI	3+13.35	860.33	LT 41.48	Survey Control Line
PVI	3+72.29	860.66	LT 41.14	Survey Control Line
PVI	3+77.89	860.87	LT 58.83	Survey Control Line
PVI	4+01.88	861.14	LT 59.00	Survey Control Line
PVI	4+07.45	861.36	LT 41.28	Survey Control Line
PVI	4+72.73	862.20	LT 41.50	Survey Control Line
PVI	4+77.87	862.30	LT 58.83	Survey Control Line
PVI	5+01.94	862.58	LT 58.94	Survey Control Line
PVI	5+07.57	862.80	LT 41.17	Survey Control Line
PVI	5+69.63	863.00	LT 38.28	Survey Control Line
PVI	5+74.22	863.00	LT 56.32	Survey Control Line
PVI	5+98.50	863.10	LT 57.49	Survey Control Line
PVI	6+04.91	863.16	LT 40.14	Survey Control Line
PVI	6+71.56	863.35	LT 41.56	Survey Control Line
PVI	6+76.66	863.39	LT 58.82	Survey Control Line
PVI	7+00.88	863.45	LT 58.82	Survey Control Line
POE	7+08.30	863.63	LT 10.00	Survey Control Line

4.6 Planting and Site Reclamation

Planting and site reclamation activities include reclaiming temporary access and staging areas, planting riparian vegetation and upland native grass mixtures as well as removal of silt fence erosion control installations.

Planting Notes:

- Mark clearing limits and place silt fence or other erosion control measures.
- Flag all trees to be protected during construction and fence at drip line to prevent damage to root system.
- Clear access roadways, with minor grading/fill as necessary.
- Retain any trees removed on-site for use as part of ELJ construction (if appropriate material)

Do other construction, then

- Remove any quarry spalls or stone placed for temporary access roadways.
- Regrade access roadway as necessary to stabilize slopes
- Till any cleared or graded areas with small machinery to a minimum depth of 4 inches.
- Within the project footprint, use hand labor to remove non-native species including Himalayan blackberry (Rubus procerus), Scotch broom (Cytisus scoparius), reed canary grass (Phalaris arundinaceae), etc.
- Mulch any cleared or graded areas within 48 hours of completion of grading and tilling (such as with straw mulch, jute fabric, or composted mulch).
- Hydroseed all cleared/graded areas within 7 days of completion of grading and tilling using seed mix specified and tackifier and cellulose mulch at rate specified for slopes from 1-10%.
- Plantings of native trees and shrubs will occur during the period from October 1st through March 31st.
- Riparian plantings will occur within 100 feet of river and in shaded slope areas; upland plantings will occur on other areas as field specified by the project biologist.

- Composted mulch shall be imported and spread to a minimum 1 foot in diameter around all planted trees and shrubs to a minimum depth of 2 inches, without burying the crown of the plant.

Table 12. Plant Species Specifications

Species Name	Common Name	Strata	Size	Spacing	Location	Quantity
Alnus rubra	Red alder	Tree	1 gal	15 ft o.c.	riparian	20
Populus balsamifera	Cottonwood	Tree	1 gal	15 ft o.c.	riparian	20
Pseudotsuga menziesii	Douglas fir	Tree	1 gal	20 ft o.c.	upland	20
Tsuga heterophylla	Western hemlock	Tree	1 gal	15 ft o.c.	riparian	20
Thuja plicata	Western red cedar	Tree	1 gal	15 ft o.c.	riparian	20
Amelanchier alnifolia	Serviceberry	Shrub	1 gal	15 ft o.c.	upland	20
Cornus stolonifera	Red-osier dogwood	Shrub	1 gal	8 ft o.c.	riparian	40
Lonicera involucrata	Twinberry	Shrub	1 gal	8 ft o.c.	riparian/upland	20
Ribes sanguineum	Red-flowering currant	Shrub	1 gal	8 ft o.c.	upland	30
Rubus spectabilis	Salmonberry	Shrub	1 gal	8 ft o.c.	riparian	30
Sambucus racemosa	Red elderberry	Shrub	1 gal	10 ft o.c.	riparian/upland	20
Salix lasiandra	Pacific willow	Shrub	cuttings	2 ft o.c.	riparian	50
Agrostis oregonensis	Oregon bentgrass	Grass	seed	hydroseed	all cleared areas	3 lbs
Calamagrostis canadensis	Bluejoint reedgrass	Grass	seed	hydroseed	all cleared areas	3 lbs
Festuca rubra	Red fescue	Grass	seed	hydroseed	all cleared areas	3 lbs

5. MCACES COST ESTIMATE

5.1 Introduction and Methodology

The cost estimate for the Green River Fish Habitat Restoration Pilot Project was prepared as a Time and Materials estimate. The cost estimate was prepared in this manner since it is anticipated that the construction contract will be Time and Materials and also to predict the amount of manhours and equipment required to meet the construction schedule. The following methodology was used in the preparation of the Time and Material MCACES cost estimate for the Green River Fish Habitat Restoration Pilot Project.

a. The estimate was developed in accordance with guidance contained in ER 1110-2-1302, Civil Works Cost Engineering, and ER 5-7-1 Total Project Summary.
b. The effective pricing of the MCACES database is Jan 2001, therefore data from 2Q01 of the Civil Works Construction Cost Index System (EM 1110-2-1304, tables revised 30 September, 2002) was utilized.
c. Price levels were escalated to the anticipated midpoint of construction in September 2003. The escalation cost factor for 4Q03 Fish and Wildlife Facilities was taken from the Civil Works Construction Cost Index System (EM 1110-2-1304, tables revised 30 September, 2002).
d. Labor costs were based on the National Database (NAT01A) provided by the Seattle District.
e. Equipment costs were taken from EP 1110-1-8 Construction Equipment Ownership and Operating Expense Schedule as contained in the NAT99A database provided by the Seattle District.
f. Costs for Lands and Damages, Relocations, and Cultural Activities were not included in the estimate.
g. Costs for Construction Supervision and Administration (S&A) and Engineering and Design (E&D) were included as project costs and were calculated by percentages (12% and 10% respectively).
h. Bonding Costs were based on Class B Bond Rate as shown in ER 1110-2-1302, Appendix D.

i. Contingency Costs were included as project costs. Per ER 1110-2-1302, Civil Works Cost Engineering, the contingency for Project/Feature Desing of a project expected to cost less than $10 million is 20%.
j. Profit was calculated based on ER 1110-2-1302, Civil Works Cost Engineering, Appendix D.
k. Sales Tax was estimated at 8.5%

5.2 Schedule Labor and Equipment

The schedule for construction of the Green River Fish Habitat Restoration Pilot Project restricts all in water work to the month of August. Work anticipated to be performed prior to August 1st includes Site Preparation (construction surveying, fence removal, gate installation, silt fence installation) and Site Access/Staging (clearing and grubbing, cut/fill/compaction of access road, grading). It was anticipated that the Site Preparation and Access/Staging work would begin July 28th. Work anticipated to be performed after August 31st includes Site Reclamation and Revegetation (replanting of temporary construction areas, remove temporary construction items). It was anticipated that the Site Reclamation and Revegetation work would be completed by September 15th. The remaining work would be performed during the month of August. The labor and equipment required to perform all construction activities within this schedule have been estimated and are shown in Appendix F.

5.3 Materials

The primary materials for the Green River Fish Habitat Restoration Pilot Project include, import fill to construct the access road and gravel nourishment berms, water control diversion materials, rootwads to construct the engineered log jams, trees and shrubs for plantings, access gates, and temporary crossing items. Material costs were developed by obtaining quotes from vendors, previous project experience and by utilizing RS Means cost data.

5.4 Cost Summary

The cost estimate for construction of Restoration Zone 1 is $1.26 million dollars. Table 13 is shows the line item MCACES costs for the project.

Table 13. Summary MCACES Cost Estimate

	Activity	Unit Cost
Upstream Site	Mobilization/Demobilization	$3,912
	Construction Survey	$1,902
	Clear and Grub	$14,539
	Erosion Control	$3,012
	Excavation - Access Road	$40,791
	Fill - Riprap	$3,409
	Fill - Borrow Pitrun	$33,687
	Fill - Crushed Rock	$9,968
	Fill - Bi-Op Gravel	$118,510
	Fill - Structural Backfill Gravel	$20,323
	Access Gates	$7,375
	Reclamation/Revegetation	$20,968
	Total Upstream Site	**$278,396**
Downstream Site	Mobilization/Demobilization	$10,741
	Construction Survey	$2,773
	Clear and Grub	$31,994
	Diversion	$293,669
	Dewatering	$8,599
	Erosion Control	$7,309
	Demolition- Fence Removal	$933
	Excavation - Access Road	$29,963
	Fill- On Site Material	$3,266
	Fill - Riprap	$7,044
	Fill - Borrow Pitrun	$68,478
	Fill - Crushed Rock	$21,876
	Fill - Bi-Op Gravel	$145,249
	Fill - Structural Backfill Gravel	$14,623
	Access Gates	$7,375
	Engineered Log Jams	$277,376
	Reclamation/Revegetation	$47,660
	Total Downstream Site	**$978,928**
	Total Green River Resoration Zone 1	**$1,257,323**

PAGE INTENTIONALLY LEFT BLANK

6. REAL ESTATE

6.1 Real Estate Analysis

A preliminary real estate meeting was conducted on February 24, 2003 to coordinate real estate submittals and identify deliverables for the real estate department as they relate to the Green River Restoration Pilot Projects. Attendees included representatives of the Corps (Seattle District), PGS, and Tetra Tech. Several items were discussed and an approach developed to support the real estate department's needs and provide for implementation of the Pilot Projects. A real estate submittal was completed on April 4 containing maps and notes detailing real estate information for the project location, such as parcel ID numbers, property ownership, property line survey and legal descriptions, approximation of Ordinary High Water Mark (OHWM), utility locations, and easement requirements.

Two separate types of easements were identified: temporary access and construction right of entry easement areas and 7-year access easement areas. In Zone 1 these locations are entirely on public lands under the jurisdiction of the Washington Department of Natural Resources (WDNR) and Tacoma Public Utilities (TPU). Throughout the process, several revisions were made based on comments from meetings with the Corps, WDNR, TPU, and the Washington Department of Ecology (WDOE). Maps and details of the real estate submittals can be found in Appendix G.

6.2 Draft Level 1 Assessment of HTRW

Tetra Tech was contracted by the Seattle District of the Army Corps of Engineers to assist in the Planning and Design of the Howard Hanson Dam Downstream Pilot Restoration Project Implementation. As part of that contract Tetra Tech conducted a preliminary (Level 1) assessment of the Green River Pilot Project Zone 1 footprint to determine the potential current and historical influence of contamination from activities in the area.

The area covered in the assessment is limited primarily to the area within and immediately surrounding the proposed footprint of Restoration Zone 1, and includes the Tacoma Watershed Office buildings and grounds, and portions of the Tacoma Public Utilities (TPU) Headworks Office/Facility just upstream of the Zone 1 footprint. For a detailed account of the work activities completed in the Level 1 assessment, see Appendix G.

PAGE INTENTIONALLY LEFT BLANK

7. PUBLIC OUTREACH AND AGENCY COORDINATION

During the course of the Pilot Project, the Corps held two inter-agency coordination meetings and one public information meeting to explain the project and receive input from regulatory agencies and interested parties. A brief description of these meetings is presented below. Meeting minutes and list of attendees can be found in Appendix I.

The first inter-agency meeting was held at the Corps offices in Seattle on March 28, 2003. Agencies in attendance included the Corps; Washington Department of Natural Resources (WDNR); Tacoma Public Utilities (TPU); and Washington Department of Ecology (Ecology).

The second inter-agency meeting was also held at the Corps Seattle offices on April 9, 2003. Agencies in attendance included the Corps, WDFW, Muckleshoot Tribe Fisheries Dept (MT), National Marine Fisheries Service (NMFS), Washington Department of Fish and Wildlife (WDFW), and King County Division of Natural Resources (KCDNR). Four consultants involved with the project were also present (Tetra Tech, GeoEngineers, Perkins GeoSciences, and R2 Resource Consultants). The purpose of the meeting was to update the agencies on the description and status of the project development, and promote relevant input and discussion.

The public information meeting was held at the Ravensdale Community Center on April 23, 2003. Six Corps staff attended, joined by two staff from the prime consultant on the project (Tetra Tech). Approximately 25 to 35 members of the public were in attendance. All questions raised by the public were answered by Corps and consultant's staff during the meeting. A complete accounting of the questions and answers presented at the meeting can be found in Appendix I.

PAGE INTENTIONALLY LEFT BLANK

8. REFERENCES

Chow, Ven Te, 1959. Open-Channel Hydraulics. McGraw-Hill

Drury, Tracy Arthur, 1999. Stability and Pool Scour of Engineered Log Jams in the North Fork Stilliguamish River, Washington. Thesis, University of Washington.

Dunne, Thomas, and William Dietrich, 1978, Technical Appendix A-Hydrology and Geomorphology of River of Green: recreation and conservation on the upper and lower green river.

King County, et. al, 1996, Draft Water Resources Inventory Area 9, Habitat Limiting Factors and Reconnaissance Report, Green Duwamish and Central Puget Sound Watersheds.

Kondolf, M.G. et al, 1993, The Sizes of Salmonid Spawning Gravels, Water Resources Research, Vol. 29, No. 7, Pages 2275-2285.

Madsen, Susan W., and Stuart M. Beck P.E. Ph.D, 1997. Howard Hanson Dam – Additional Water Storage Project Gravel Nourishment Opportunities in the Lower Green River.

Meyer-Peter, E., Müller, R. (1948). Formulas for Bedload Transport, Proceeds 2nd Meeting International Association of Hydraulic Structures Res. Stockholm, Sweden, Appendix 2. pp. 39-64.

National Marine Fisheries Services, 2000. Biological Opinion of the Programmatic Biological Assessment for Howard Hanson Dam, Operation and Maintenance, Additional Water Storage Project.

Perkins, Susan J, 1999. Geomorphic Evaluation of Gravel Placement in the Green River, Washington. Report prepared for Jones and Stokes Associates, Inc., Bellevue, Washington and the US Army Corps of Engineers, Seattle District.

Thorne, C.R., J.C. Bathurst, R.D. Hey (editors), 1987. Sediment Transport in Gravel-Bed Rivers. John Wiley and Sons.

U.S. Army Corps of Engineers, 1998. "Howard Hanson Additional Water Storage Draft Feasibility Report and Environmental Impact Statement.

U.S. Army Corps of Engineers, 2000. "Howard Hanson Additional Water Storage – Phase 1, Fish and Wildlife Mitigation and Restoration Conceptual Design Report", Seattle District.

U.S. Army Corps of Engineers, 2000a. "Green/Duwamish River Basin Ecosystem Restoration Study," Final Feasibility Report, Seattle District.

U.S. Army Corps of Engineers, 2001, “Hydrologic Engineering Management Plan, Green River Fish and Wildlife Habitat Mitigation and Restoration Project”. Seattle District

U.S. Army Corps of Engineers, 2001b, Howard A. Hanson Dam, Water Control Manual.

U.S. Army Corps of Engineers, 2003, “Howard Hanson Dam, Phase I AWSP, Fish and Wildlife Mitigation and Rstoration Site Investigations and Surveys to Initiate Detailed Design.” Seattle District

U.S. Army Corps of Engineers, 2003b, Personal communication from Monte Kaiser regarding backfill specification on May 2, 2003.

U.S. Water Resources Council, 1981, Guidelines for Determining Flood Flow Frequency, Bulletin #17B.

Washington Department of Ecology Website, 2003, Water Quality Database for the Kanaskat Gage.

Washington State Authorize Code (WAC, 173-201), Water Quality Standards for Surface Water of the State of Washington