**U.S. Army Corps of Engineers Seattle District**

# Water Year 2005 Monitoring Report
# Howard Hanson Dam Additional Water Storage Project
# Zone 1 Fish Habitat Restoration Project
# Green River, Washington

October 2006

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# Additional Water Storage Project
# Zone 1 Fish Habitat Restoration Project

**King County, WA**

## Water Year 2005 Monitoring Report

**October 2006**

**Prepared By:**
**U.S. Army Corps of Engineers and**
**R2 Resource Consultants, Inc.**

## Table of Contents

## List of Figures

## List of Tables

## Appendices

# 1. INTRODUCTION

The U.S. Army Corps of Engineers, Seattle District (Corps) and the City of Tacoma (Tacoma) are currently implementing Phase I of the Howard Hanson Dam (HHD) Additional Water Storage Project (AWSP). The AWSP is a dual purpose water supply and ecosystem restoration project authorized in the Water Resources Development Act of 1999. Funds were first appropriated for construction in 2002. Phase 1 of the AWSP includes additional water storage behind HHD to 1167 ft for municipal and industrial purposes and construction of a suite of habitat restoration and mitigation projects (USACE 1998). The mitigation projects are required to offset impacts to habitat caused by the additional water storage and larger reservoir.

Three of the AWSP habitat projects are located in the middle Green River immediately downstream of HHD. They include:

- Annual gravel nourishment of the Green River below HHD.
- Placement in the lower river of approximately 50% of large wood debris (LWD) and 50-70 tons of small wood debris (SWD) that collects behind HHD each year. This is referred to as 'loose' wood.
- Construction of two engineered log jams (ELJs) in the Green River below HHD.

Gravel nourishment and 'loose' wood are considered AWSP restoration projects. Log jams are considered AWSP mitigation projects.

The general objective of these projects is to restore in part the natural processes that have been disrupted by HHD. The dam and reservoir currently trap 100% of gravel and wood that reaches the dam. Consequently, downstream reaches have become gravel and wood 'starved', resulting in an armoring of the streambed and decrease in habitat complexity that adversely affects fish spawning and rearing (Perkins 1999, Kerwin and Nelson 2000). This condition has progressively worsened since dam completion in 1962.

In 1999, Puget Sound Chinook salmon and bull trout were each listed as threatened under the Endangered Species Act (ESA) (64 FR 14308, 64 FR 58910). As a result the Corps was required to consult with NOAA Fisheries and U.S. Fish and Wildlife Service to ensure that HHD operations including the AWSP did not jeopardize Chinook salmon or bull trout. The resulting biological opinions (Bi-op) identified several reasonable and prudent measures including gravel nourishment, wood transport around the dam, and log jam construction that are necessary and appropriate to minimize take under the ESA (NOAA 2000, USFWS 2000).

## 1.1. Project Description and Location

In order to meet objectives of the AWSP habitat projects described above and ESA requirements, the Corps constructed the zone 1 fish habitat restoration project in 2003. The zone 1 project is located at RM 60 of the Green River, three miles upstream from Kanaskat-Palmer State Park, and 4.5 miles downstream from HHD. The project included construction of two ELJs and two gravel nourishment berms. The log jams contained 81 and 88 logs each and are designed to be stable to the 100-year flood. The gravel berms were constructed with spawning size gravel 0.5 – 4 inches in diameter below ordinary high water.

The gravel berms were designed to erode over the winter during high flows. They will be re-constructed each August. The initial AWSP project goal was 3,900 cubic yards of spawning size gravel to be placed annually. As a result of the ESA consultation, the gravel restoration project was expanded to include up to an additional 8,000 cubic yards for a potential maximum of 12,000 cubic yards placed annually in the Green River. Monitoring data will determine the actual amount of gravel placed to ensure that project objectives are met and potential adverse effects minimized. Additional project details can be found in the project construction report (USACE 2003a). Figure 1 illustrates the constructed project in 2003.

Transport of wood debris around the dam and placement on the gravel berms was implemented in August 2004. Annual decisions regarding transport of wood around the dam will be dependent on the amount of wood received at the reservoir over the previous year, mobilization and effectiveness of wood placed at RM 60, and the need for wood at other habitat projects. This decision process will be adaptive and based on discussions with stakeholders.

All three of these projects were designed and constructed in concert to achieve certain synergies between the individual habitat projects. For example, it was recognized that the log jams would effectively sort and store gravel from the nourishment berms creating salmonid spawning habitat.

### 1.2. General Project Objectives

Gravel nourishment:

- Increase available spawning opportunities in the middle Green River for Chinook salmon, coho salmon, and steelhead trout.
- Reconnect side channel and floodplain habitat.
- Reverse streambed armoring in the middle Green River.
- Restore the natural gravel transport process interrupted by HHD.

‘Loose’ wood:

- Increase habitat complexity and LWD in the middle Green River.
- Increase the amount of riverine pool area in the middle Green River.
- Increase cover habitat for salmonids.
- Create conditions for local gravel storage.
- Restore the natural wood transport process interrupted by HHD.

Log jams:

- Provide cover for both adult and juvenile salmonids.
- Provide rearing habitat for juvenile salmonids.
- Create riverine pool habitat.
- Sort and store gravel to create salmonid spawning habitat.
- Increase flow to the left bank side channel immediately downstream of the log jams.

Specific design criteria can be found in sections 3.2 for the gravel project and section 4.1 for the log jams.


Figure 1. Post construction aerial photo of constructed gravel berms and log jams at RM 60 of the Green River, 21 September 2003.

### 1.3. Monitoring Plan Overview

The project is designed to be adaptively managed so that monitoring data will determine whether project modifications or maintenance is required. The first five years of gravel nourishment will be intensively monitored to determine gravel transport rates, effective loading quantities, optimal size specifications, and general project effectiveness. The Corps plans to experiment with gravel quantities and sizes in order to better understand gravel transport in the middle Green River and to determine the most effective loading strategy. The data collected during this five year pilot period will provide the background for management of the 50 year project. Periodic monitoring will still be required after this five year period to adaptively manage the project and ensure that objectives are met. A GIS database has been developed that will become the repository for collected data and a tool for project analysis.

The log jams and 'loose' wood project will also be monitored during this period to ensure that objectives are being achieved. A detailed monitoring schedule is outlined in Table 1. Additional detail including methodology can be found in the project monitoring plan (USACE 2003b).

Specific monitoring questions include:

Gravel
- Are gravel berms effectively providing spawning gravels to the river each year?
- What is the rate of gravel transport through the reach? How does gravel size affect transport?
- How is substrate composition changing downstream?
- What is the effect of gravel nourishment on Chinook salmon and steelhead trout spawning?

Log jams
- Are log jams stable?
- Is flow being directed into the side channel?
- Do log jams create pool and cover habitat for fish? Are fish using the habitat?

Geomorphology
- Is there any change in channel morphology?
- Is there a change in water surface elevation?
- Is there any channel migration?
- Is there localized storage of spawning gravel?
- Are there signs of bank erosion?

Downstream habitat and loose LWD
- How has 'loose' LWD and gravel affected habitat in the middle Green River?
- Is there an increase in number of pools?
- Is there an increase in LWD?
- Is there increased side channel habitat available to fish?

This monitoring report covers the 2005 water year which is from fall 2004 to fall 2005. It includes data collected from post-high flow site visits in 2004 and 2005, annual gravel monitoring in summer 2005, and Chinook spawner surveys in fall 2005. Due to the timing of Chinook spawning in the early fall, this species will typically use gravels that were eroded the previous winter. For example, gravel placed in any given year will typically erode in the November-December period, and subsequently be available for Chinook spawning the following September – October. Monitoring data for Chinook salmon spawning therefore indicates use of gravels usually eroded during the previous year.

This report contains limited data regarding the 'loose wood' project. Separate annual monitoring activities and reports will be produced addressing this specific project.

Table 1. Monitoring Schedule.

| | Methods | Year 0 WY 2003 | Year 1 WY 2004 | Year 2 WY 2005 | Year 3 WY 2006 | Year 4 WY 2007 | Year 5 WY 2008 |
|---|---|---|---|---|---|---|---|
| **1. Gravel Nourishment** | | | | | | | |
| **1.1 Gravel Transport** | | | | | | | |
| 1.1.1 Gravel Berm Erosion and Transport Rate | Low flow/Spring survey of gravel berms. | | X | X | X | X | X |
| | Post high-flow survey/visual inspection of gravel berms | | X | X | | | |
| 1.1.2 Gravel Transport, Deposition, and Composition | Survey established cross sections | X | X | X | X | X | X |
| | Wolman pebble counts | X | X | X | X | X | X |
| | Gravel patch mapping/aerial photo analysis | | X | X | X | X | X |
| | Post high flow visual inspection | | X | X | X | X | X |
| **1.2 Chinook Spawning Activity** | | | | | | | |
| 1.2.1 Chinook Spawning | Spawner Survey (fall) | X | X | X | X | X | X |
| **2. Engineered Log Jams** | | | | | | | |
| **2.1 Performance and Stability** | | | | | | | |
| 1.1.1 Settlement and Deformation | Low flow visual inspection and photo comparison | | X | X | X | X | X |
| | Topographic survey of control points (if settling observed or suspected ) | X | X | | | | |
| | Post high-flow visual inspection and photo analysis | | X | X | | | |
| 1.1.2 Wood Accumulation/Loss | Visual inspection and photo anaylsis | | X | X | X | X | X |
| 1.1.3 Ballast Material | Visual inspection and photo anaylsis | | X | X | X | X | X |
| **2.2 Effect on hydraulics** | | | | | | | |
| 2.2.1 Pool Development | Survey pool dimensions | | X | X | X | X | X |
| 2.2.2 Side Channel Flow | Flow survey at 1000 cfs | X | X | | | | X |
| **2.3 Fisheries Use** | | | | | | | |
| 2.3.1 Juveniles | Snorkel surveys (spring, summer, fall) | X | X | | | | X |
| 2.3.2 Adult Chinook | Snorkel survey (fall) | X | X | | | | X |
| **3. Channel Geomorphology** | | | | | | | |
| 3.1 Planform Analysis | Survey established cross sections | X | X | X | | | X |
| | Thalweg profile mapping | X | | | | | X |
| | Aerial photo analysis | X | X | X | X | X | X |
| 3.2 Side Channel and Floodplain Connectivity | Aerial photo analysis | X | X | X | X | X | X |
| | Side channel water level (low flow) | X | X | X | X | X | X |
| 3.3 Channel Stability | Field survey | X | X | X | X | X | X |
| **4. Habitat Monitoring** | | | | | | | |
| 4.1 Habitat mapping | Field survey | 2001 | | | X | | |

**Annual Schedule**

**Low flow gravel berm survey:** no later than June 15 assuming flows allow access.

**Post high-flow monitoring:** at least 10 days following first 5500 cfs event of the year or any 7000+ cfs events.

**Low-flow monitoring:** Completed before July 31.

**Reporting:** draft by October 30, final by December 30

# 2. HYDROLOGIC SUMMARY

## 2.1. Water Year 2005 Overview

Figure 2 illustrates the annual hydrograph for the 2005 water year (October 1, 2004 - September 30, 2005), as measured at the USGS gage at Palmer (#12106700), located at RM 60.3 in Zone 1, just above the upper gravel loading site. The gage is downstream from HHD and reflects routine management of outflows for flood control, provision of in-stream minimum flows for fisheries, and water supply needs. Compared to the average annual hydrograph (Figure 3), 2005 was characterized by its low total runoff (85% of normal), near record low inflow in March (<1% non-exceedance), and successive high flows that ceased after the 18 January, 2005 bankfull event (1.5 year recurrence interval). Snow pack was 4% of normal on April $15^{th,}$ 2005 (L. Schick, pers. Communication) and drought conditions were declared by Governor Gregoire.

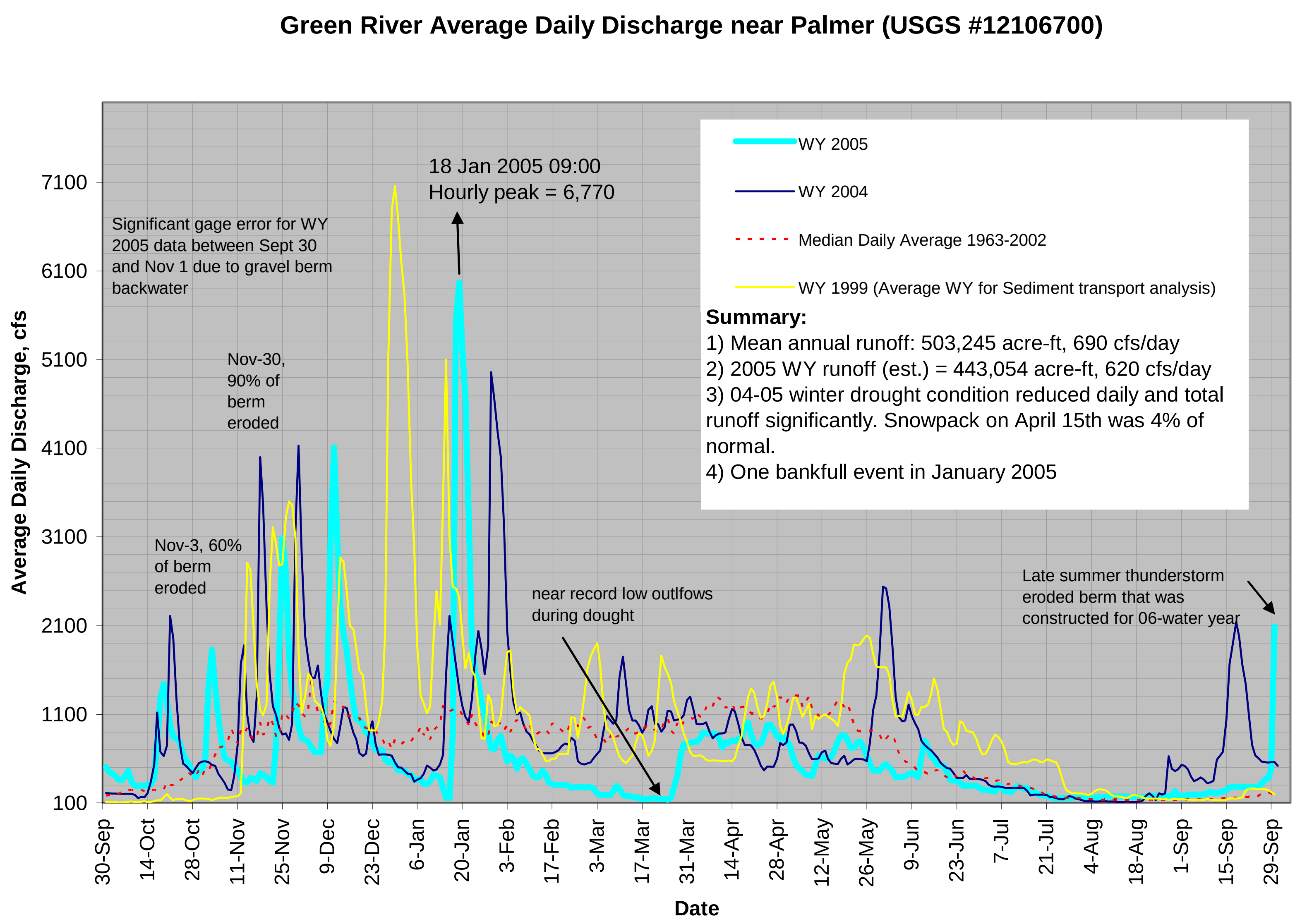



Figure 2. Green River at Palmer 2005 Water Year Hydrograph.

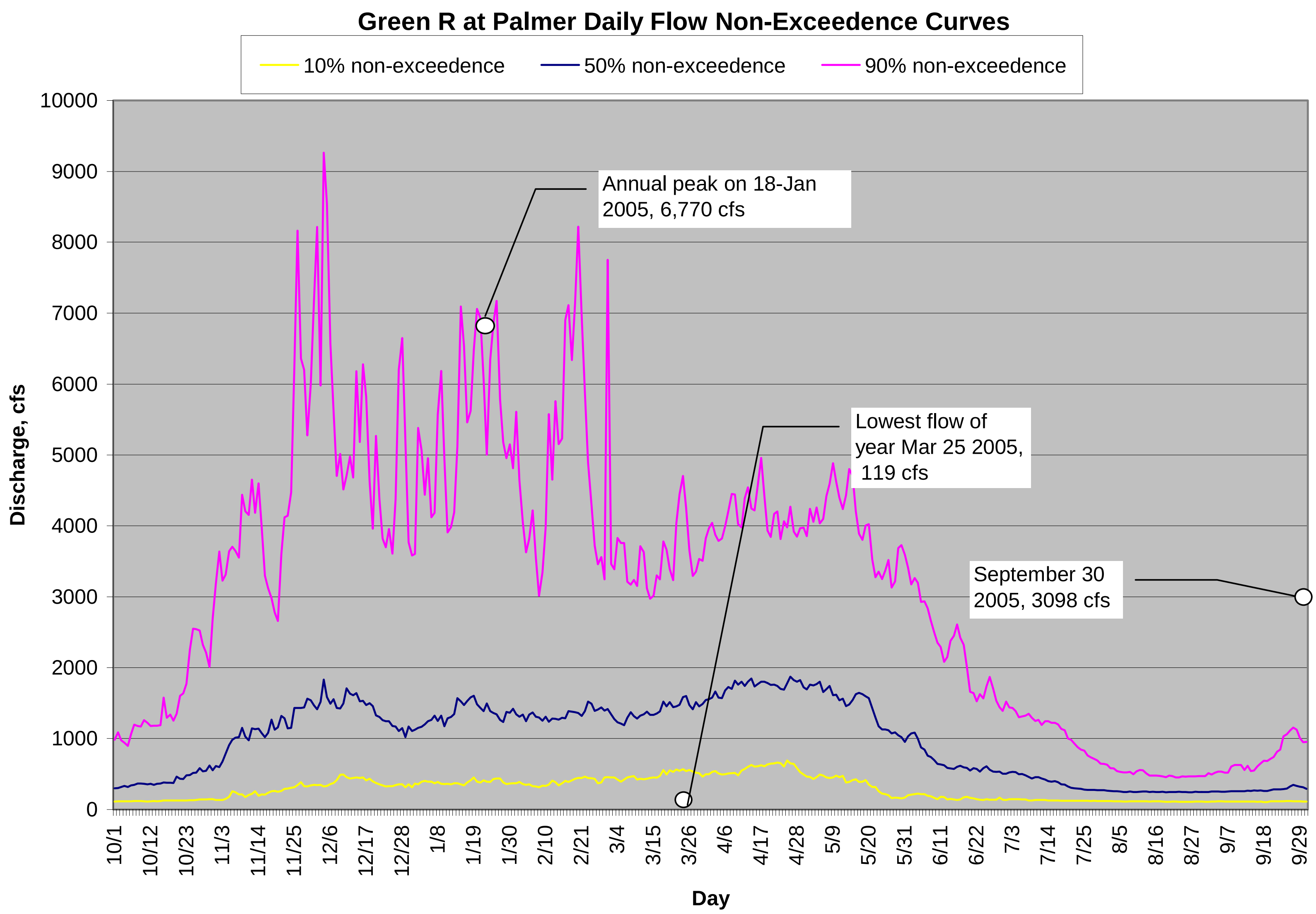



Figure 3. Green River at Palmer Non-Exceedence Discharge Curves Comparing Select WY 04 Events

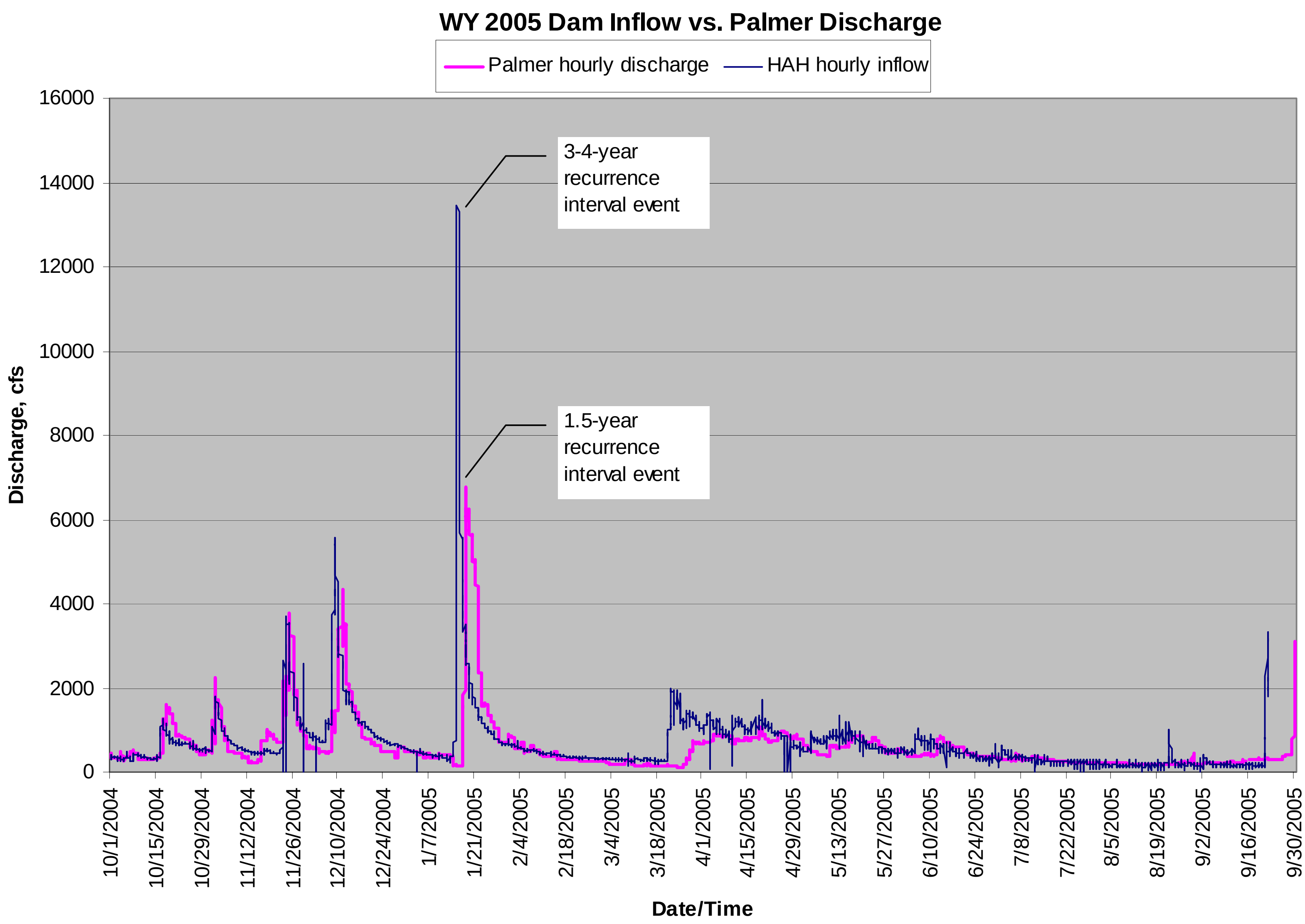



Figure 4. Green River at Palmer vs. HAH Dam Inflow WY 2005

# 3. GRAVEL NOURISHMENT

## 3.1. WY 2005 Gravel Nourishment

In August 2004, a total of 7,024 tons of gravel (approximately 4,126 cubic yards) was placed at the upper loading zone in a single continuous berm at approximately RM 60 of the Green River (Figures 5, 6). The upper loading zone is located on the left bank just downstream from the USGS gage in a riffle-cascade reach. The lower loading zone is located just upstream of the log jams on the left bank in a run-riffle-cascade reach and is not as steep or confined as the upper zone. No gravel was loaded at the lower loading zone in WY 2005. The pre-project streambed material in the upper loading zone consisted primarily of boulders, with some cobble and gravel. The lower loading zone streambed consisted of sands, gravels, cobbles, and boulders. The gravel nourishment berms were constructed by end-dumping from dump trucks onto the landward edge of the berm. This gravel was then pushed out and graded up to the ordinary high-water mark by a small bulldozer. In WY 2004 the upper berm was constructed in a “sawtooth” pattern. The lower berm was composed of two “teardrops”. The purpose of the two configurations was to determine if certain gravel berm configurations or more easily eroded by the river. WY 2004 monitoring report showed that the configuration made little difference since both berms were nearly totally entrained and transported. As a result of the WY 2004 monitoring, the final configuration of the berms was adjusted such that all gravel was placed at the upper loading site in a continuous berm (no sawtooth) that extended from the OHW line to the center of the channel. The gravel spec maximum sieve size was increased to 5-inches from 4-inches to retain more gravel in the nourishment reach.

The specifications for gravel placed in WY 2004 and WY 2005 are described in Table 2. Additional details about the WY 2004 construction can be found in the project construction report (USACE 2003a).

Table 2. Summary of gravel placed at RM 60 in WY 2004 and WY 2005

| **Summary of gravel placed in Green River at RM 60 (zone 1)** | | |
|---|---|---|
| | WY 2004 (placed August 2003) | WY 2005 (placed August 2004) |
| sieve size | % finer | % finer |
| 6 inch (152 mm) | | |
| 5 inch (127 mm) | | 99.4 |
| 4 inch (102 mm) | 100 | 92.6 |
| 3 inch (76 mm) | | 76.8 |
| 2 inch (51mm) | 65 | 55.3 |
| 1 inch (25 mm) | 27 | 10.9 |
| 0.5 inch (13 mm) | 6 | 2.1 |
| **Quantity placed:** | | |
| total tons: | 7555 | 7024 |
| cubic yards (0.6 cubic yards/ton): | 4533 | 4214 |

Figure 5. Construction of WY 2005 Gravel Nourishment Project

### 3.2. Performance Criteria

Gravel performance criteria include:

- Mobilize a majority (90%) of the gravel at the bankfull event (1.5 year recurrence interval = 6870 cfs)
- Load gravel in a manner to achieve a relatively heterogeneous gravel composition in downstream locations
- Store gravel in zone 1 reach to provide salmonid spawning opportunities
- Increase spawning opportunities downstream of gravel nourishment locations

### 3.3. Monitoring Activities

In WY 2005, gravel monitoring consisted of:

- aerial photo analysis,
- high flow inspections,
- low flow cross section surveys,
- low flow grid pebble counts,
- low flow gravel patch mapping,
- Chinook salmon spawner surveys.

Raw data can be found in the attached appendices. The methods and results of the gravel monitoring activities are provided in the following sections.

Aerial photographs are used on an annual basis to evaluate effects of the project including identification of gravel patches and changes to gravel bars. One photographic series was taken in August 2005. The flight line was from approximately RM 56 to RM 61. River discharge during the photograph was approximately 170 cfs. Due to the sun angle and lack of cloud cover, shadows and glare obscure portions of the channel. The photograph negative scale was 1" = 600' with 0.5-foot pixel resolution. The vertical accuracy met standards for Class 2 orthophotographs: as accurate as the USGS Digital Elevation Model (DEM) data used to create orthophotographs. Thereby, 90 percent of all points have at least a 7-meter RMSE accuracy and 10 percent are in the 8-15 meter range.

#### 3.3.1. Gravel Berm Erosion Rates

USACE visually inspected and took photographs of the upper gravel berm about once every two weeks, from construction (August 2004) until late November 2004, by which time nearly all of the gravel had been eroded. From Figure 4 above, and Figures 6 and 7 below, it is seen only 2 small runoff events (1,600 and 2,200 cfs) were required to erode more than half of the nourishment gravel from the upper berm. After the late November event (3,900 cfs) it is estimated that about 90% of the gravel was eroded. Thus by the time the “design flood” (1.5-year event) occurred in January 2005, the river had nearly eroded all the gravel placed in August available to it for transport to downstream reaches. Based on low flow field assessments (Appendix D, Gravel Patch Mapping,) and photo analysis (Appendix A, Photo Point Comparisons) it is estimated that 96% (6,670 CY,) of the nourishment gravel was eroded from the upper gravel nourishment berm between summer 2004 and summer 2005. In summer 2004 the un-eroded gravel volume estimates were 120 CY at the upper berm and 150 CY at the lower berm. In summer 2005 the un-eroded volume estimate was 353 CY. It appears that the upper loading site saw an increase in the retained volume (223 CY vs. 120 CY) that may have been attributable to repair of the riprap at the upper loading zone ramp in summer 2004. From site observations it appears that the stabilized ramp creates a hydraulic shadow for the gravel along the left bank downstream of the loading ramp. Based on this assessment USACE shifted the placement of gravel in summer 2005 towards the river in an effort to reduce the impact of the shadow on gravel erosion.

From the WY 2004 monitoring it was found that gravel berm configuration did not appear to be an important factor in berm erosion. WY 2005 monitoring further confirmed this observation, as nearly all the gravel was quickly eroded by the river, well before the highest flows of the year occurred. Channel encroachment, bed slope, and discharge appear to be more important variables than berm geometry. Due to the proximity and composition of the gravel berm and the steepness of the upper loading reach, the berm was actively eroding at all discharges, although the rate of erosion greatly increased with discharge, especially when the berm was overtopped. Remnant berm gravel was observed downstream of obstructions to scouring flows, such as large boulders that shield the gravel, and vegetation that creates roughness along the bank, slowing flow.

Although LWD was added to the berm in 2004, and the maximum sieve size for the gravel was increased, not enough detailed data was obtained to tell if these changes had a significant impact on erosion rates. Review of photographs contained in Appendix E shows that there is some local scour created by LWD that falls into the channel adjacent to the gravel berm which may increase erosion rates as long as the LWD is present. Also, LWD placed on the upper portion of the bar appeared to be correlated with scour of the bar when flows overtopped the bar. Since the upper loading zone has consistently eroded 95% of the placed material, enhanced erosion from LWD placement on the gravel berms, if it is occurring, should only be considered a marginal benefit. If larger sized gravel is placed at the loading zone, the presence of the LWD may help, or, possibly hinder the erosion process. More monitoring is required to assess this interrelation. Also, the interaction with spawning fish should be considered. In several instances before major berm erosion had begun, but where flows were high enough to overtop portions of the berm, pink salmon were seen spawning on top of the nourishment berm, which was subsequently eroded by higher flows. Future modifications to the berm configuration should factor in the likely erosion mode and rate and the potential negative impacts on spawners.


Figure 6. Erosion of upstream end of upper gravel nourishment berm, showing LWD transport

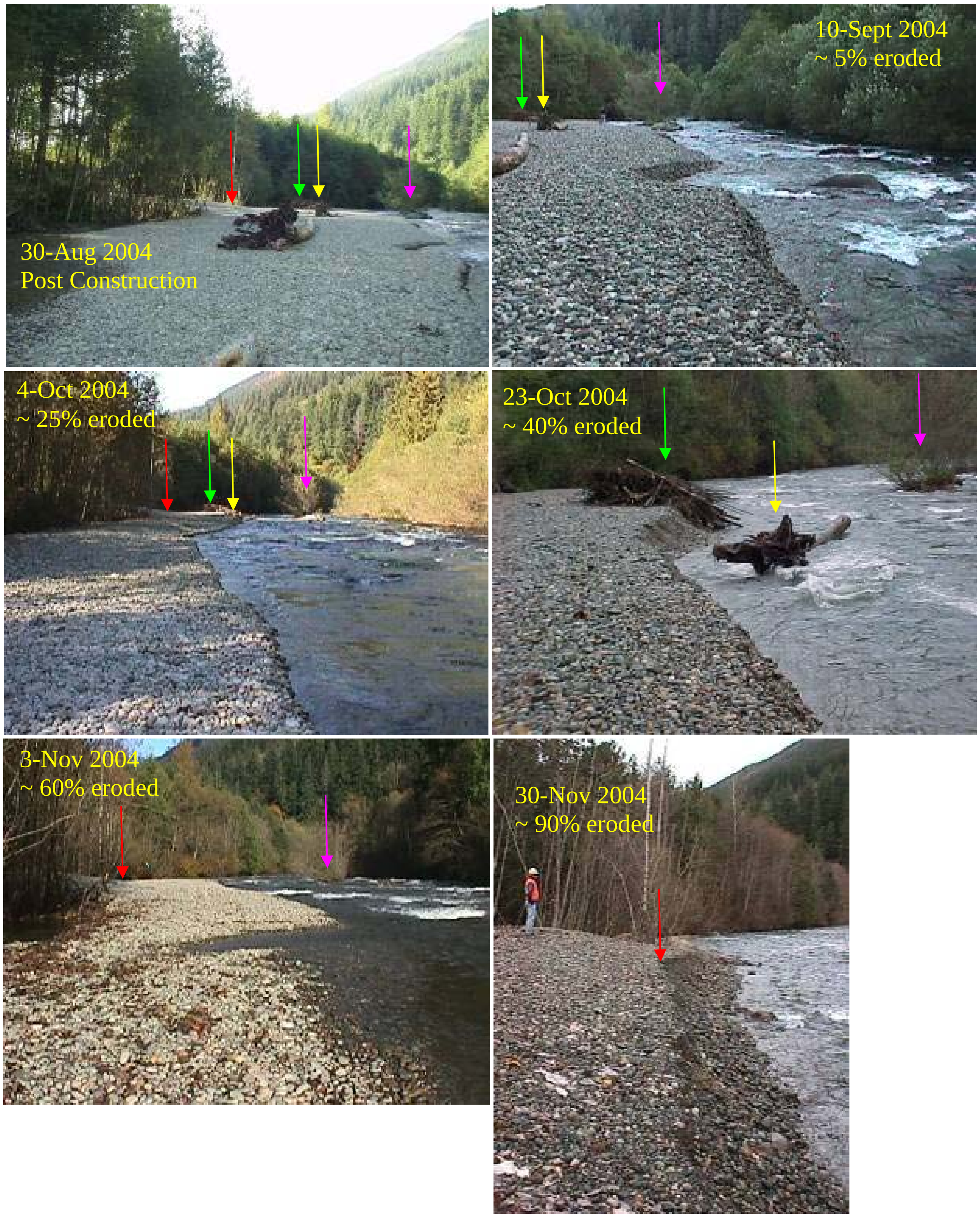



Figure 7. Erosion of downstream end of upper gravel nourishment berm, showing LWD transport

### 3.3.2. Gravel Transport, Deposition, and Composition

Gravel transport and deposition was evaluated by erosional photo analysis, aerial photo analysis, gravel path mapping, and by cross section surveys at established transects. Gravel composition was evaluated by annual grid pebble counts at established transects, 3” grid photos at significant depositional or erosional features, aerial photo analysis, and gravel patch mapping between RM 60 and RM 58.

#### 3.3.2.1. Cross Section Surveys

Twenty-eight baseline cross-sections were established in 2002 (USACE 2003c). Permanent cross sections were established with cap and rebar and adjacent tagline post; intermediate cross sections were also established with rebar endpoints and have decimal numbering system. Cross section locations are identified in Figures 9-13.

In summer 2005, 4 cross sections were re-surveyed by USACE including KP 1.7, 1.9, 3.0, and 3.2. These cross sections were experiencing the most change of those surveyed in 2004 (which included KP 1.7, 2.0, 3.0, 3.2, 4.2, 4.6, and 5.0). Since the other cross sections were not experiencing as much change, it was decided that they would be re-surveyed 5 years after the start of the gravel nourishment project as part of the geomorphic evaluation.

To aid in the cross section monitoring, USACE retained Tetratech and Pacific Geomatic Services (PGS, Inc.) to relocate and position permanent bank station end points that allow for rapid cross section location and re-survey (so that control does not need to be surveyed in from a benchmark every year). The permanent cross section monitoring points that were physically established with nails or steel caps are shown below:

Table 3. 2005 Cross Section Survey Control Points

| PT | NORTHING (FT) | EASTING (FT) | ELEVATION (FT) | DESCRIPTION |
|---|---|---|---|---|
| 593 | 115149.411 | 1746910.87 | 853.96 | REBAR-RPC ELJ1 BANK MONITOR |
| 690 | 115008.171 | 1747295.888 | 860.00 | REBAR-RPC ELJ2 BANK MONITOR |
| 7003 | 115186.308 | 1747398.286 | 852.31 | KP 2.0 IP 2 REP |
| 7004 | 115132.918 | 1747498.569 | 853.51 | KP 1.9 IP 2 REP |
| 7005 | 115057.565 | 1747327.966 | 854.06 | KP 2.0 IP 1 LEP |
| 7006 | 115014.630 | 1747439.293 | 853.44 | KP 1.9 IP 1 LEP |
| 7007 | 115107.610 | 1747325.707 | 858.68 | NAIL/YPW IN LOG |
| 7008 | 115124.380 | 1747339.239 | 858.85 | NAIL/YPW IN LOG |
| 7009 | 115174.880 | 1746806.751 | 852.09 | KP 3.2 IP 1 LEP |
| 7010 | 115407.020 | 1746844.552 | 850.73 | KP 3.2 IP 2 REP |
| 7011 | 115320.041 | 1747103.406 | 853.66 | KP 3.0 IP 2 REP |
| 7012 | 115158.600 | 1747045.809 | 853.19 | KP 3.0 IP 1 LEP |
| 7014 | 114716.128 | 1747800.993 | 855.56 | KP 1.7 IP 1 LEP |
| 7015 | 114758.996 | 1747922.505 | 855.34 | KP 1.7 IP 2 REP |

The above coordinates are expressed in terms of the Washington State Plane Coordinate System, North Zone, NAD 27, based on control points supplied by USACE in the vicinity of HHD. Elevations are per the NGVD29.

All monitoring cross section surveys used a 300 ft fiberglass tape staked across the channel to record stationing and a Leica auto level, stadia rod, and survey bench marks to survey elevations across the section (Figure 8). Cross section data for WY 2005 is shown below in Figures 14-17. Raw survey data is contained in Appendix B. For comparative purposes the 2002 baseline and the WY 2004 data are shown.

In 2004, it was observed that significant amounts of gravel are being stored between KP 2.0 and 3.0. Other surveyed cross sections only indicated minor changes. In 2005 a similar trend of gravel storage continues above both logjams. Over 1 ft of aggradation was recorded at KP 1.9 in the middle of the channel, and over 3 ft of aggradation was recorded on the left bank. The thalweg near the right bank appears to have scoured somewhat. At KP 3.0 the channel has continued to fill, with over 1.5 ft of aggradation recorded in the middle of the channel upstream of ELJ 1. The thalweg has also aggraded somewhat. Upstream of the ELJs, at KP 1.7, the trend observed in the field (aggradation) is not observed in the cross section surveys. It is not clear at this point if the apparent scour at this section is indeed occurring despite the presence of clearly visible gravel bars (Appendix C). It is notable that the water level in the side channel is higher in the side channel than main channel, since this is opposite of what was observed in 2004. WY 2006 results will be used as a check against the WY 2005 results to see if this trend is still observed. If it is not observed the 2005 data will be assumed to be in error, unless some other explanation can be found. At KP 3.2, just downstream of ELJ 1, change remained limited. Some deposition was observed in the main channel, side channel, and on top of the vegetated island. The majority of deposition observed was along the left bank of the main channel. A common feature to all surveyed sections is the location of the thalweg along the right bank. Between WY 2004 and WY 2005 deposition along the left bank seems to have concentrated flow to a greater degree on the right bank. This is most apparent at KP 1.9, just above ELJ 2.

Figure 8. Typical cross section survey equipment (KP 1.7, looking at right bank)

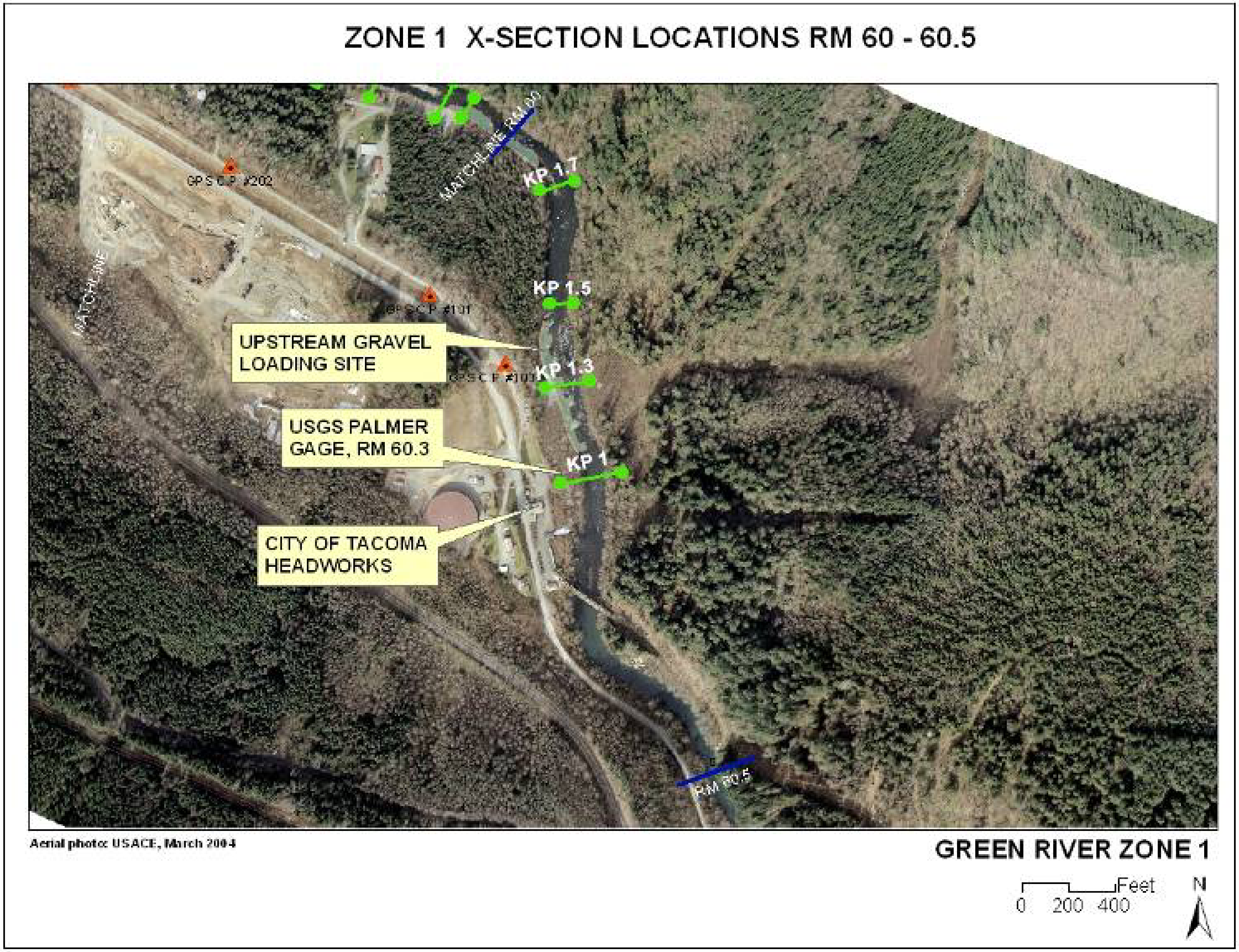



Figure 9. Cross section locations RM 60 – 60.5.


Figure 10. Cross section locations RM 59.5-60.


Figure 11. Cross section locations RM 59 – 59.5.


Figure 12. Cross section locations RM 58.5-59.


Figure 13. Cross section locations RM 58 -58.5.

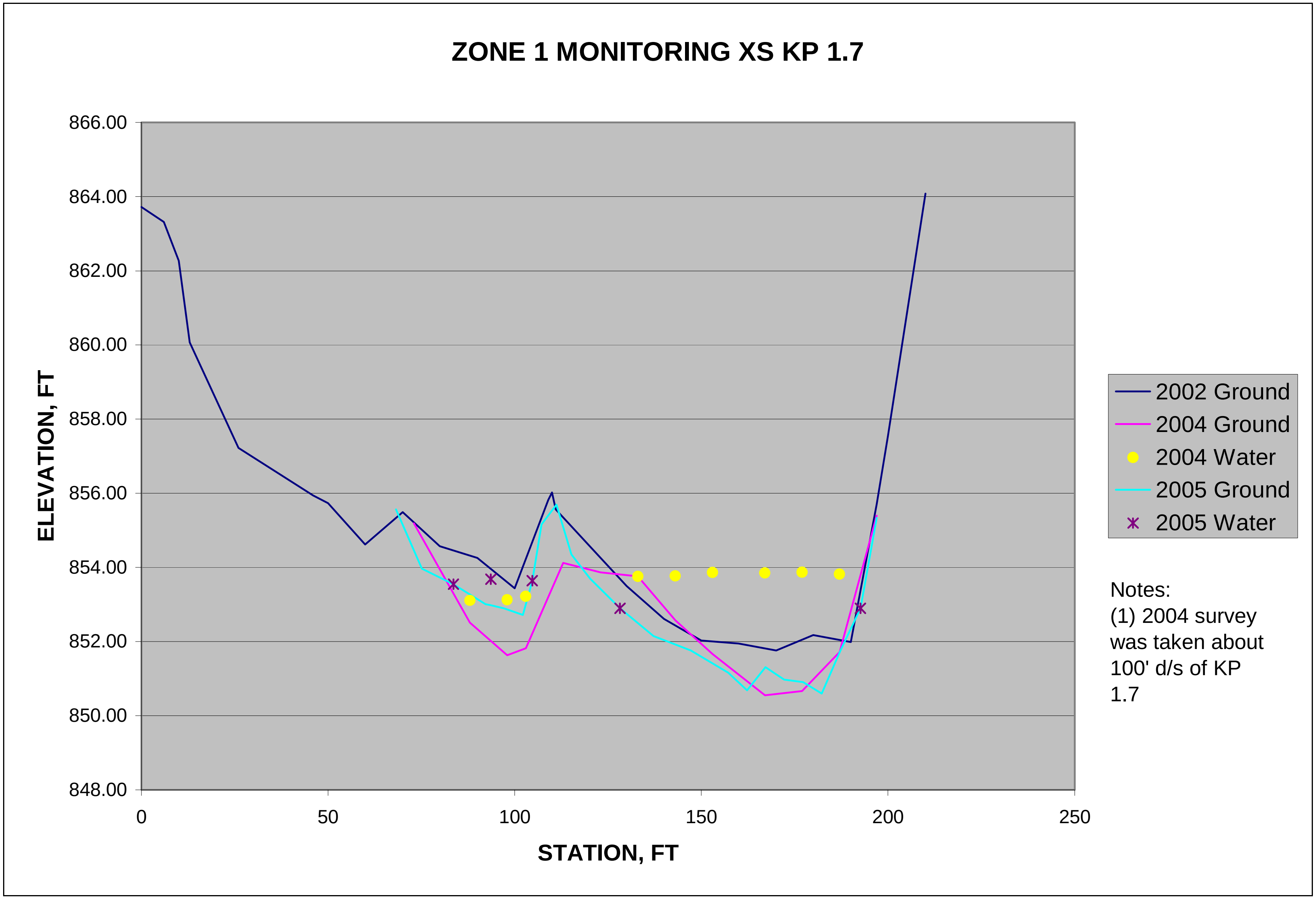



Figure 14. Cross section survey data KP 1.7 (WY 2004 flow at Palmer, 8/3/04, 120 cfs, WY 2005 7/28/05, 151 cfs).

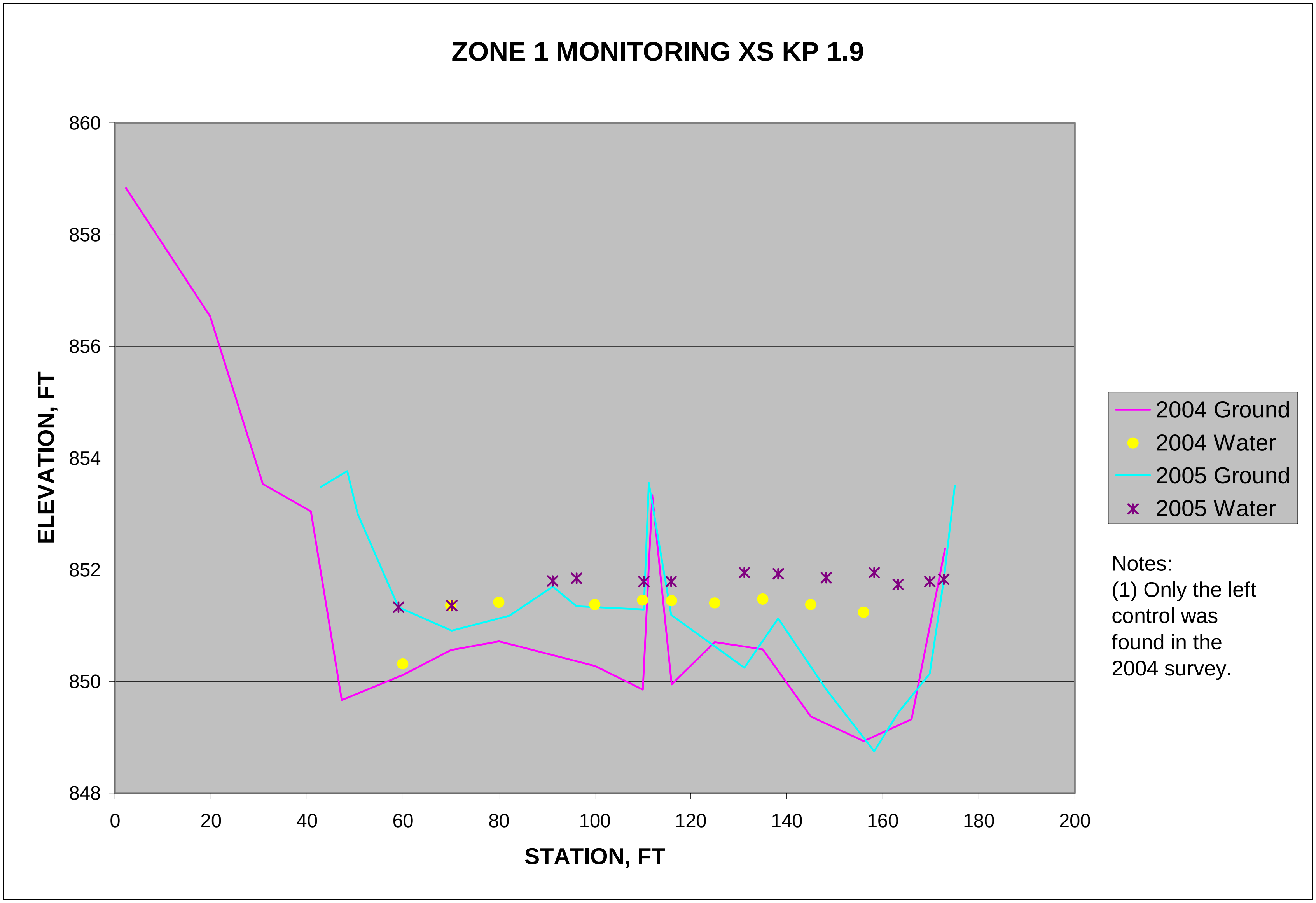



Figure 15. Cross section survey data KP 1.9 (WY 2004 flow at Palmer, 8/3/04, 120 cfs, WY 2005 7/28/05, 151 cfs).

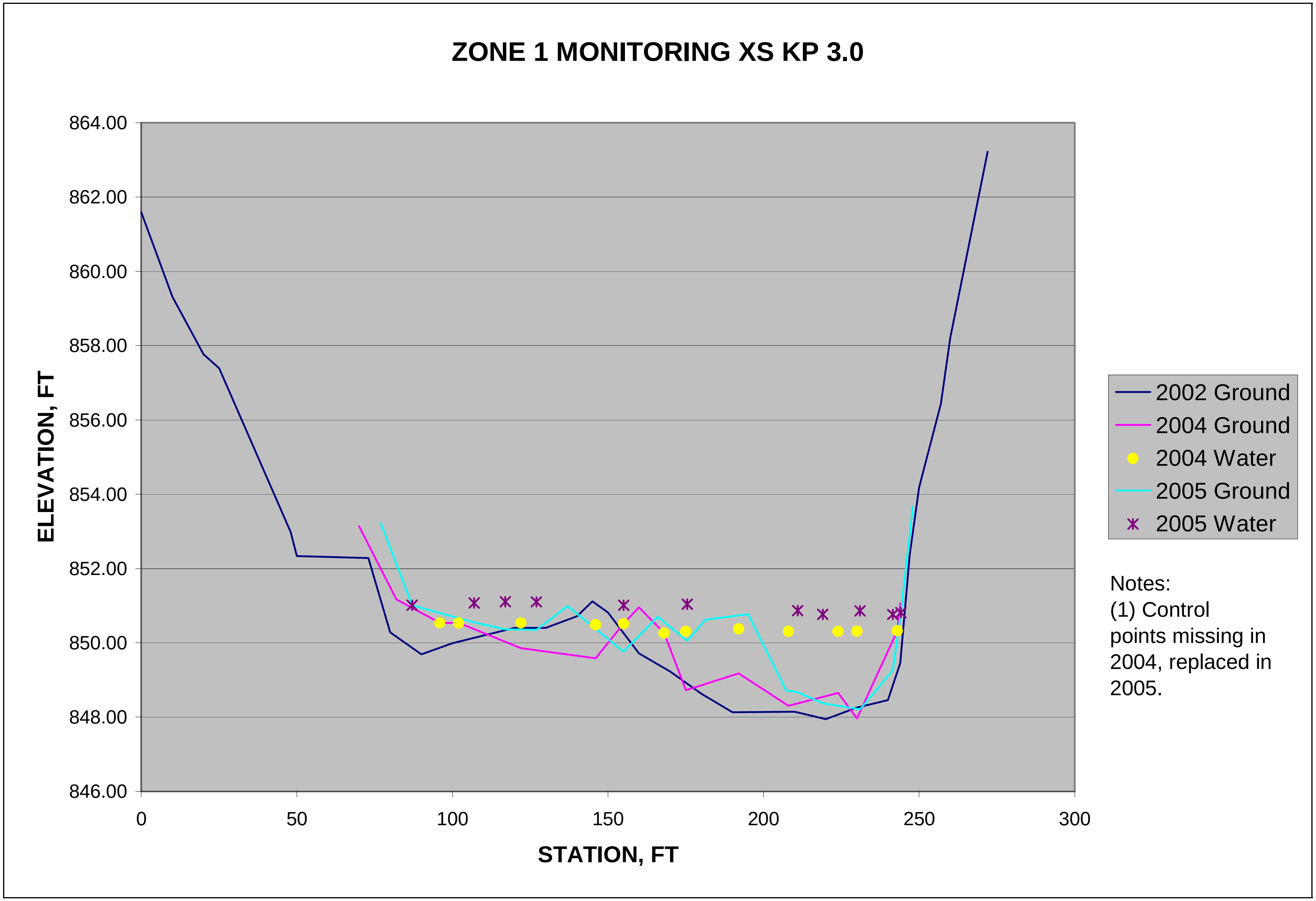



Figure 16. Cross section survey data KP 3.0 (WY 2004 flow at Palmer, 8/3/04, 120 cfs, WY 2005 7/28/05, 151 cfs).

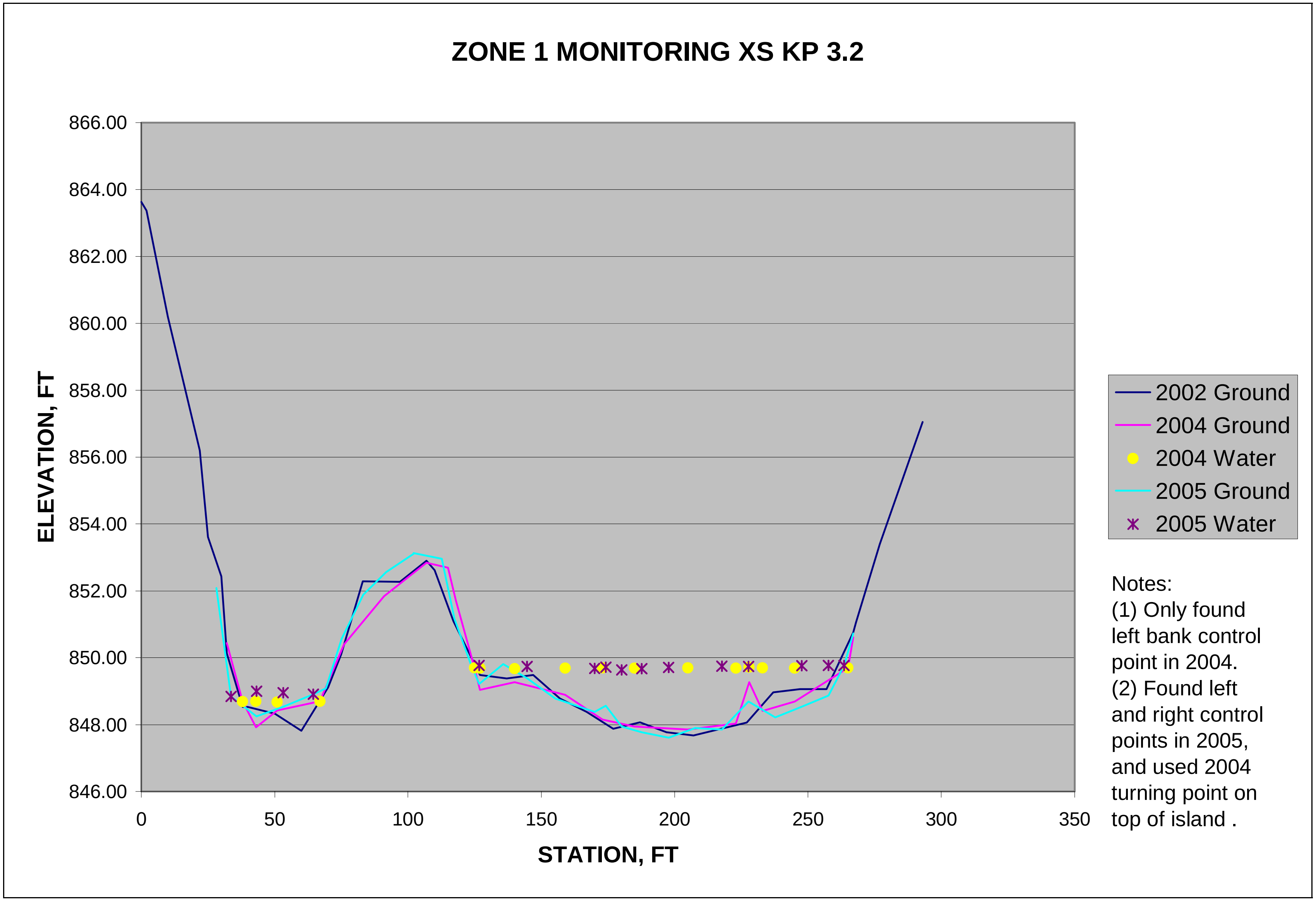



Figure 17. Cross section survey data KP 3.0 (WY 2004 flow at Palmer, 8/3/04, 120 cfs, WY 2005 7/28/05, 151 cfs).

#### 3.3.2.2. Gravel Transport Rates

Gravel transport rates are typically expressed in terms of tons or cubic yards per year passing a given transect or reach. Gravel transport rates can be measured with a bedload sampler, inferred from cross section surveys, and estimated with a bedload transport function. In WY 2004 bedload transport rates were inferred from aerial photo analysis (plume tracking). Observations of gravel bar formation or scour over a short time period, or change in the dominant bed sediment size can be used as anecdotal evidence of gravel transport. In WY 2005, anecdotal information regarding transport rates included:

- Observations of a large gravel bar developing just below KP 5.2 on the left and right bank by winter of 2004-2005 (Figure 18). Patch mapping indicated that gravels were likely from upstream nourishment site since they exhibited the same size range and character (color, shape, composition) as nourishment gravels.
- Noticeable gravel deposits were also observed on an existing cobble bar on the right bank just below the TPU pipeline crossing (KP 9) after winter 2004-2005 high flow events.
- Recreational rafters encountered in summer 2005 below KP 5 reported seeing more gravel in the nourishment reach than they remembered seeing before
- Summer 2005 rafting recon indicated that nourishment gravel is entering the Green River gorge (based on visual assessments of deposits at Kanaskat Palmer State Park)
- Summer 2005 gravel patch mapping (Appendix C) indicated that the large interstices between boulders and cobbles are typically filled with gravel (paving) in the nourishment reach.

From the above anecdotal information the following semi-quantitative assessments of transport rates can be made:

- Between summer 2003 and summer 2005 (2 years of gravel loading) some nourishment gravel had traveled 4 miles or more from the loading site.
- Significant gravel bars are forming and bed paving is occurring about 1 mile below the loading site. Moderate sized gravel bars are forming about 2 miles below the loading site. This indicates that in two years time enough gravel has been transported at least one mile or more, such that visible bar formation is occurring.
- From Figure 2 above, the highest recorded discharge in WY 2004 and WY 2005 was 6,770 cfs in January of 2005, equivalent to a 1.5 year return period flood event. Thus significant gravel transport has occurred during a period of one “bankfull” event and several smaller events.

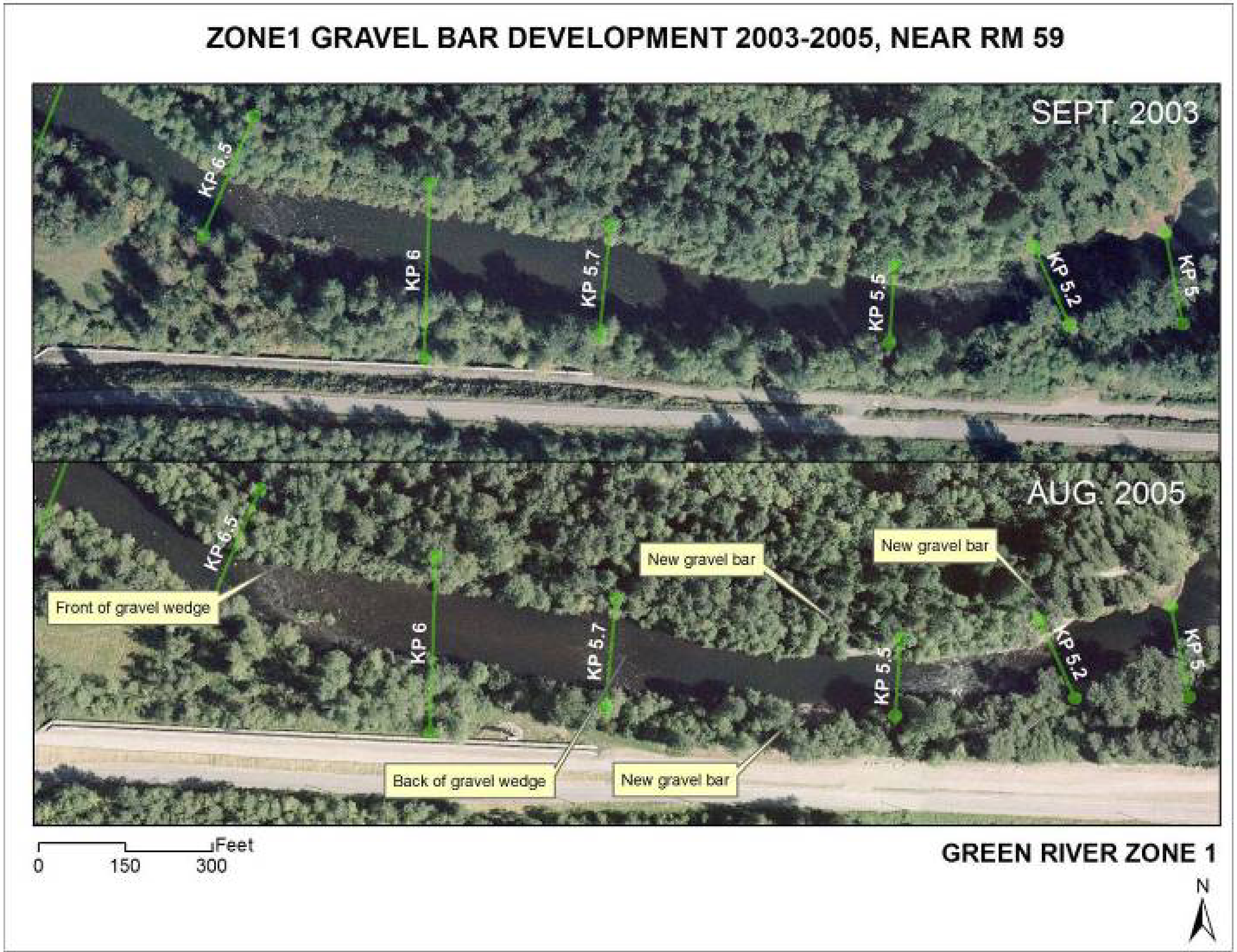



Figure 18. New gravel bars and paving near RM 59 as a result of nourishment gravel placement near RM 60.

### 3.3.2.3. Gravel Patch Mapping

Gravel patch deposition areas were mapped during low-flow field surveys and to the extent feasible using aerial photographs. Areas of deposition were measured and hand drawn on 1” = 100’ scale maps in the field (Appendix C). The field data were used to create a GIS layer of the depositional areas that were added to the GIS database, and shown in Figures 23-26. Gravel patch mapping was conducted between the Tacoma Headworks near KP 1.0 and the USGS Palmer Gage, to RM 58, just below KP 10.0. The mapping exercise delineated relatively homogenous patches of streambed based primarily on the percent of the patch that is gravel (less than 5” nominal grain diameter) (Figure 23). Each patch was further classified by the percent of nourishment (“placed”) gravel to “native” gravel (Table 4, Figure 25), the size range of patch bed material was recorded (fines to boulders), and in some cases the apparent d50 was also recorded. For the majority of patches the gravel deposit depth was visually estimated by comparing the elevation of gravel to the largest exposed bed materials.

#### 3.3.2.3.1. Percent Native Gravel vs. Percent Placed

This variable is based on visual assessments based on familiarity with native material in control reaches and percent native/placed tests (Table 4, Figures 18, 24). At locations where the deposit is nearly all gravel, it is important to distinguish the percent that is native to the reach, if information about the amount of gravel in the reach is desired. In this test, each monitor picks up a streambed particle at their foot, at each step, walking a random line. Each monitor classifies the particle as either: definitely native, definitely placed, or unknown, based on the mappers’ familiarity with native gravels and nourishment gravels. Typically native gravels in the study reach are distinguished by the color (dark grey or orange), large size (2 inches or greater), angularity or rough texture of the rock (Figure 19). Native gravels contrast greatly with placed gravels which are uniformly smooth and rounded, colored (white, green, red, grey), and narrow size range (0.5 inches to 5 inches in size). Staining of the placed gravels in the summer can make distinction difficult. Particles that do not clearly match the above descriptions are recorded with a question mark in the field book. The ratio of percent placed to native is used directly without adjustment. The percent of question mark entries is a direct measure of the evaluators confidence in the estimate, but does not necessarily reflect uncertainty in the percentage. From Figure 23 it is seen that the percent of placed gravel decreases in the downstream direction, which indirectly reflects the transport rate and volume

Table 4. 2005 Estimate of Percent Placed Gravel by Cross Section

| **Placed Gravel as Percentage of All Gravel** | | |
|---|---|---|
| | % P if not called out on map based on % Gravel | |
| Location | < 50 | > 50 |
| Upstream of loading zone | 0 | 0 |
| loading zone-KP 3.2 | 75 | 95 |
| KP 3.2-KP 4.6 | 75 | 95 |
| KP 4.6-KP 6 | 60 | 60 |
| KP 6 - KP 7 | 55 | 60 |
| KP 7 - KP 10 | 40 | 60 |

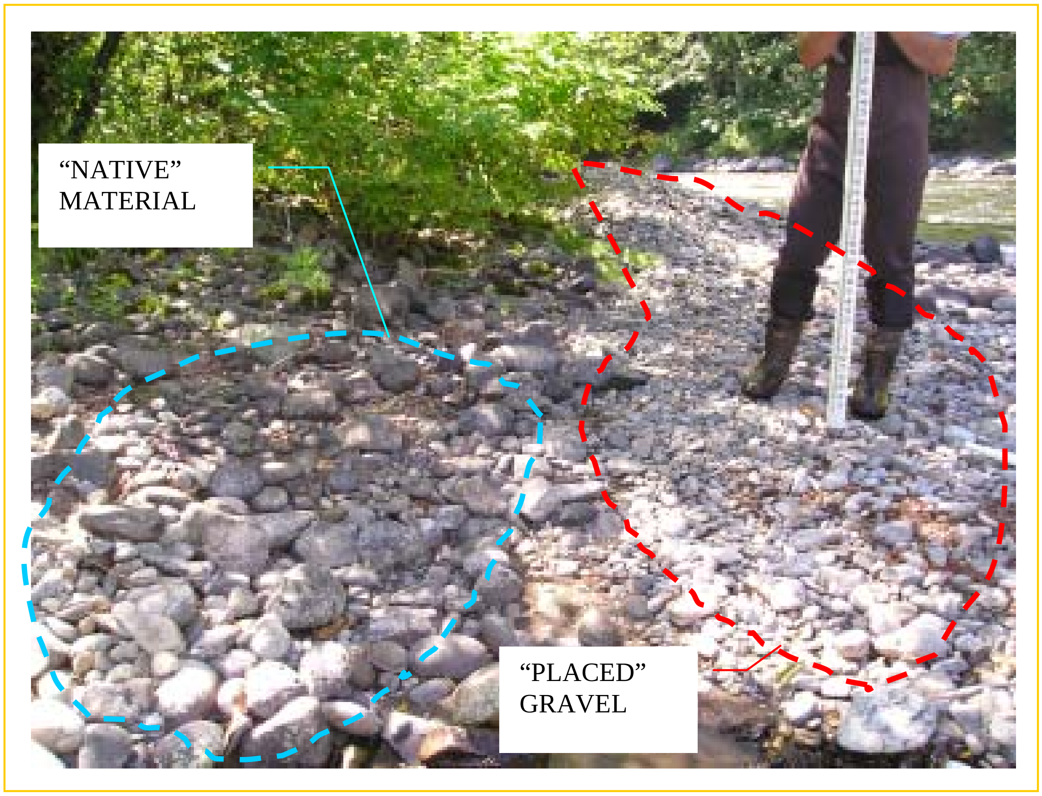



Figure 19. Example of difference of native and placed gravel deposit near KP 9.

### 3.3.2.3.2. Gravel Patch Depth Estimates

Depth is estimated from cross section surveys, direct measurements, and visual observations and can be checked with digging test pits to the armor layer. In most cases depth is estimated by using the visual estimate of the diameter of the ring formed by the gravel around the "d90" sized particles exposed above the gravel deposit. This is used as a proxy for gravel depth. Essentially we are estimating the depth of gravel in the voids between the largest bed materials. The depth needs to be reduced to account for bed irregularity and other uncertainties (filled holes). For this study bed depth estimates 12" or less (majority of estimates) that were based on surface observations rather than measurements were reduced by a factor of 2 to account for bed irregularity and taper to zero depth at the edges of the deposit. The factor of 2 is somewhat arbitrary since it would be nearly impossible to verify without excavating gravel at several cross sections and surveying the bed topography. Future patch mapping will help identify areas of significant aggradation that require cross section surveys to reliably quantify gravel deposit depths and volumes. A map of the patch depth estimates is contained in Figure 24.

The purpose of estimating gravel depths was to provide a rough check of potential deposit volumes. This allows a "ball-park" check on the gravel patch mapping ability to identify a majority of the deposited nourishment gravel. Ideally the "mass in" from the loading zone should be equal to the mass of material deposited in the study area, minus losses to floodplain storage, attrition (breaking down to sand sizes or finer) and transport out of the study reach. None of these loss factors are measured or estimated, but should be part of the qualitative assessment of the results of any sediment budget computation.

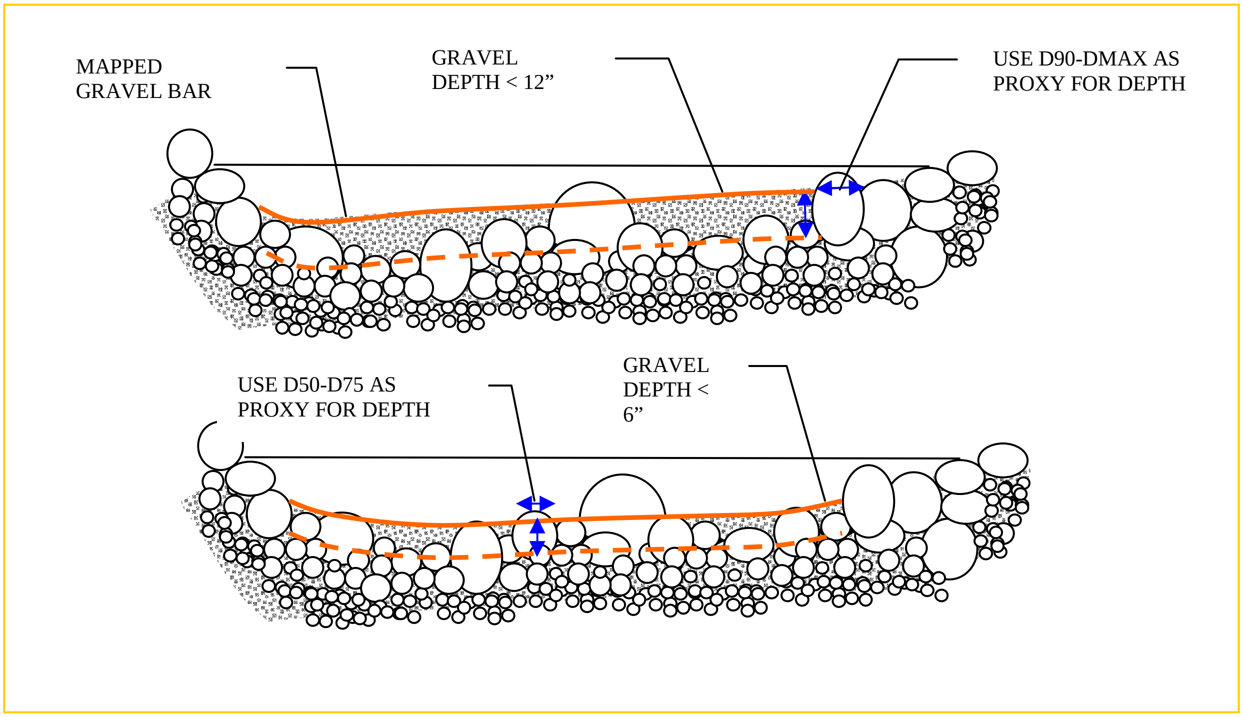



Figure 20. Diagram of visual depth estimate methodology/assumptions.

### 3.3.2.3.3. Gravel Patch Volume Computation

Given the general lack of gravel sources due to dam construction and the highly armored nature of the pre-project streambed, it was estimated that the gravel patches encountered in the study reach would have a high likelihood of originating from the nourishment berms. For purposes of comparison, it was decided that USACE would try to assign a volume to the mapped patches and compare the cumulative mapped volume to the cumulative placed volume (pseudo sediment budget). The gravel patch volume is simply the mapped patch area multiplied by the estimated depth of the deposit. Since the percentage of gravel in each patch varies, the total gravel volume is simply the visual estimate of percent gravel multiplied by the patch volume. For purposes of this project, encountered gravel is defined as particles having an intermediate axis length between 5 inches and 0.5 inches (same size range as placement gravel). Percentage estimates of native angular and discolored gravels vs. clean rounded (placed) gravels are made to further reduce the gravel deposit volume; so that the final computed volume reflects the total volume of nourishment gravel in a given patch. The equation for nourishment gravel volume at a given patch is as follows:

$$V\ (yd3) = D\ (ft) \times AREA\ (ft2) \times \%GR \times \%PL / 27(ft3/yd3),$$

Where D is reduced by a factor of 2 if based on visual surface estimate and 12” or less.

#### 3.3.2.3.4. Gravel Patch Area, Volume, and Depth Summary

Table 5 describes the total area, depth, and volume of gravel patches between cross sections. A total of 197 unique patches were mapped, with the percent gravel varying from less than 5% gravel to greater than 95% gravel (Figure 23). Appendix C contains detailed patch information including unique ID numbers reflecting the gravel patch location relative to bounding cross sections. The data indicate that the center of the mapped nourishment gravel area occurs near RM 59.1 (55% of study reach length), and the center of volume occurs near RM 59.8 (17% of study reach length). In contrast the center of area in WY 2004 was located further upstream near RM 59.7, as was the center of volume, located near RM 59.94. The total area of mapped gravel deposits for WY 2005 is 34 acres, vs. 7.5 acres in WY 2004, although the comparison is skewed heavily by the 2005 methodology which mapped patches even if they had less than 5% gravel. The center of the mapped gravel volume traveled about 0.1 miles downstream between WY 2004 and WY 2005. By in large most gravel was located upstream of ELJ 1 in WY 2004 and remained heavily concentrated here in WY 2005. The total volume of mapped gravel for WY 2005 is 12,535 cubic yards. In contrast in WY 2004, using different methodology and a smaller study area, a total of 4,200 yd3 was mapped.

Considering all mapped patch areas and neglecting gravel source (native/placed), the average estimated gravel patch depth is 10 inches (Table 5). In contrast, the average patch depth in WY 2004 was 12 inches. This difference is partly attributable to inclusion of patches with minimal gravel in 2005 whereas in 2004 only patches with distinct gravel concentrations were mapped. In WY 2005 patches with the greatest depths were located near the logjams (Figure 24), where gravel was filling scour pools. Mapped patches with the least gravel depth were consistently found at riffles, where gravel filled the interstices of cobble and boulder bed materials, but was otherwise absent.

Gravel patches closest to the loading zones had a greater percentage of the largest sized nourishment gravels (4-5 inches) than patches observed downstream of the loading zones, indicating that the river transports the finer grain sized fractions more efficiently. Notable homogenous deposits of 1-2 inch minus gravels were observed along the vegetated margins of the channel and on top of vegetated bars for the length of the study reach, indicating that the finer gravel fractions are entrained higher in the water column and readily transported. This could explain the observed sorting.

Mid channel bed paving (filling of large bed material interstices with waves or wedges of gravel) is noticeable at near KP 1.7, KP 1.9, 3.0, 4.0 and in the side channel between KP 3.2 and KP 3.7, near the boat launch between KP 4.4 and 4.8, at the tail-out of the fishing hole at KP 5.2, outlet of Signani slough (KP 6), KP 7, KP 8, Pipeline tail-out at KP 9 (right bank), and between KP 10 and RM 58 (left bank). Notable gravel bars are building on the right and left bank between KP 5.2 and 5.5, behind natural and manmade obstructions. These appear to be “dead storage” zones for nourishment gravel, since the deposits are occurring on top of sandy beaches that pre-date the nourishment project. A similarly pronounced bar was also located behind a bedrock outcrop near KP 10. Gravel point bars are emerging at KP 1.7 (left), KP 1.9 (left), KP 3 (left), KP 8.0-8.2

(left), and KP 9.0 (right). These were existing locations for cobble point bars or glides prior to the nourishment project.  Mid channel bars were observed primarily in the vicinity of the ELJs (upstream), but were also visible at the Signani Slough outlet, and near KP 10. Refer to Appendix C for photographs of the aforementioned deposits.

As additional nourishment gravel is placed in future years, it will be more difficult to distinguish from the previous years gravel. Total gravel volumes, as indicated in Figure 22, will therefore be a primary method for tracking gravel movement through the reach.

#### 3.3.2.3.5. Patch Mapping Data Quality Control

Delineation of homogenous gravel patch areas, based on apparent percent gravel is relatively straightforward in the field, and less error prone than identifying the actual percentage of the mapped unit that is gravel, provided the aerial photos used in the mapping are recent, accurate, and detailed enough to be able to properly locate oneself in the field. Ortho-rectified 0.5-ft pixel aerial images  are used in the mapping effort and provide resolution adequate to identify submerged gravel patches and individual small boulders encountered in the field. Aided by the images patch location is straightforward. All other parameters used for classification of the patch are more subjective and should be considered semi-quantitative at best. Thus the error in the patch boundaries is not considered as significant as the possible error in the volume estimate. The error in the WY 2005 patch mapping volume estimates are not known because there are no baseline patch maps prepared using the same methodology, and there is not another methodology available to reliably track mass transport of different particle sizes within the allowed monitoring budget. The close comparison with the cumulative placed volume indicates that the method is likely over-predicting gravel volume since gravel that has passed through the reach is not counted in the total. It is assumed that the majority of gravel was still retained in the study reach during the field mapping exercise and that the close comparison lends credibility to the methodology, meaning that the over-prediction is not substantial.

Given the highly subjective nature of the assessments, some quality control measures were employed. Two experienced observers walked each side of the river to delineate and classify patches of gravel. Both crew members needed to agree on the extent of each patch, the percent gravel in the patch, and the ratio of percent native to placed. The order of the mapping (upstream to downstream) is designed to familiarize the field crew with the upstream “control” reach, such that they are readily able to distinguish “placed” gravel from native gravel. Where time allowed, data quality control checks were performed:

- Pebble counts at transects (Appendix D) were used to check the percent native/percent placed and the mappers’ estimate of percent gravel in the overlapping patches
- Where the error in the visual depth estimate could lead to significant miscalculations of patch gravel quantity (this usually occurs where deposits were extensive), typical cross sections of the deposit were measured, test pits were excavated with a shovel to the underlying armor layer, or cross section data was used to estimate depth.

Future mapping exercises that employ the same methodology should help establish a trend that can be used to assess whether the data provided with the patch volume estimates are reliable or useful enough to include in future monitoring. At minimum the methodology appears to provide a detailed, semi-quantitative snap-shot of spatial gravel locations and concentrations that could not be provided without considerably more extensive (and expensive) pebble counts and cross section surveys. A secondary benefit of annual patch mapping is team member familiarization with the reach which allows for early identification of problematic geomorphic changes.

## Table 5. WY 2005 Gravel Patch Mapping Area and Volume Estimate Summary

| | % REACH LENGTH | From RM | To RM | From XS | To XS | Patch Area, SF | Sum Patch Depth x Area | Patch Area Weighted Depth, in | Area, Acres | Cum. Acres | % AREA | Volume, cy | Cum. Volume | % Vol | Total Vol/Total Area, in |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0% | 60.31 | 60.23 | 1 (USGS GAGE) | 1.3 | 8115 | 6616 | 9.8 | 0.16 | 0.16 | 0% | 139 | 139 | 1.1% | 264.15 |
| | 4% | 60.23 | 60.16 | 1.3 | 1.5 | 5180 | 6284 | 14.6 | 0.11 | 0.27 | 1% | 185 | 324 | 2.6% | 11.57 |
| | 7% | 60.16 | 60.06 | 1.5 | 1.7 | 57747 | 36335 | 7.6 | 1.29 | 1.56 | 5% | 425.24 | 750 | 6.0% | 2.39 |
| | 11% | 60.06 | 59.96 | 1.7 | 1.9 | 63532 | 64677 | 12.2 | 1.41 | 2.98 | 9% | 983.62 | 1733 | 13.8% | 5.02 |
| | 16% | 59.96 | 59.94 | 1.9 | 2 | 11466 | 14332 | 15.0 | 0.26 | 3.24 | 9% | 479.06 | 2212 | 17.6% | 13.54 |
| | 17% | 59.94 | 59.88 | 2 | 3 | 40050 | 66429 | 19.9 | 0.87 | 4.11 | 12% | 1788.35 | 4001 | 31.9% | 14.47 |
| | 19% | 59.88 | 59.83 | 3 | 3.2 | 39887 | 66375 | 20.0 | 0.90 | 5.01 | 15% | 1753.15 | 5754 | 45.9% | 14.24 |
| C.O.V. | 21% | 59.83 | 59.73 | 3.2 | 3.7 | 104069 | 65639 | 7.6 | 2.32 | 7.33 | 21% | 436.50 | 6190 | 49.4% | 1.36 |
| | 26% | 59.73 | 59.64 | 3.7 | 4 | 60341 | 39208 | 7.8 | 1.32 | 8.65 | 25% | 198.99 | 6389 | 51.0% | 1.07 |
| | 30% | 59.64 | 59.56 | 4 | 4.2 | 55046 | 40497 | 8.8 | 1.24 | 9.89 | 29% | 151.22 | 6541 | 52.2% | 0.89 |
| | 33% | 59.56 | 59.43 | 4.2 | 4.4 | 88613 | 66145 | 9.0 | 2.01 | 11.90 | 35% | 173.71 | 6714 | 53.6% | 0.64 |
| | 39% | 59.43 | 59.32 | 4.4 | 4.6 | 59136 | 53480 | 10.9 | 1.32 | 13.21 | 38% | 916.29 | 7631 | 60.9% | 5.02 |
| | 44% | 59.32 | 59.2 | 4.6 | 4.8 | 74254 | 101217 | 16.4 | 1.68 | 14.89 | 43% | 1846.31 | 9477 | 75.6% | 8.06 |
| | 50% | 59.2 | 59.11 | 4.8 | 5 | 58177 | 34395 | 7.1 | 1.32 | 16.21 | 47% | *71.47* | 9548 | 76.2% | 0.40 |
| | 54% | 59.11 | 59.07 | 5 | 5.2 | 20449 | 21394 | 12.6 | 0.45 | 16.67 | 48% | 229.87 | 9778 | 78.0% | 3.64 |
| C.O.A. | 55% | 59.07 | 59.02 | 5.2 | 5.5 | 33662 | 29706 | 10.6 | 0.74 | 17.41 | 51% | 173.60 | 9952 | 79.4% | 1.67 |
| | 58% | 59.02 | 58.93 | 5.5 | 5.7 | 58628 | 42413 | 8.7 | 1.29 | 18.70 | 54% | 380.52 | 10332 | 82.4% | 2.10 |
| | 62% | 58.93 | 58.87 | 5.7 | 6 | 43693 | 30628 | 8.4 | 0.97 | 19.67 | 57% | 138.77 | 10471 | 83.5% | 1.03 |
| | 64% | 58.87 | 58.8 | 6 | 6.5 | 57638 | 39765 | 8.3 | 1.26 | 20.93 | 61% | 178.40 | 10649 | 85.0% | 1.00 |
| | 67% | 58.8 | 58.73 | 6.5 | 7 | 49017 | 24509 | 6.0 | 1.09 | 22.02 | 64% | 30.95 | 10680 | 85.2% | 0.20 |
| | 71% | 58.73 | 58.64 | 7 | 7.5 | 90335 | 65591 | 8.7 | 2.02 | 24.04 | 70% | 406.47 | 11087 | 88.5% | 1.46 |
| | 75% | 58.64 | 58.6 | 7.5 | 8 | 28108 | 19885 | 8.5 | 0.61 | 24.65 | 72% | 37.88 | 11125 | 88.8% | 0.44 |
| | 76% | 58.6 | 58.51 | 8 | 8.2 | 62048 | 34005 | 6.6 | 1.38 | 26.02 | 76% | 98.64 | 11223 | 89.5% | 0.52 |
| | 80% | 58.51 | 58.47 | 8.2 | 8.4 | 38379 | 23321 | 7.3 | 0.86 | 26.89 | 78% | 125.24 | 11349 | 90.5% | 1.06 |
| | 82% | 58.47 | 58.42 | 8.4 | 8.6 | 43227 | 27364 | 7.6 | 0.95 | 27.84 | 81% | 154.2738991 | 11503 | 91.8% | 1.16 |
| | 84% | 58.42 | 58.41 | 8.6 | 8.8 | 14906 | 11773 | 9.5 | 0.32 | 28.16 | 82% | 110.149187 | 11613 | 92.6% | 2.39 |
| | 85% | 58.41 | 58.3 | 8.8 | 9 | 85988 | 51796 | 7.2 | 1.90 | 30.06 | 87% | 164.474538 | 11778 | 94.0% | 0.62 |
| | 90% | 58.3 | 58.07 | 9 | 10 | 143268 | 92579 | 7.8 | 3.19 | 33.25 | 97% | 455.8946466 | 12233 | 97.6% | 1.03 |
| | 100% | 58.07 | 58 | 10 | NA | 50317 | 38558 | 9.2 | 1.14 | 34.39 | 100% | 301.1864259 | 12535 | 100.0% | 1.94 |

**REACH STATISTICS**

| | | | | Sum Patch Depth x Area | Patch Area Weighted Depth, in | Area, Acres | Volume, cy |
|---|---|---|---|---|---|---|---|
| STUDY REACH LENGTH | 2.24 | MI | TOTAL | 1545276 | | 34 | 12535 |
| MAPPED AREA TOTAL | 34 | ACRES | AVG | 53285.4 | 10.1 | 1.2 | 432.2 |
| MAPPED VOLUME TOTAL | 12535 | CY | MEDIAN | 55046.1 | 8.7 | 1.2 | 185.0 |
| REACH AVERAGE DEPTH (NOURISHMENT GRAVEL) | 2.7 | IN | MIN | 5180 | 6 | 0 | 31 |
| REACH AVERAGE DEPTH (ALL GRAVEL) | 10.1 | IN | MAX | 143268 | 20 | 3 | 1846 |

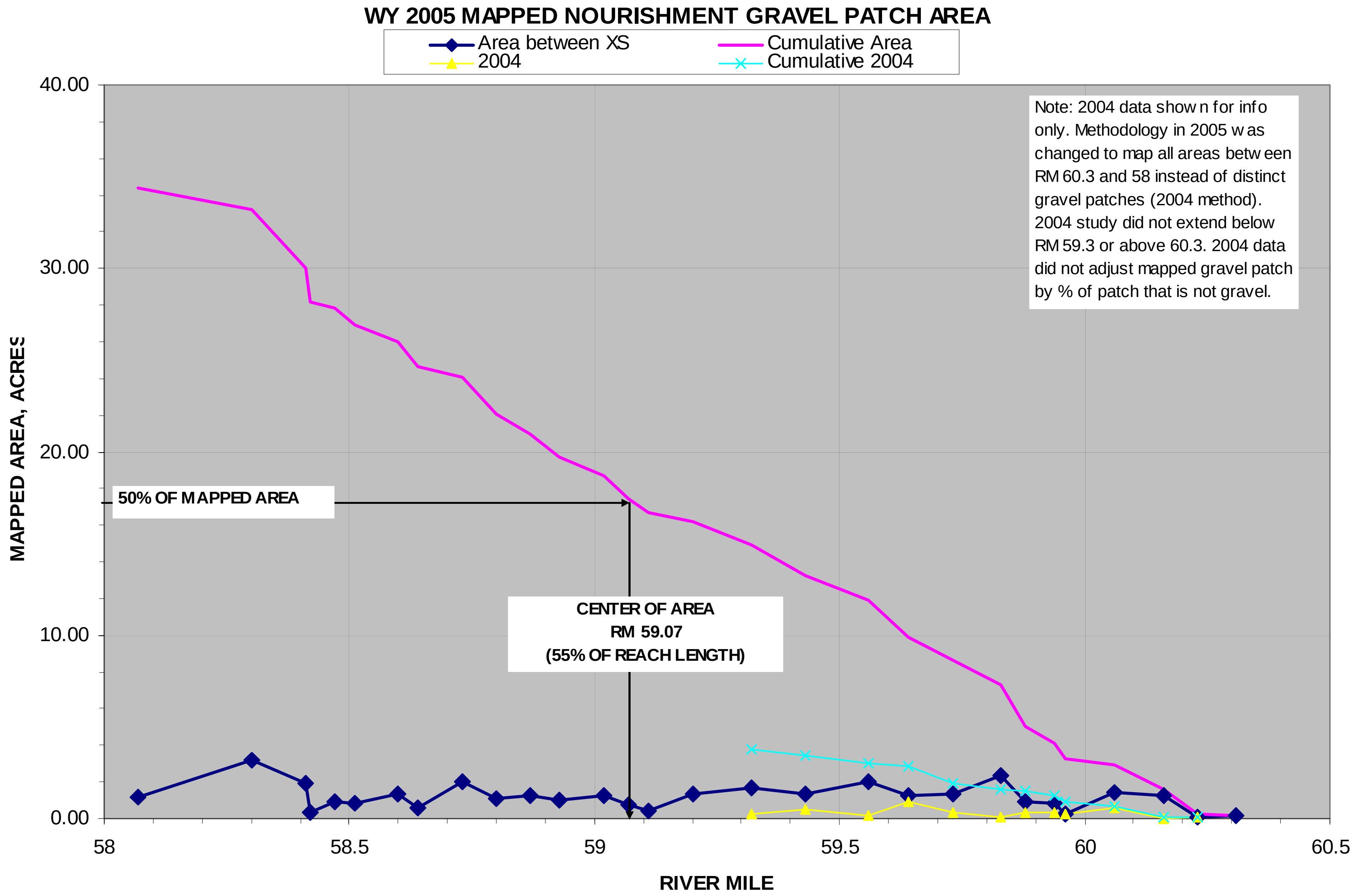



Figure 21. Zone 1 Gravel Patch Mapping, Profile of Mapped Gravel Patch Area, WY 2004-WY 2005

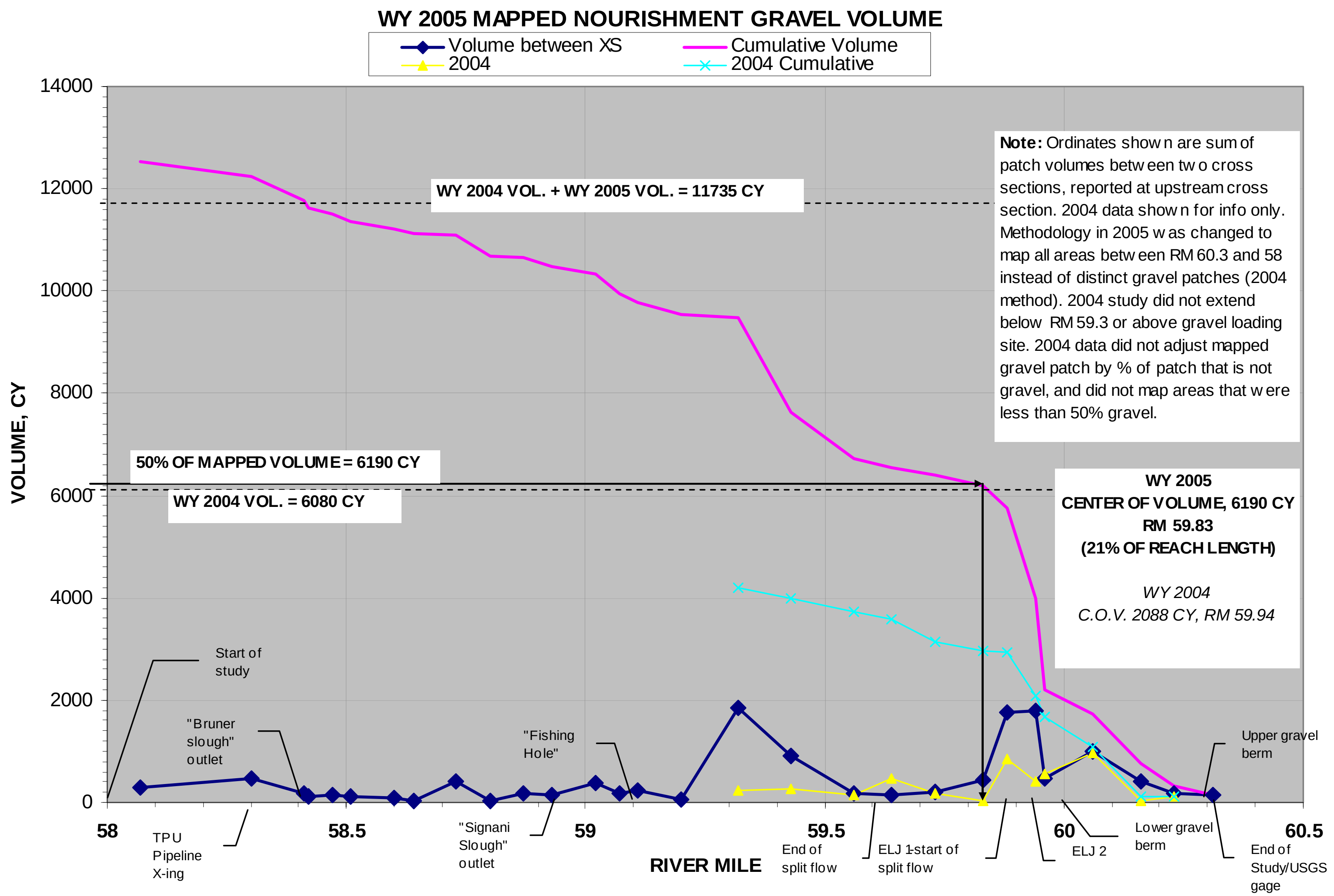



Figure 22. Zone 1 Gravel Patch Mapping, Profile of Mapped Gravel Volume, WY 2004-WY 2005

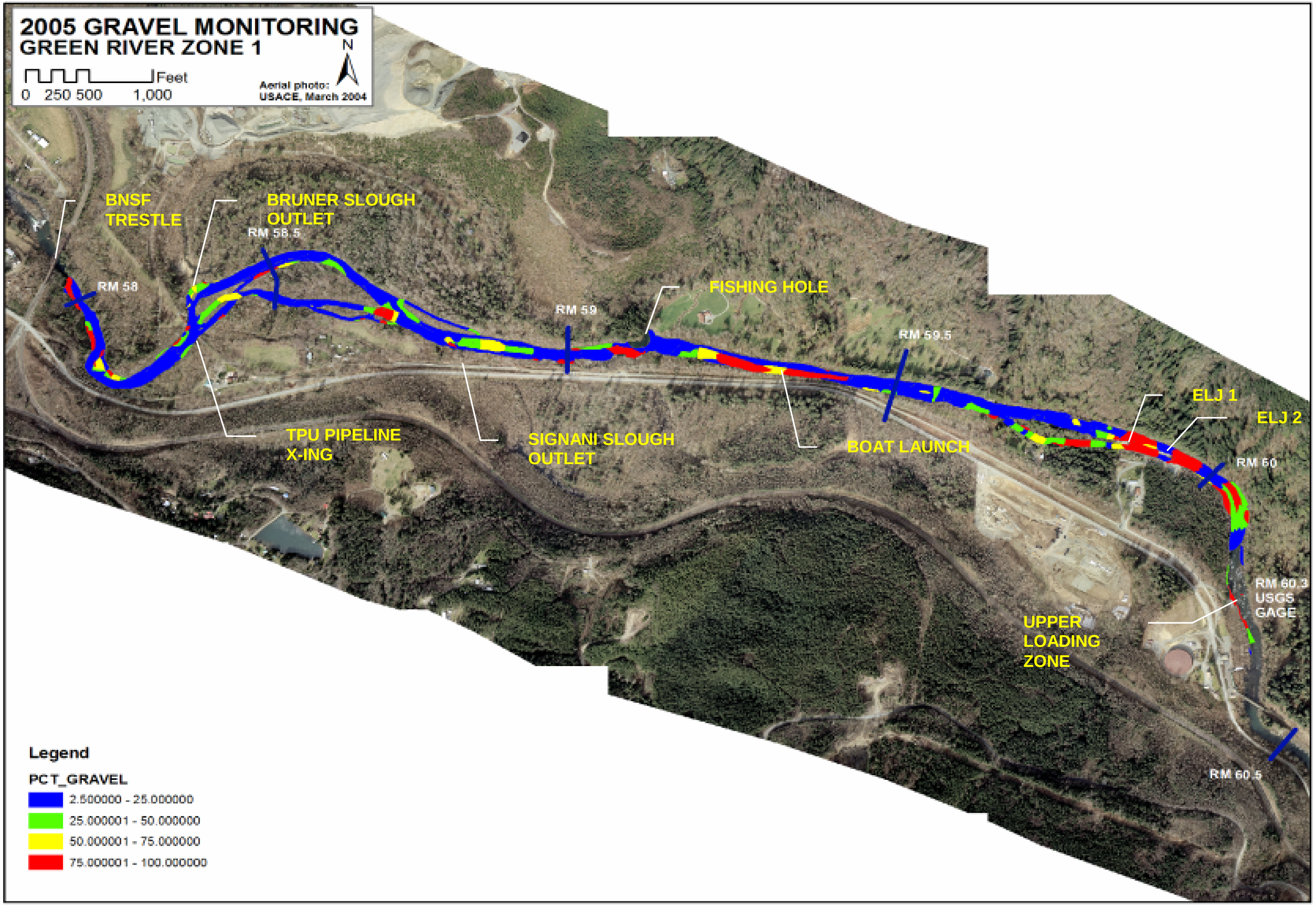



Figure 23. Zone 1 WY 2005 Gravel Patch Mapping (Percent Gravel)

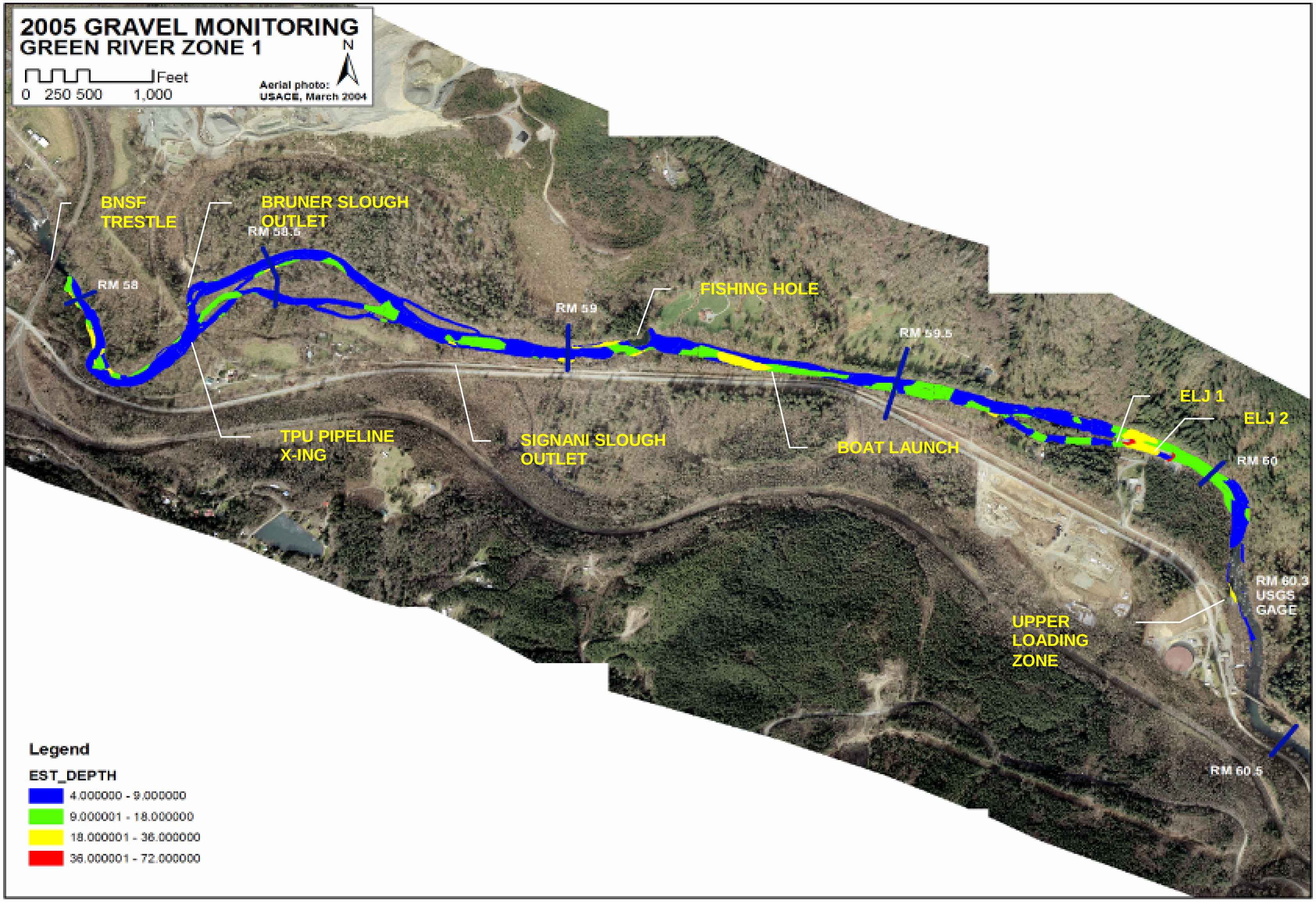



Figure 24. Zone 1 WY 2005 Gravel Patch Mapping (Estimated Gravel Patch Depth)

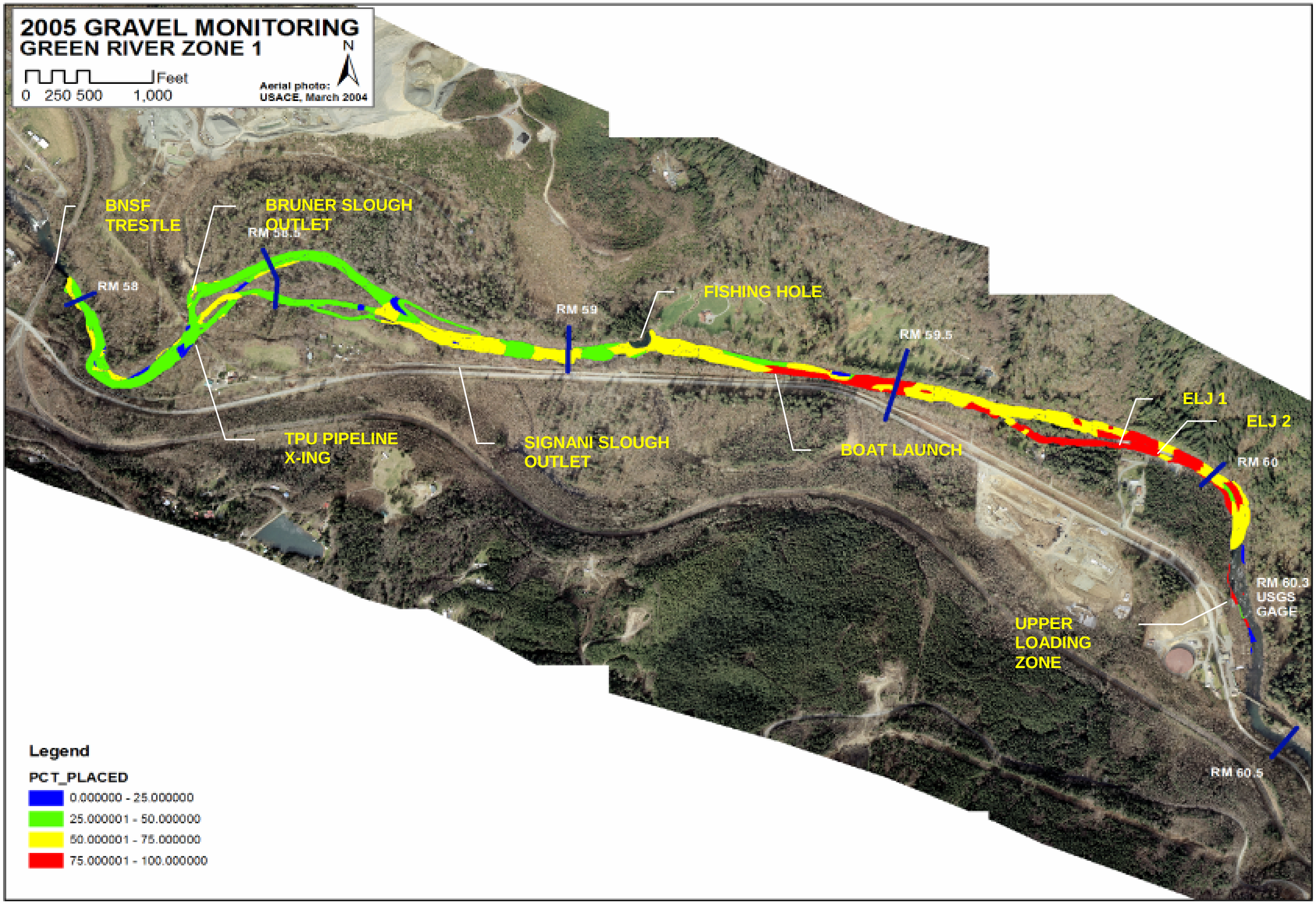



Figure 25. Zone 1 WY 2005 Gravel Patch Mapping (Bi-Op Gravel percentage)

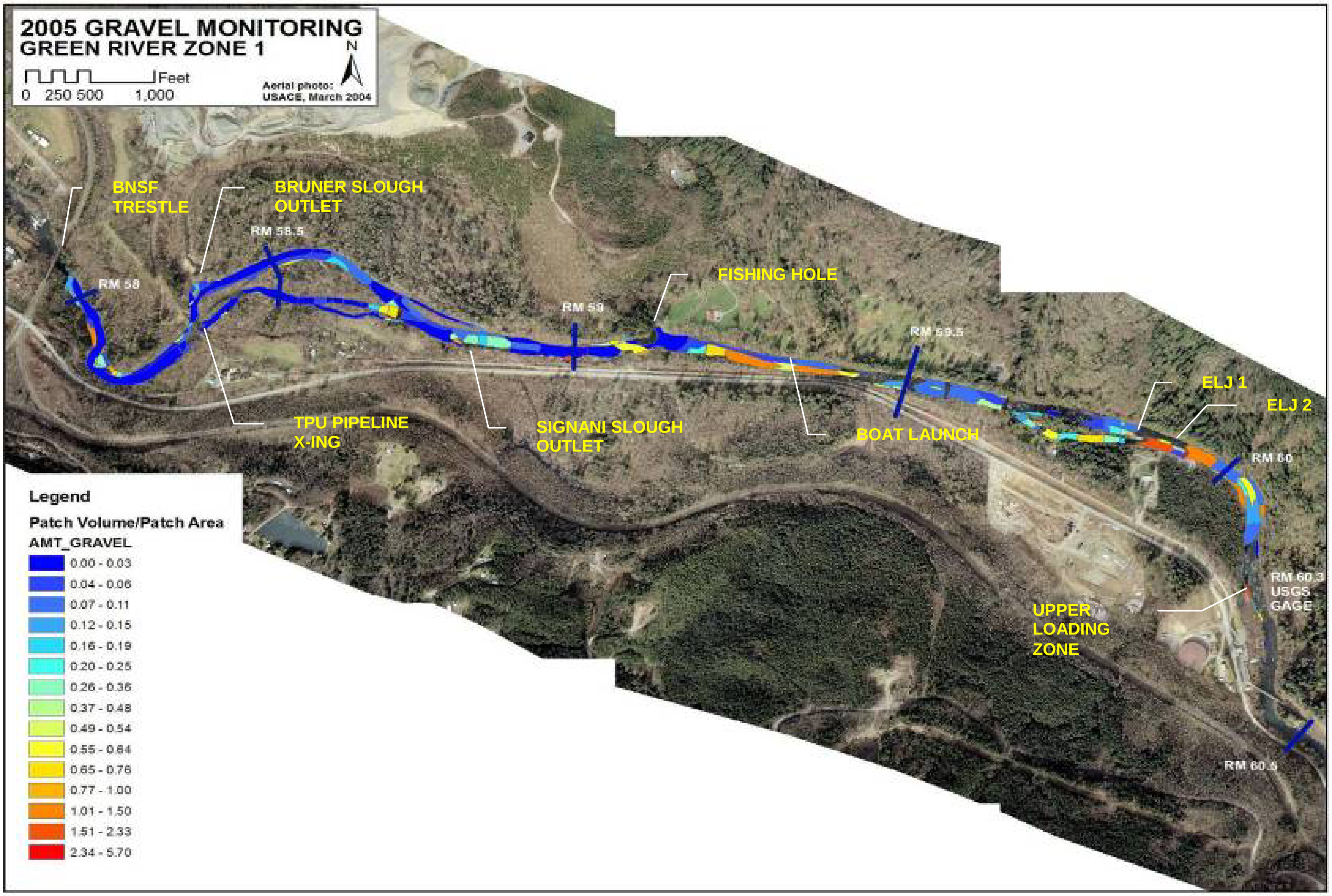



Figure 26. Zone 1 WY 2005 Gravel Patch Mapping (Gravel Intensity= BiOp Gravel Volume / Patch Area)

#### 3.3.2.4. Downstream Sediment Composition

Sediment size distribution and composition data was collected using the Wolman pebble count method (Wolman 1954). This consisted of collecting samples along a channel grid at predefined monitoring transects (Table 4). The grid was formed by heel-toe traverses of surveyed cross sections. If necessary the grid was varied to allow for sampling when deep areas were encountered or where one crossing did not generate a sample size greater than 100 particles. Samples where bedrock was encountered were noted but were not included in the grain size distribution plots. The median axis diameter of each pebble was measured to the nearest tenth of an inch, using 6-inch metal calipers, accurate to 0.01 inches. Each particle less than the maximum size placed at the nourishment berm was classified as either “angular” or “rounded”, to help establish the percentage of the gravel that was “placed” or “native”.

In WY 2004 USACE selected areas that had readily observable changes in the dominant streambed material for sampling. These occurred at KP 2.0 and KP 3.0, and to a lesser extent at KP 1.7, KP 3.2, and KP 4.0. In WY 2005, enough gravel was observed downstream of KP 4 to warrant sampling at all baseline stations (USACE 2002).

To support the pebble count data, and to allow for possible visual classification data set, significant bars and native gravel sources were photographed using a 3-ft x 3-ft x 3-inch metal grid or a stadia rod for reference scale. A sample photograph is shown in Figure 29. The remaining photo set is contained in Appendix C.

The major change observed in the data contained in Table 4 is a fining of the bed around the logjams where the deepest deposits are observed (KP 1.9/2, 3). The change was not observed at other locations; in fact the data suggest a slight coarsening of the bed at runs located above the project (KP 1) and just below the logjams (KP 4). However at the bottom end of the study area (KP 8, 9, 10), the bed noticeably fined. From the grain size data, it appears that there are two waves of gravel in the study area, although the patch mapping suggests there are three waves (the third located near the boat launch). The boat launch was reported to have a significant amount of gravel in the baseline study

Table 6. WY 2005 pebble count locations and data summary

| WY 2005 | | | % finer | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sediment Size Description | | Sieve Size (in) | KP 1.0 Run | KP 1.9 Run | KP 3.0 Run / Glide | KP 4.0 Run | KP 4.6 Glide | KP 5.2 Pool Tailout | KP 6.0 Glide | KP 7.0 Glide | KP 7.0 Side | KP 8.0 Run | KP 9.0 Riffle | KP 10.0 Pool Tailout |
| Boulder | | 102.4 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |
| | | 51.2 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |
| | | 25.6 | 97.17 | 99.07 | 98.68 | 99.03 | 99.04 | 100.00 | 98.32 | 98.85 | 100.00 | 100.00 | 94.34 | 100.00 |
| Cobble | Large | 12.8 | 85.85 | 95.37 | 97.37 | 90.29 | 91.35 | 99.18 | 94.96 | 94.25 | 100.00 | 95.28 | 84.91 | 97.10 |
| | Small | 6.4 | 72.64 | 92.59 | 93.42 | 74.76 | 74.04 | 94.26 | 79.83 | 86.21 | 96.77 | 83.02 | 70.75 | 86.96 |
| Gravel | Very Coarse | 3.2 | 51.89 | 79.63 | 83.55 | 64.08 | 69.23 | 81.15 | 58.82 | 65.52 | 70.97 | 57.55 | 58.49 | 66.67 |
| | Coarse | 1.6 | 36.79 | 40.74 | 32.24 | 33.01 | 37.50 | 40.16 | 30.25 | 35.63 | 41.94 | 30.19 | 37.74 | 42.03 |
| | Medium | 0.8 | 24.53 | 13.89 | 9.21 | 12.62 | 10.58 | 9.02 | 13.45 | 10.34 | 22.58 | 20.75 | 21.70 | 11.59 |
| | Fine | 0.4 | 15.09 | 3.70 | 5.26 | 4.85 | 6.73 | 0.82 | 9.24 | 4.60 | 19.35 | 10.38 | 16.04 | 4.35 |
| Sand | Coarse | 0.2 | 8.49 | 3.70 | 2.63 | 3.88 | 3.85 | 0.00 | 5.04 | 1.15 | 16.13 | 0.94 | 9.43 | 2.90 |
| | Medium | 0.1 | 7.55 | 2.78 | 1.32 | 3.88 | 3.85 | 0.00 | 5.04 | 1.15 | 12.90 | 0.94 | 6.60 | 1.45 |
| Fines | | 0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | | Particle Size (in) | | | | | | | | | | | |
| WY 2005 $d_{50}$ | | | 2.93 | 1.89 | 2.03 | 2.34 | 2.10 | 1.89 | 2.58 | 2.23 | 1.94 | 2.64 | 2.41 | 2.00 |
| WY 2004 $d_{50}$ | | | -- | 1.24 | 1.91 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Baseline (2002) $d_{50}$ | | | 1.93 | 3.45 | 3.65 | 2.21 | 2.13 | 1.46 | 2.59 | 2.44 | 2.32 | 4+ | 3.08 | 3.08 |

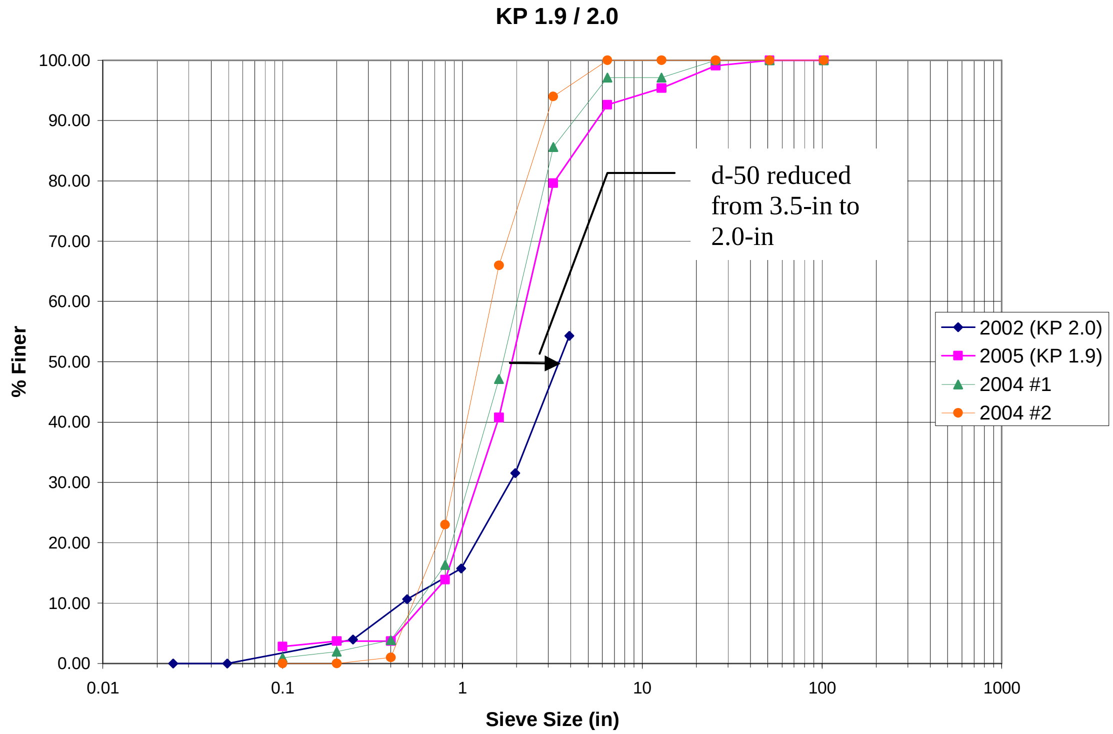



Figure 27. Change in dominant grain size (d-50) upstream of ELJ 2.

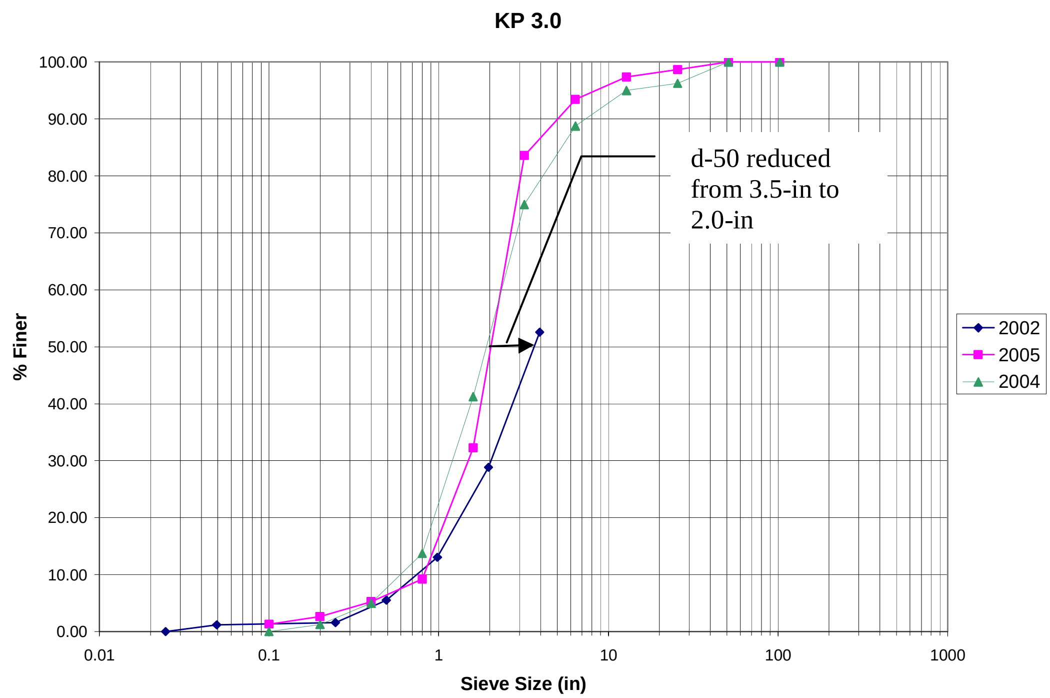



Figure 28. Change in dominant grain size (d-50) upstream of ELJ 1.

Figure 29. Grid photo of nourishment gravel formed bar located near ELJ 2

### 3.3.3. Chinook Salmon Spawning Activity

Chinook salmon spawning is a primary endpoint used to evaluate effectiveness of the gravel nourishment. Two separate and independent data sets will be used to evaluate Chinook spawning: 1) spawner surveys conducted by the Corps in the Palmer reach that identify and map locations of individual redds, and 2) spawner surveys conducted by Washington Department of Fish Wildlife (WDFW) that sum the number of redds for defined reaches.

#### 3.3.3.1. Palmer Reach Spawner Survey

**Methods**

The objective of the fall spawner survey was to identify the specific location of individual Chinook salmon redds so that data can be analyzed in the context of Restoration Zone 1 logjam placement and gravel nourishment locations. Chinook salmon spawning surveys were conducted near the expected peak of the 2005 fall spawning season on 18 October (peak based on WDFW unpublished data 1999-2005). The spawning surveys encompassed 23,175 lineal ft of the upper Green River between RM 56.0 and RM 60.4.

The spawner survey was conducted by a team of three biologists floating in a 12 ft rubber raft, beginning at the upper site boundary (Tacoma Foot Bridge) and proceeding downstream to the end of the survey reach (Kanaskat-Palmer State Park). A single observer surveyed each shoreline while the third observer surveyed the deepwater portion of the channel while floating in the raft. Total spawner counts represented all live and dead fish observed within the survey reach. Longitudinal distribution of redds and spawner count data were delineated using a

Garmin 76™ handheld GPS unit, USGS 7.5 minute topographical maps, and aerial photographs. While Chinook salmon were the primary species of interest, other spawning salmonids (e.g., sockeye,pink, and coho salmon) were identified and enumerated. Water temperature (to the nearest 0.5°C) and stage (to the nearest (0.01 ft) were recorded using a handheld thermometer and staff gage measurements, respectively. Underwater visibility, measured using a Secchi disk attached to a tag line, was used to denote the survey coverage. Representative photographs were taken of individual redds and geographical reach demarcations. All data were entered electronically using MS Excel™ and cross-referenced with original field data forms for QA/QC purposes. Data were also entered into the GIS database. Unless otherwise noted, all statistical analyses were performed using SigmaStat™.

**Results**

A total of 297 live adult salmon (13.0 salmon•1,000 $ft^{-1}$) were observed during initial spawner surveys conducted on 15 October 2004 in the upper Green River (Table 4). The spawner survey encompassed the upper Green River beginning at the City of Tacoma Foot Bridge, downstream to Kanaskat-Palmer State Park. Chinook salmon were the most abundant species, accounting for more than 50% of the live fish, 9% of the carcasses, and 97% or the redds that were observed. Pink salmon were next in abundance totaling 124 live fish or 41.8 %. Due to the large return of pink salmon and the timing of the survey, dead pink salmon accounted for the majority of carcasses counted (92.0 %). Twenty-five live coho (8.4%) and four coho redds were counted. No sockeye salmon were observed during the 2005 survey. The number of spawning salmon (64.6 salmon•1,000 $ft^{-1}$), carcasses (1,045 carcasses salmon•1,000 $ft^{-1}$), and redds (46.2 redds salmon•1,000 $ft^{-1}$) was greatest within Restoration Zone 1 compared to upstream or downstream reaches of the Green River (Table 7; Figure 30).

Table 7. Reach delineation, species, and total number of live, dead, and redds observed during spawner survey conducted in upper Green River, King County, Washington, 15 October 2005.

| Zone | Reach Length (ft) | Species | Live Fish | Carcasses | Redds |
|---|---|---|---|---|---|
| **RESTORATION ZONE 1** | | | | | |
| | **650** | **Chinook** | 18 | 36 | 30 |
| | | **Coho** | 1 | 0 | 0 |
| | | **Pink** | 23 | 643 | n/a |
| | | **Sockeye** | 0 | 0 | 0 |
| | | **Sub-total** | 42 | 679 | 30 |
| | | **No.•1,000 $ft^{-1}$** | ***64.6*** | ***1,044.6*** | ***46.2*** |
| **NON RESTORATION ZONE** | | | | | |
| | **22,175** | **Chinook** | 130 | 337 | 108 |
| | | **Coho** | 24 | 0 | 4 |
| | | **Pink** | 121 | 3671 | n/a |
| | | **Sockeye** | 0 | 0 | 0 |
| | | **Sub-total** | 275 | 4,008 | 112 |
| | | **No.•1,000 $ft^{-1}$** | ***12.4*** | ***180.7*** | ***5.1*** |
| **GRAND TOTAL** | | | | | |
| | **22,825** | **Chinook** | 148 | 373 | 138 |
| | | **Coho** | 25 | 0 | 4 |
| | | **Pink** | 124 | 4,314 | n/a |
| | | **Sockeye** | 0 | 0 | 0 |
| | | **Total** | 297 | 4,687 | 142 |
| | | **No.•1,000 $ft^{-1}$** | ***13.0*** | ***205.3*** | ***6.2*** |

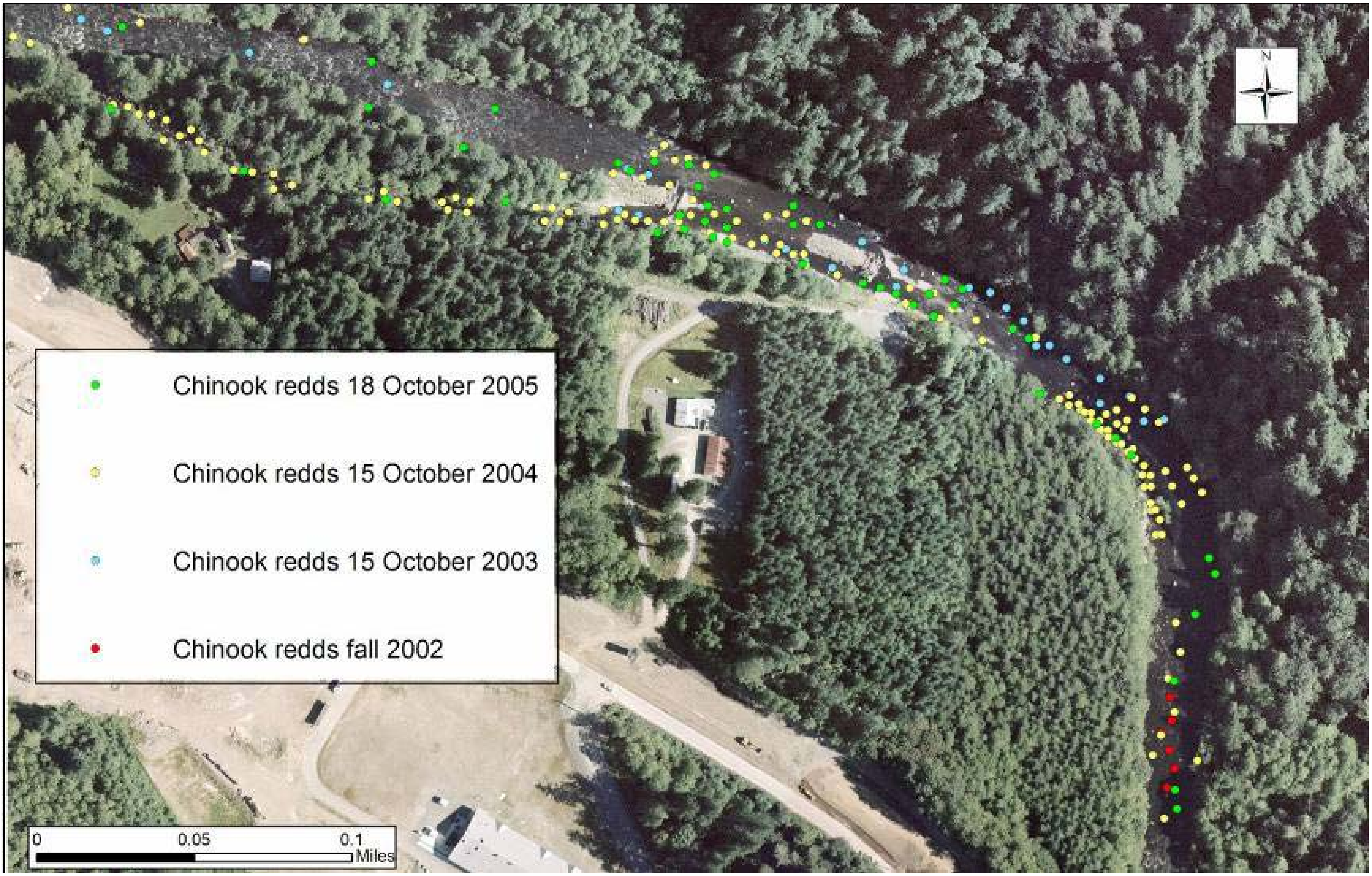


Figure 30. Location of Chinook salmon redds in Restoration Zone 1, 2002-2005 (aerial photo from 2 August 2005).

Chinook redd density observed within Restoration Zone 1 during 2005 (46.2 redds•1,000 $ft^{-1}$) was still higher than the average Chinook redd density observed in the upper Green River from 1999-2005 by WDFW (20.2 redds•1,000 $ft^{-1}$; std. dev. = 11.8). Year 2005 Chinook salmon redds were generally found in the same spawning locations as in 2004, but in lower numbers. In particular, during 2005 there were noticeably fewer redds below the Kanaskat-Palmer Highway bridge, specifically in the side channel located on the opposite bank from the hatchery (Appendix F).

The effect of gravel nourishment is beginning to be demonstrated downstream of the project reach. For example, in 2005, we observed numerous Chinook spawning in reaches downstream from the gravel supplementation zone that were devoid of spawning-sized gravels the previous year. The transport of spawning-sized gravels to further downstream reaches should be expected in the coming years, increasing the importance for annual spawning surveys in the upper Green River. As the gravels are dispersed, we should expect to see spawning Chinook more evenly distributed throughout this reach, instead of the heavy concentrations in areas of suitable substrate.

#### 3.3.3.2. WDFW Redd Counts

Chinook salmon redds/mile around the project reach are presented in Figure 31. These data are an estimate of total redds in the reach based on a series of aerial and boat surveys. Table 8 describes number of redds/mile in this reach divided by average redds/mile in the Green River for the given year. This provides some indication of the amount of spawning in this reach relative to the rest of the Green River.

Table 8. Chinook redds per mile at zone 1 project reach divided by Green River average (from Cropp 2005)

| **Chinook redds/mile** | |
|---|---|
| Year | RM 59.2 - 60.4 / Green River average |
| 1999 | 0.35 |
| 2000 | 0.14 |
| 2001 | 0.96 |
| 2002 | 0.55 |
| 2003 | 1.21 |
| 2004 | 0.83 |
| 2005 | 0.45 |

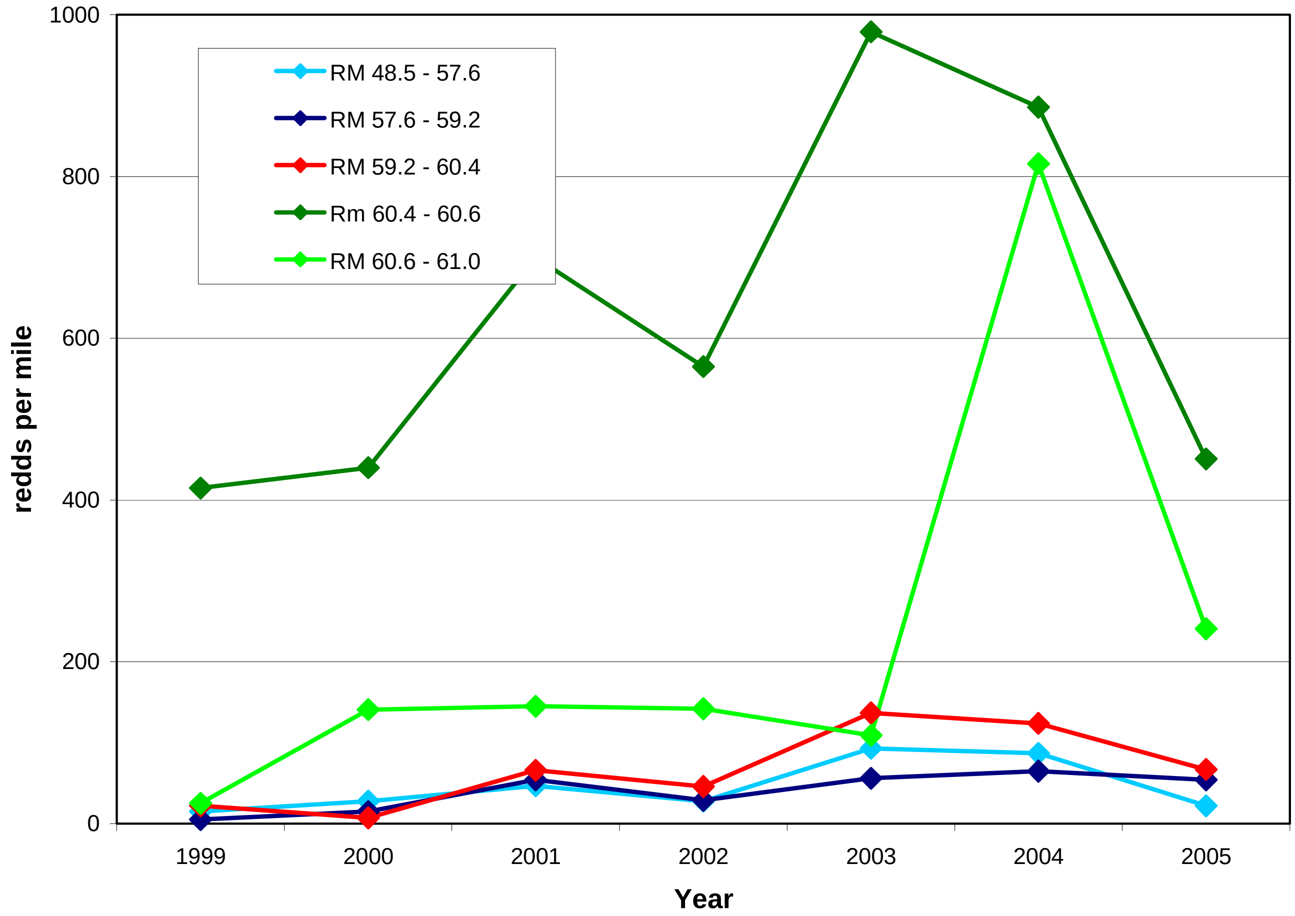



Figure 31. Chinook salmon redd density (redds per mile) observed in Green River above and below gravel nourishment site at RM 60, King County, Washington, 1999-2004 (from Cropp 2005).

The RM 60.4 – 60.6 and 60.6 – 61.0 reaches contain the last available spawning gravels before the Tacoma Headworks Dam.

### 3.3.4. Steelhead Trout Spawning Activity

#### 3.3.4.1. WDFW Redd Counts

Steelhead redd data collected by Washington Department of Fish and Wildlife are presented in Table 9. These data are an estimate of total redds in the reach based on a series of aerial and boat surveys. The data indicate Steelhead trout spawning activity has increased downstream of the zone 1 project relative to previous years (Figure 32). Gravels were placed in August 2003, so Winter/Spring 2004 was the first year that nourishment gravels were available to Steelhead.

Table 9. Steelhead redds per mile divided by the Green River average redds/mile (from Cropp 2005)

| Year | Total Estimated Wild Redds | Redds per mile (RM 57.5 - 61.0) / Green River average redds per mile |
|---|---|---|
| 1998 | 993 | 0.4 |
| 1999 | 997 | 0.9 |
| 2000 | 706 | 1.8 |
| 2001 | 705 | 0.5 |
| 2002 | 567 | 1.0 |
| 2003 | 903 | 0.5 |
| 2004 | 1365 | 1.8 |
| 2005 | 745 | 3.1 |

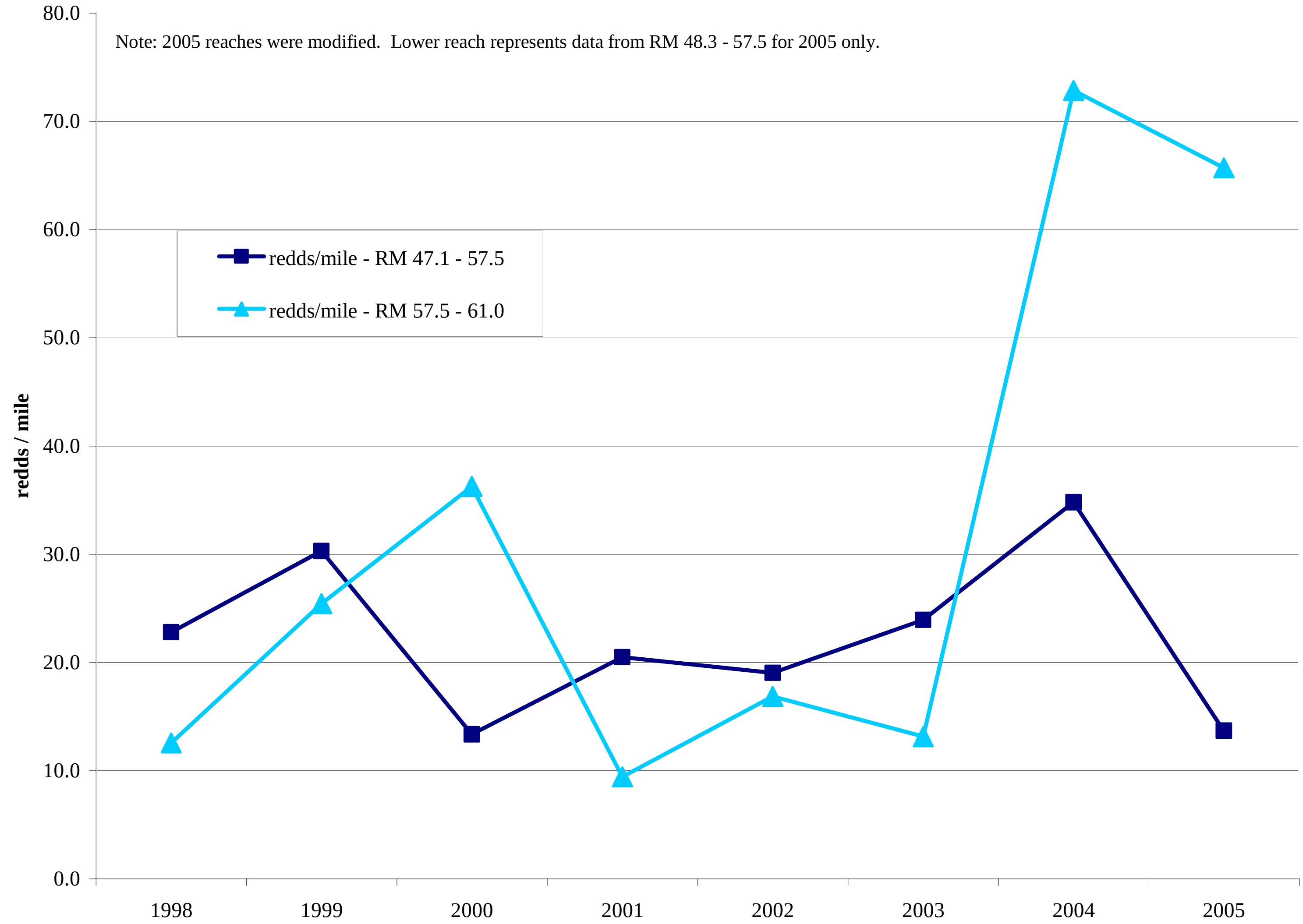



Figure 32. Steelhead trout redd density (redds per mile) observed in middle Green River above and below gravel nourishment site at RM 60, King County, Washington, 1999-2005 (from Cropp 2005).

## 3.4. Performance Summary

- The project experienced erosion of 95% of the berm gravel in less than 4 months, under moderate flow conditions. This met the performance criterion of 90% mobilization.
- Gravel berm configuration is of limited importance in facilitating gravel berm erosion.
- LWD placement on the gravel berm appears to increase local scour of the gravel berm when flow is in contact with the LWD.
- USACE mapped 10 acres of streambed that consisted of 50% or more gravel (nominal diameter <= 5 inches). This represents about 29% of the total mapped streambed acreage (34 acres).
- USACE mapped 2.1acres of streambed consisting of 50% gravel or more around the ELJs (vs. 1.36 acres in 2004) and 1.28 acres (vs. 0.32 acres in 2004) in the downstream side channel. This represents a significant amount of gravel storage in the treatment reach.
- USACE identified potential nourishment gravel deposits below the loading zone essentially equal in volume to the cumulative placement volume.
- Pebble counts in this area indicate that the baseline d-50 grain size was reduced from 3.5-inches to less than 2-inches in the vicinity of the logjams. Generally, nourishment gravel “paving” resulted in a decrease in the d-50 grain size throughout the study reach, indicating that gravel nourishment is impacting the entire study reach.
- Large, recent gravel bars at the bottom of the study reach indicate that gravel is passing though the study reach.
- Spawning surveys indicate Chinook spawning in nourishment gravels (Figure 29). However, total Chinook spawning activity decreased in the restoration reach in 2005 as did the percent of total Green River redds in this reach.
- While total number of steelhead redds was lower in 2005 in the Green River. The proportion of redds in the Palmer reach was higher relative to the rest of the Green River
- The USGS Palmer stream gage experienced no stage changes due to the gravel berm.

## 3.5. Adaptive Management

### 3.5.1. Palmer Stream Gage Backwater and Gravel Nourishment Berm Footprint

Gravel placement at the upper gravel berm caused significant backwater at the USGS gage that is located immediately upstream in 2003 and 2004. This backwater persisted until the gravel at the upstream end of the berm had eroded. This required the USGS to re-rate the Palmer gage several times during the period of time where the gravel berms were creating backwater. To address this issue USACE undertook studies to determine the maximum amount of nourishment gravel that can be placed and the configuration of the berm that will eliminate or minimize backwater (USACE 2005). The analysis indicated that up to 5,300 yd3 (8,830 tons) could be placed in a modified configuration that would eliminate backwater at the gage. The model also predicts that the minimum backwater impact from placing 12,000 yd3 (21,000 tons) in the upper loading zone in the recommended configuration would be about 0.5 ft. No gage backwater was reported during or after construction of the gravel bars in August 2005, indicating that the adaptive management analysis correctly predicted the hydraulic impact for the 7,000 ton loading rate using this modified configuration. This modified configuration will remain the standard for future loading.

### 3.5.2. WY 2004 and WY 2005 Gravel Nourishment

Review of the patch mapping indicates that there is a fair amount of larger sized gravel located between KP 1.5 and KP 1.9, perhaps indicating that the larger sized material is stable in the steeper reaches above the logjams. The presence of this deposit may also indicate that bimodal transport of gravel is occurring, that the deposit of larger material is actually a slow moving wave. If this trend persists (permanent nourishment gravel deposits noticeably fining downstream of loading zone) then the project will likely have approached an optimum nourishment gravel loading rate and spec. Given the uncertainty in hydrology, it would be premature to assume that an optimum annual loading rate or spec exists, since some years could experience a significantly higher transport potential than the loading rate, or vice versa. Until the data shows otherwise, it will be assumed that the gravel nourishment spec should continue to include at least 5-inch sized gravels/cobbles to help stabilize finer gravel deposits and to “colonize” more erosive areas of the streambed.

From site observations it appears that the stabilized ramp creates a hydraulic shadow for the gravel along the left bank downstream of the loading ramp. Based on this assessment USACE shifted the placement of gravel in summer 2005 towards the river in an effort to reduce the impact of the shadow on gravel erosion.

Table 10. Summary of gravel placed in the Green River at RM 60.

| sieve size | August 2003 placed<br>% finer | August 2004 placed<br>% finer | August 2005 target<br>% finer |
|---|---|---|---|
| 6 inch (152 mm) | | | |
| 5 inch (127 mm) | | 99.4 | 100 |
| 4 inch (102 mm) | 100 | 92.6 | 85-95 |
| 3 inch (76 mm) | | 76.8 | 70-90 |
| 2 inch (51mm) | 65 | 55.3 | 50-70 |
| 1 inch (25 mm) | 27 | 10.9 | 20-40 |
| 0.5 inch (13 mm) | 6 | 2.1 | 0-5 |
| **Quantity placed:** | | | |
| total tons: | 7555 | 7024 | 7000 |
| cubic yards (0.6 cubic yards/ton): | 4533 | 4214 | 4200 |

## 3.6. Changes to Monitoring Protocol

### 3.6.1. WY 2005 Gravel Patch Mapping

The gravel patch mapping methodology was modified in WY 2005 to reflect recommendations in the WY 2004 report. The new mapping methodology consisted of overlaying 8.5”x11” pieces of frosted mylar on top of detailed 1” = 100 ft gridded aerial photos taken during the most recent leaf-off period. Homogenous zones and patches of gravel were then mapped in pencil on a clipboard. All mapping was completed in two days with two experienced engineers. The task was relatively efficient, simple, and allowed for a greater level of detail. Where possible field tests of gravel composition and depth were made to calibrate visual estimates of the field crew. Completed maps were scanned and spatially rectified in Arc GIS 8.3, using the Georeferencing extension. Polygons of the mapped areas were then digitized in Arc GIS. Field data was attributed to each polygon to allow for visual categorization of patch attributes. The quality of the field notes and resulting report data are considered a significant improvement over WY 2004.

### 3.6.2. WY 2005 Cross Section Surveys

Survey of cross sections in WY 2004 proved to be somewhat difficult because of difficulty locating benchmarks and uncertainty over whether or not the benchmark had been disturbed. Basedon recommendations in the 2004 report, USACE retained the services of Tetratech and PGS, Inc to permanently locate the cross section bank end points with rebar and a marked aluminum cap. This work was completed in July 2005, allowing for incorporation into the WY 2005 report data. This benchmark establishment allows for significant reductions in time to survey cross sections, and a significant reduction in the uncertainty in the resulting elevation data.

# 4. ENGINEERED LOG JAMS

## 4.1. Design and Performance Criteria

- Stable to the 100-year flood flow which is 12,500 cfs.
- Top of the log jams will be a minimum 1-foot above the 100-year water surface elevation.
- Create and maintain scour pools.
- Increase flow into downstream side channel.
- Provide habitat for fish.

## 4.2. Monitoring Activities

The objective of log jam monitoring is to evaluate performance and general effectiveness toward achieving project objectives. In WY 2005, monitoring consisted of an evaluation of structural stability, analysis of side channel flow, survey of scour pools, and fisheries activity. Photographs and analysis were collected during high flow events and during the summer low flow period.

### 4.2.1. Log Jam Stability

#### 4.2.1.1. High Flow Monitoring

As described in the WY2004 report, ELJ 2 was constructed below the design elevation which resulted in the overtopping of the jam at unacceptably low flows. The river was eroding ballast material at the top of the jam at about 1/3 of the design flow. Because of concerns that ELJ 2 was losing more ballast material than was desired, and was at risk of being overtopped frequently, it was decided by USACE to add two additional structural layers (rows of wood and ballast rock) to raise the jam above the expected design flood elevation 860.0 ft (@ 12,500 cfs) and to armor the top front of the jam with large river rock. A design report and construction plans were produced for the modifications that included updates to the HEC-RAS model to calibrate to observed conditions, a structural stability analysis of the ELJ, and a ballast material erosion analysis (USACE 2004b). The construction work was completed in August 2004. The final constructed top elevation of ELJ 2 was 861.0 feet as shown in the construction plans. The final construction report should be consulted for additional detail.

WY 2005 high flow monitoring indicates that ELJ 2 has benefited from the 2004 retrofit. The freeboard appears to have increased dramatically (Figures 33-34, 37). Few signs of ballast or log instability were observed. The freeboard appears to be about even with the design freeboard, and overtopping is not anticipated at or below the design flood event.

WY 2005 high flow monitoring indicates that ELJ 1 continues to maintain its freeboard despite bed aggradation experienced upstream and downstream of the ELJ (Figures 35-36, 38). The freeboard appears to be less than the design freeboard, and overtopping is anticipated at or below the design flood event. Since the ELJ is designed to resist flotation, failure would not be a concern unless there was dramatic loss of ballast material. Ballast and wood loss will be monitored to see if retrofit of ELJ 1 will be necessary in the future.

Figure 33. ELJ 2 Jan 30, 2004 4,815 cfs


Figure 34. ELJ 2, 20 Jan 2005 5,200 cfs (after retrofit)

Figure 35. ELJ 1 Jan 30, 2004 4,815 cfs


Figure 36. ELJ 1, 20 Jan 2005 5,200 cfs


Figure 37. ELJ 2, 18 Jan 2005 6,450 cfs, 3 hr after peak of 6,770 cfs


Figure 38. ELJ 1, 18 Jan 2005 6,450 cfs, 3 hr after peak of 6,770 cfs

#### 4.2.1.2. Settlement and Deformation

Based on visual observations and photographic comparison, the two ELJs generally appear stable and have not experienced serious settlement or deformation to the structural log members. Noticeable deformation of racking material is illustrated in Figures 39-50.

#### 4.2.1.3. Wood Loss and Accumulation

No significant change in the wood loss or accumulation has been observed since construction, as seen in Figures 39-42, although several racking logs that were placed on the front of the log jams have been repositioned by two years of high flow events. In 2004, some of the racking pieces were found downstream; two were found racked into an existing wood jam in Kanaskat Palmer state park, and one was found near KP 8 in a side channel, racked into an existing logjam. No new logs were found downstream of the ELJs in WY 2005, although the racking wood has continued to shift noticeably since WY 2004. ELJ stability is not at risk from loss of racking members, although ongoing loss of racking members could be indicative of conditions that over time may result in loss of structural stability through erosion of ballast material or structural members.

Some small wood debris (< 10 ft long) racked into both structures in WY 2005, but no major LWD were noted. ELJ 1 had accumulated more racking debris, however. ELJ 2 post-retrofit construction photos are not available for comparison with WY 2005 photo-points, but based on log jam photos and found LWD tag numbers, it is believed that ELJ 1 has experienced more displacement and loss of racking material. The position of some racking material may pose a “strainer” risk to boaters.

#### 4.2.1.4. Ballast Material

No unacceptable losses of ballast were observed in WY 2005, despite the relatively steep side slopes (> 1.5H:1V) of the ballast retrofit at ELJ 2 (Figures 49-50). ELJ 1 has experienced some noticeable coarsening of the surface ballast material, but no indications of significant ballast loss have been observed to date. Vegetation, including willow and alder seedlings, is beginning to colonize the entire backside of ELJ 1 despite the ballast being noticeably lower than designed. Additional detail regarding the design analysis for the 2004 retrofit construction can be found in the 2004 retrofit design memorandum (USACE 2004b).

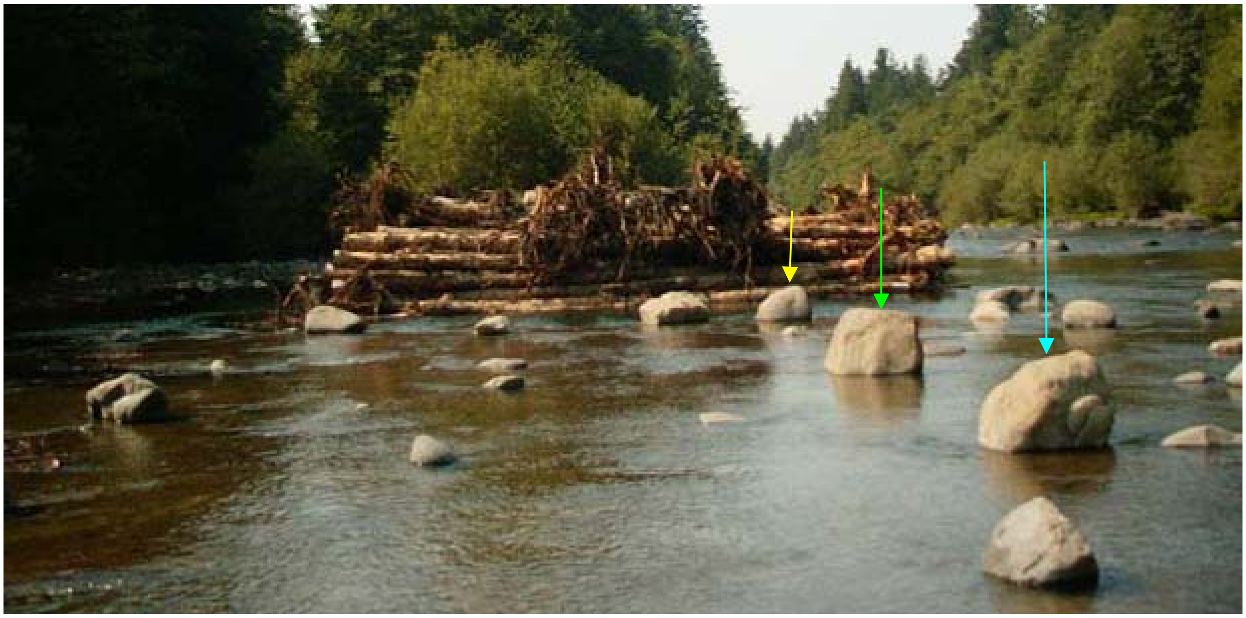


Figure 39. ELJ 1 September 3, 2003

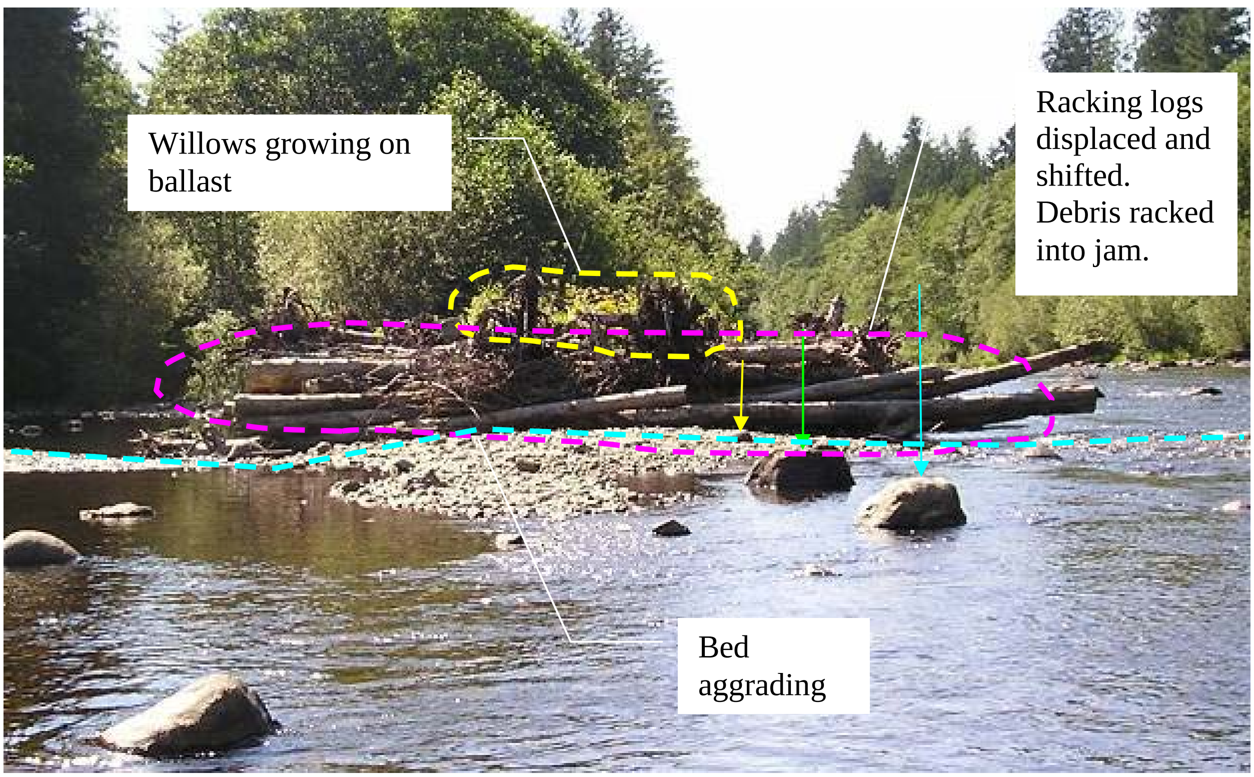



Figure 40. ELJ 1 July 25, 2005

Figure 41. ELJ 2 September 3, 2003

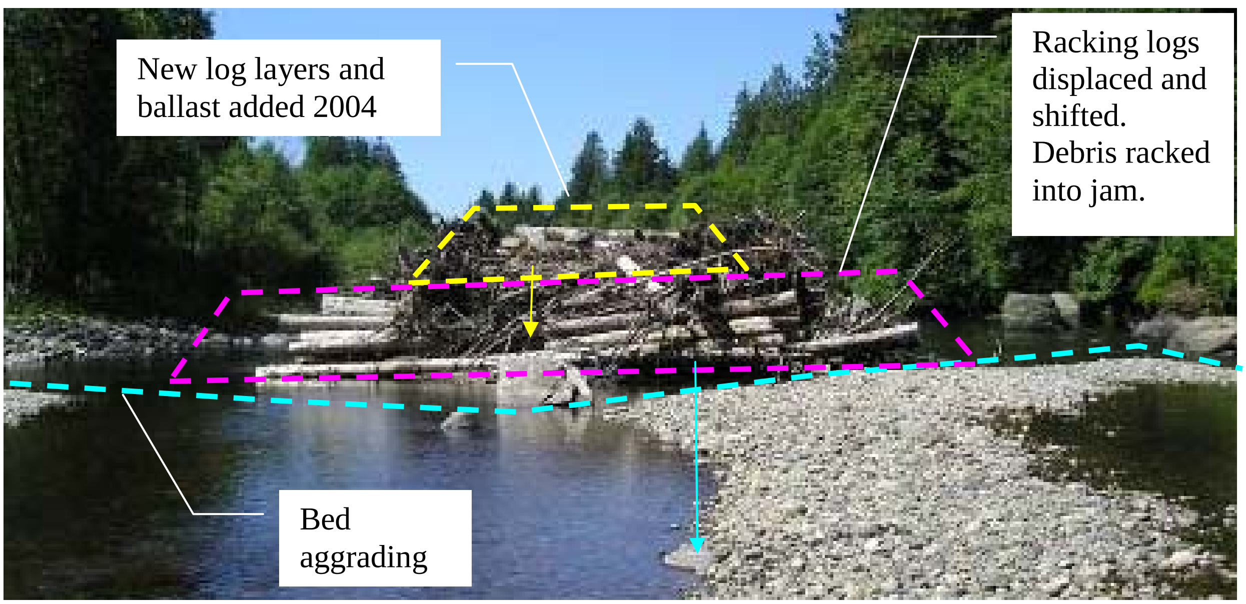
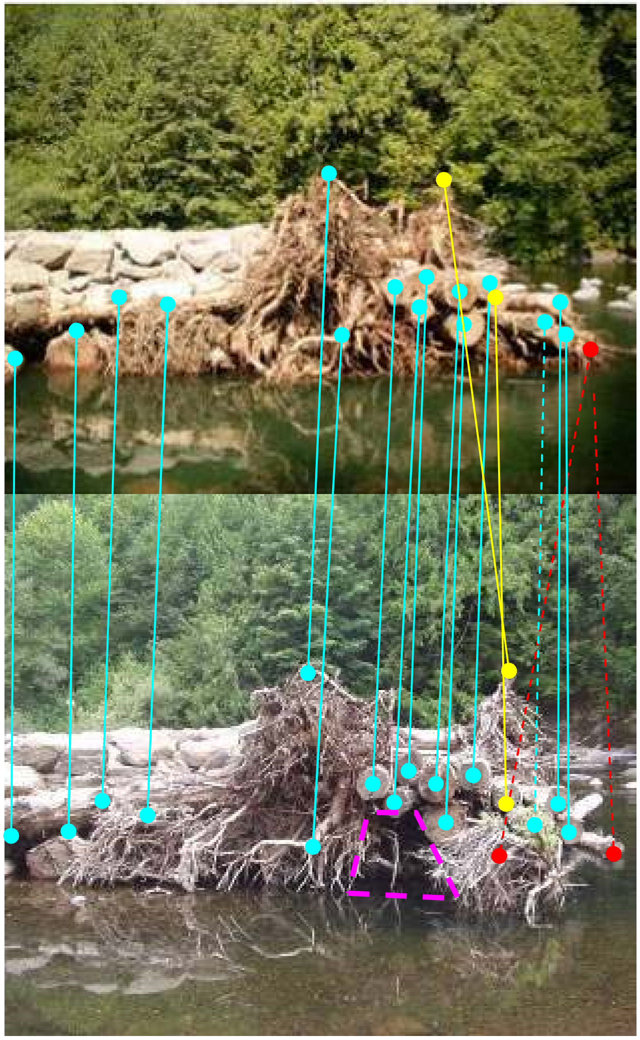



Figure 42. ELJ 2 July 25, 2005



ELJ #1: 2003-2004, left side

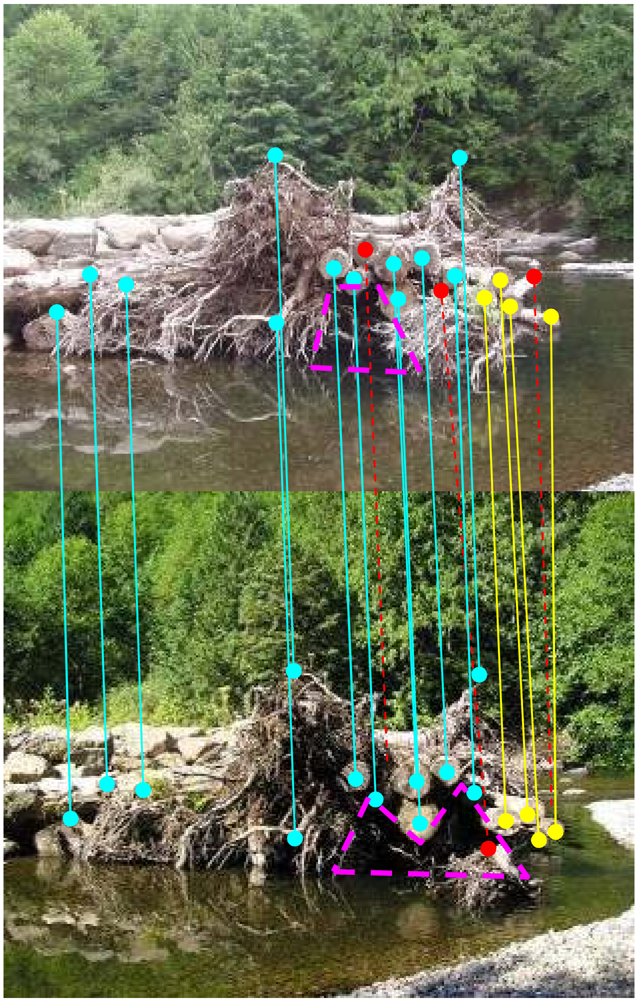
1) 15 logs clearly visible in WY 2003 (Sept 2003) have no apparent change when viewed from left bank. One log appears obscured by a log/rootwad that has shifted

2) Two logs appear to have shifted somewhat. The spacing between the top log/rootwads appears to have increased. Racking material may be shifting, pulling the log/rootwad forward.

3) A log/rootwad has appeared in the pool, and appears to have been rotated downstream and to the left. Another log/rootwad at the front of the jam appears to have been lost.

4) A pocket has opened up in the racking material, indicating that some racking pieces may have been pulled out of the right side of the jam

Figure 43. ELJ 1 Log Position Changes, WY 2003-2004



<u>ELJ #1: 2004-2005: left side</u>

1) 12 logs clearly visible in WY 2004 (August 2004) had no apparent change when viewed from right bank in WY 2005 (July 2005).
2) 4 logs appear to have shifted somewhat.
3) 1 log/rootwad near the front of the jam appears to have shifted significantly, and is being buried by gravel filling the scour pool.
4) 1 racked log appears to have been pulled out of the middle of the racked material
5) 4 racked logs at the front of the jam appear to have either been repositioned.
6) The pocket on the left side of the ELJ racking material may be enlarging.

Figure 44. ELJ 1 Log Position Changes, WY 2004-2005

Figure 45. September 23, 2004 ELJ 2 ballast, left side, post-retrofit

Figure 46. July 25, 2005, ELJ 2 ballast, left side

Figure 47. September 3, 2003, Post Construction, Ballast for ELJ 1, right side

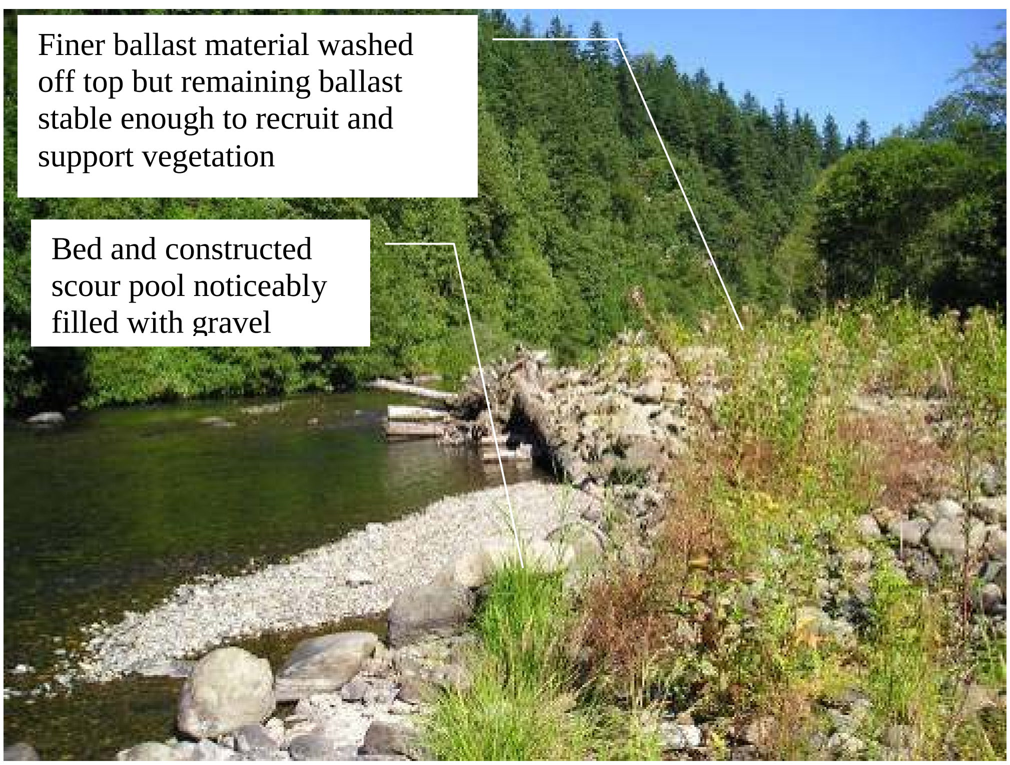



Figure 48. July 25, 2005, Ballast for ELJ 1, right side

Figure 49. September 3, 2003, Post Construction, Ballast for ELJ 1, left side

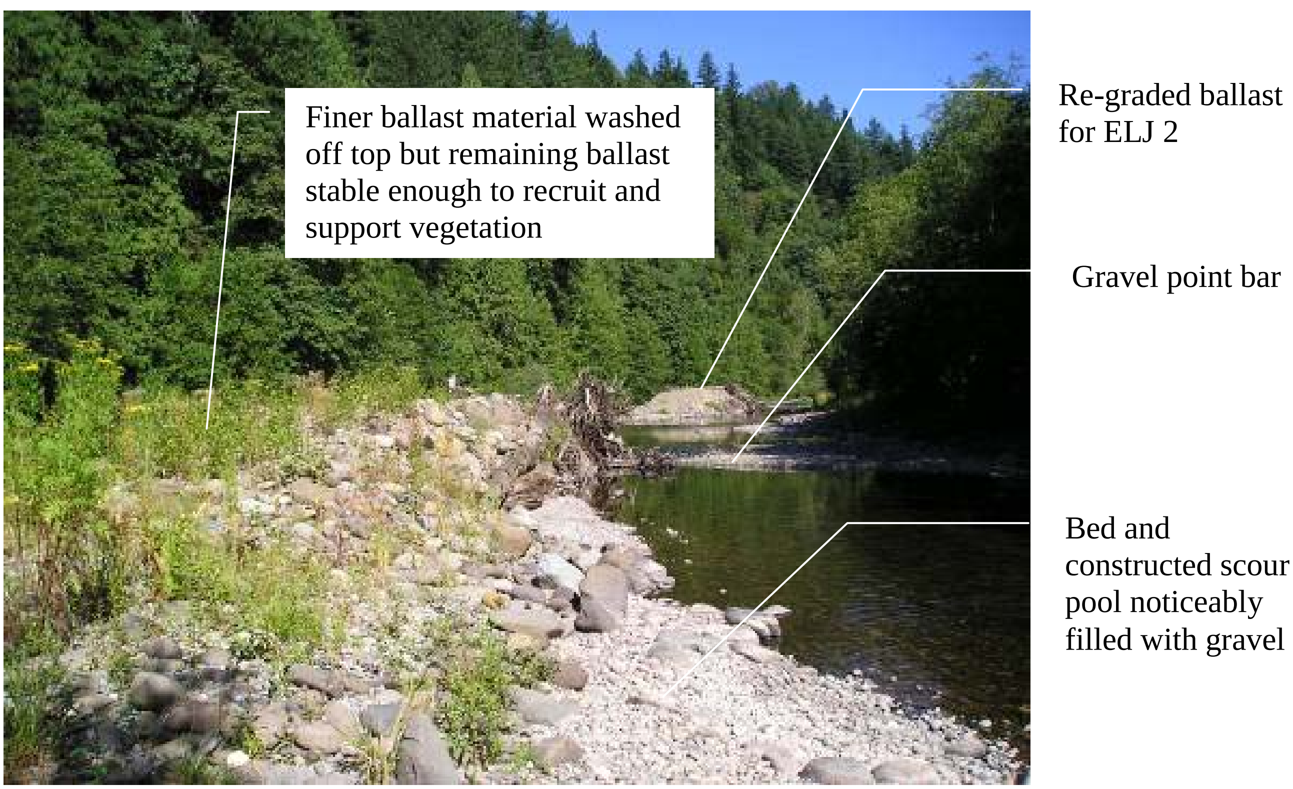



Figure 50. July 25, 2005 Ballast for ELJ 1, left side

### 4.2.2. Pool Development

Pool area associated with the log jams was measured in terms of area and residual depth. Residual depth is the difference between the scour pool invert and the invert of the pool tail-out. Monitoring intervals included post-construction, WY 2004, and WY 2005. Apparent trends based on data contained in Table 11 and Figure 51 includes a slight decrease to significant enlargement of the pool area but a consistent decrease in depth. Pool area has slightly decreased at ELJ 1 (-2%) but increases significantly at ELJ 2 (+76%). Measured residual pool depths have decreased 61% at ELJ 1 and 31% at ELJ 2.This is likely due to the filling of scour pools after high flow events. Based on the trend in pool area it appears that the gravel is temporarily stored at ELJ 2 but may be permanently stored at ELJ1.

The invert of scour pools remained on the left side of ELJ 2 and on the right side of ELJ 1, indicating that the flow distribution has remained somewhat consistent. Per Figure 51, plan views of the pools show the changes clearly, especially the flow patterns and pool area changes. Pool infilling and bar formation are prominent at both ELJs. The flow distribution is illustrated by the light blue arrows which are drawn in the middle of darker areas of concentrated flow where the streambed is deeper. Similarly, shallow, lighter colored areas represent the boundaries of the main flow paths and are also zones of gravel deposition.

### 4.2.3. Side Channel Flow

Based on high flow site visits in October 2003 and January 2004, the river appeared to have more flow in the side channel relative to the baseline condition. During the January 2004 high flow event (6,010 cfs), an estimate was made based on site observations of the flow distribution around the log jams. It was estimated that at the upper end flow is about 60-70% to the right of ELJ 2, and 30-40% to the left. Between the ELJs, about 10-15% of the flow returns to the right main channel. About 25% of the flow enters the side channel, and 75% remains in the main channel. On January 20, 2005, USACE estimated that the flow distribution around ELJ 2 was 50% left and 50% right of the jam. Flow left of the jam expanded downstream of the ELJ 2 ballast returning to the main channel upstream of ELJ 1. At ELJ 1, 25-40% of flow was left of the jam and the remainder was to the right of the jam. Some portion of the flow was returning to the main channel through the racked material on the front of the jam. Compared to the 2004 high flow monitoring, it is possible that flow into the side channel is increasing.

WY 2005 cross section surveys (Figure 52) indicate that both the invert elevation in the side channel and main channel has increased slightly below ELJ 1. The surveyed water level in the mainstem was essentially equal in 2004 (120 cfs) to that in 2005 (151 cfs), however the side channel water level was higher in 2005, due to bed aggradation, and perhaps to increased flow. Since the depth of flow was not greater in 2005, there is not evidence to support that the low flow distribution is increasing; however it is possible to say that the side channel has continued to remain wetted during minimum flows, despite considerable aggradation around the logjams.

Table 11. ELJ Scour Pool Area and Depth Measurements.

| LOCATION | MONITORING YEAR | POOL AREA (FT2) | % CHANGE SINCE CONSTRUCTION | POOL INVERT EL. (FT, NGVD29) | TAIL-OUT INVERT EL. (FT, NGVD29) | WATER SURFACE EL. (FT, NGVD29) | RESIDUAL DEPTH (FT) | % CHANGE SINCE CONSTRUCTION |
|---|---|---|---|---|---|---|---|---|
| ELJ 1 | 2003-AS-BUILT | 3358 | NA | 838 | 848 | NA | 10 | NA |
| | WY 2004 | 3118 | -7% | NOT SURVEYED | NOT SURVEYED | NA | NA | NA |
| | WY 2005 | 3286 | -2% | 845.89 | 849.75 | 850.21 | 3.86 | -61% |
| ELJ 2 | 2003-AS-BUILT | 2383 | NA | 840 | 850 | NA | 10 | NA |
| | WY 2004 | 3376 | 42% | 841.85 | 849 | 850 | 7.15 | -29% |
| | WY 2005 | 4201 | 76% | 843.19 | 850.1 | 851.09 | 6.91 | -31% |

* estimated tail out elevation from 2003 as-built contours, and field wading depth in WY 2004

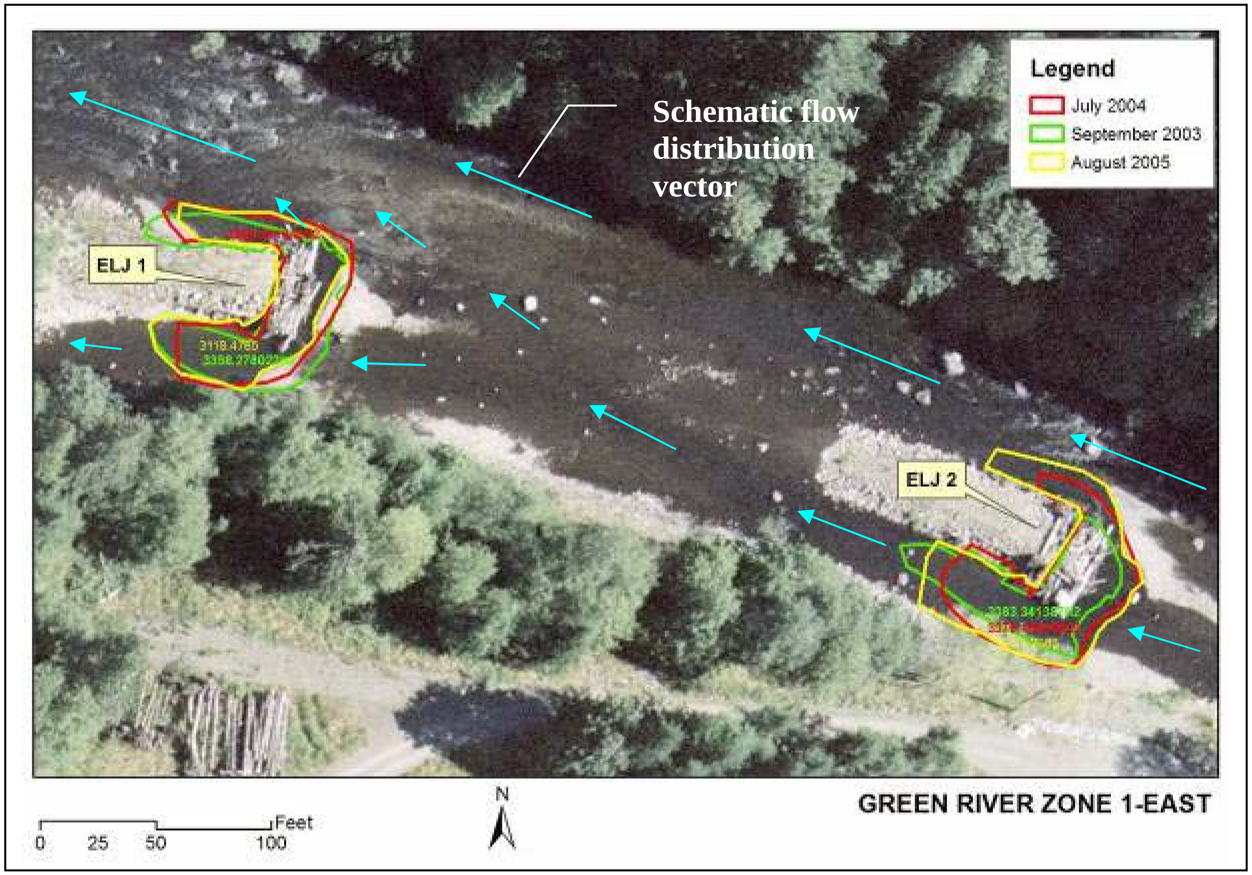



Figure 51. Scour hole development and flow distribution at ELJs (August 2005 aerial imagery)

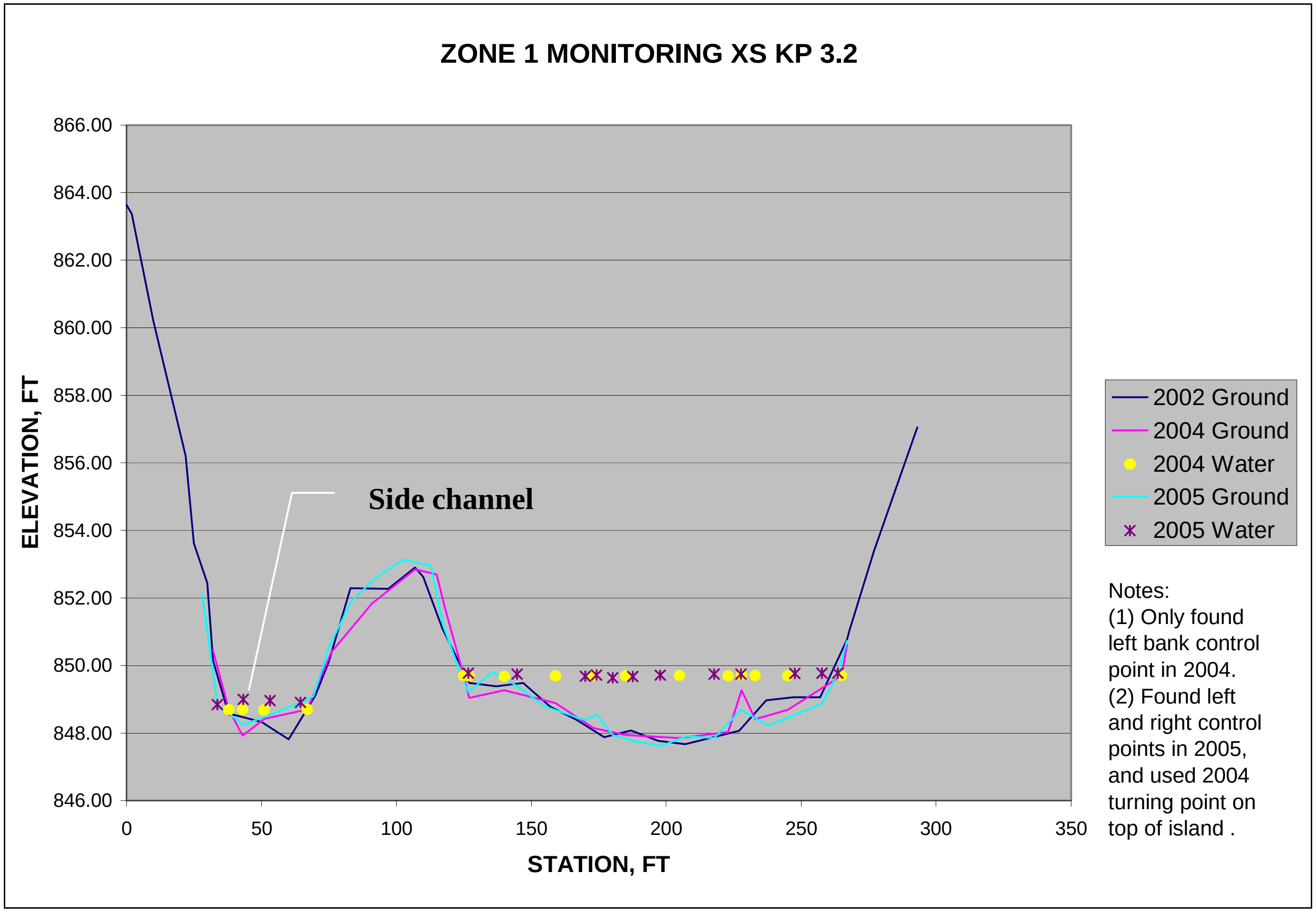



Figure 52. Cross section survey data KP 3.0 (WY 2004 flow at Palmer, 8/3/04, 120 cfs, WY 2005 7/28/05, 151 cfs).

## 4.3. Performance Summary

- ELJ1 appears to have lost at least 1 racking log and minimal ballast between WY 2004 and WY 2005 (total of 3 logs lost since construction). It generally appears to be stable, and vegetation is actively growing on the ballast. Several racking logs shifted, opening up a pocket on the left side of the jam, and the logs are protruding out of the right side. Debris had racked on the front of the jam, indicating that the ELJ will likely capture wood placed upstream, so loss of racking wood can be maintained by continued loose wood nourishment.

- ELJ2 was reported to have lost at least 1 racking log between construction and the WY 2004 report. Due to the retrofit, there was not a photo-set to compare with in WY 2005 to determine wood loss. ELJ 2 appears to have gained considerable stability due to the retrofit. No significant loss of ballast was noted. Some small wood debris was noted on the front of the racking material.

- Each log jam has functioned to maintain a scour pool, however, pool dimensions appear to be highly dynamic as gravel from the nourishment berms fills in and is scoured from the pools. This is expected to be a continual phenomenon. The log jams have successfully increased flow into the immediate downstream side channel during all flows. The pool area has increased significantly at ELJ 2 and essentially remained constant at ELJ 1, despite low-flow pool depths decreasing significantly.

## 4.4. Adaptive Management

No adaptive management activities are anticipated in the next year.

# 5. CHANNEL GEOMORPHOLOGY

The influence of ELJ construction and gravel nourishment on localized and reach scale morphology was generally evaluated using aerial photography, field observations, and cross section surveys.

## 5.1. Planform Analysis

Review of aerial photos taken since construction indicates that few noticeable changes in planform are occurring in the study reach. Except for construction of the ELJs and gravel nourishment loading zones, no major changes are apparent in the study reach except for local gravel accumulations that are noticeably reducing the number of boulders visible in the photos and shifting the location of the low flow channel.

## 5.2. Channel stability

Except for adjustment of the ELJ scour holes, no significant erosion or scour was noted between the loading zone and KP 4, although a small existing cut bank appears to be supplying gravel on the left bank near KP 1.5. A similar gravel point source is located on the left bank opposite the fishing hole (KP 5). The most widespread erosion is occurring at the outside of the bend between KP 8 and KP 8.8, near Bruner Slough. Point bars are building on the inside of the bend, indicating that the channel is migrating to the north at this location. This area has remained dynamic through the entire period of aerial photo record. Gravel nourishment is likely to increase migration rates since existing bars are likely to enlarge, pushing the thalweg further to the outside of the bend. Despite the higher flows being diverted into the side channel downstream of the ELJs, no changes to side channel banks have been observed or reported. A side channel along the landward edge of a cobble/boulder bar on the right bank downstream of KP 9 appears to have scoured somewhat in response to gravel deposition on the top and riverward edge of the bar.

Overall, the channel has remained stable throughout the monitoring period. The ELJ2 scour hole along the left bank has at times enlarged resulting in some bank erosion. However, this location is at the end of the gravel nourishment access road that is armored with riprap, which should limit the extent of scour hole enlargement. The upstream loading site experience erosion of riprap that was not properly installed. In 2004 this was repaired and appeared to fair well over the year, with few if any signs of instability observed in 2005.

## 5.3. Gravel Storage

Visual inspection indicates that gravel is temporarily stored upstream and between the ELJs, and in the scour pools. The percentage of incoming gravel stored near the ELJs and the residence time of the stored gravel is not presently known. The original with-project and newly calibrated hydraulic models suggest that KP 3.0 (area between the log jams) should experience gravel storage (aggradation) over time (USACE 2003a, 2004a). Per the models, the observed gravel deposits were more pronounced in this area implying that the models are predicting relative differences in gravel storage potential. Ongoing monitoring should focus on volumetric changes in this reach as measured by cross section changes to track changes in bed elevation and sediment transport capacity.

Due to the retrofit of ELJ 2 in summer 2004, some of the changes reported in the WY 2004 report require updating. Namely it appears that mid channel gravel deposits are unlikely to combine with deposits in the lee of ELJ 2, forming a more extensive mid channel island. Removal of some of the ballast on the back of ELJ 2 to raise its height appears to have allowed for a more abrupt expansion of flow downstream of ELJ 2, scouring some of the gravel that appeared prone to deposition in 2004. Detailed observations and measurements of flow distribution are not available to say if the flow distribution has changed significantly from 2004.

Gravel point bars are more pronounced on the left bank at KP 1.7 and near KP 3.0. On the right bank near KP 5.2 a gravel point bar is enlarging, and a sand bar/beach on the left bank appears to be storing gravel. Downstream of the TPU pipeline alternating gravel point bars are pronounced, and appear to be recent deposits. Wedges of gravel are building up in front of both ELJs, near the boat launch, fishing hole tail-out, and Signani slough outlet. At the Signani slough outlet the existing vegetated bar appeared to be enlarging in all directions.

Some nourishment gravel was noted in side channels and on top of vegetated bars, especially below the ELJs near KP 3.2 and between KP 9 and KP 10. Gravel stored on the tops of existing bars may be a sign of local bed aggradation. If local aggradation is not occurring, this may result in more flow entrenchment in the main and side channels. The entrances to some side channels showed signs of recent erosion as flow adjusted to debris accumulations. This was most pronounced below KP 7 (left side).

Wood placed on gravel bars upstream was located at the entrances to side channels or racked into existing logjams, with one exception where a piece of wood was racked against the bridge pier at the TPU pipeline crossing. No wood was observed in the wetted low-flow channel.

# 6. SUMMARY

## 6.1. Gravel Nourishment

- 95% of the constructed gravel berms were eroded by the river.
- Gravel was effectively transported to downstream locations, more than 2 miles from the loading site.
- Size of downstream substrate was measurably decreased relative to the prior year and baseline.
- Large gravel bars are developing at several locations where the bed was previously much courser
- Chinook salmon spawning decreased in the Palmer reach in Fall 2004 relative to the previous year
- Steelhead spawning increased in the Palmer reach in Spring 2005 relative to the previous year

## 6.2. Log Jams

- Both ELJs show good signs of stability despite some moderate displacement of racking wood.
- Log jams have effectively increased flow to the immediate downstream side channel. This has resulted in gravel transport to and deposition in the side channel.
- Log jams are maintaining dynamic scour pools. Pool perimeter continues to change. Pool area is increasing but depth is decreasing at ELJ 2. At ELJ 1 depth is decreasing but area is about the same.

## 6.3. Geomorphology

- Construction of the log jams extended a flow split upstream from a large island located downstream of the log jams. This increased the wetted perimeter of the reach and side channel length.
- In areas where gravel deposits were observed, comparisons with baseline conditions indicate that the bed sediments are finer, theoretically decreasing hydraulic roughness when bed load transport is not occurring (low-moderate flow).
- Log jams are creating backwater conditions upstream resulting in higher water surface elevations over baseline conditions. This is encouraging gravel bar formation mid-channel and along the left bank.
- No channel migration or bank instability has been observed that is attributable to the log jams or gravel loading.
- Gravel storage is primarily observed near the log jams (upstream and downstream), behind large obstructions, upstream of riffles, downstream of pool tail-outs, on top of cobble point bars, and in the interstices of large bed material (boulders).
- With the exception of the log jam reach, no changes to the baseline geomorphic reach types have been observed.
- Wood displaced from the log jams has not been reported to have resulted in the formation of significant log jams or channel obstructions downstream, but has contributed to the size of existing log jams.

- Wood placed on the gravel nourishment berms was observed downstream, racked into existing logjams near side channels and in front of large immobile obstructions. No wood was observed in the wetted low flow channel in the monitored reach.

## 6.4. Adaptive Management Activities in 2005

- Gravel nourishment berm limits were successfully established to eliminate backwater at the USGS Palmer gage.
- The ELJ 2 retrofit appears to have successfully increased freeboard and stability of the jam so that it is consistent with design criteria.
- The placement of nourishment gravels was shifted slightly towards the river to decrease the amount of gravel that is captured behind the stabilized access ramp that now creates a small hydraulic shadow for the gravel along the left bank just downstream of the loading ramp.

## 6.5. Changes to Monitoring Activities in 2005

- Pebble counts were taken at each transect surveyed in the baseline report to allow for more accurate comparison of substrate changes
- Annual aerial photos were re-scheduled to the late winter low-flow leaf off period to provide a low contrast image that provides superior visibility of changes along the channel banks and side channels, allowing for more accurate gravel patch mapping. This comes at a cost of not having an image that shows all low flow features encountered in the field, but in practice is not a major hindrance.
- Cross Section end points near the ELJs were permanently established to aid monitoring
- New ELJ monitoring pins were installed to track ELJ deformation and settlement
- Gravel patch mapping methodology was upgraded to provide a more detailed view of changes to the streambed, including quality control.
- Grid photos were located in the field using GPS
- Post-construction baseline photos contained in the 2003 construction report were used in the field to ensure photo points are properly re-established.

# 7. RECOMMENDATIONS FOR FUTURE MONITORING

The following recommendations for improving the data quality and data gathering efficiency for the physical monitoring project are based on the experience of the monitoring staff and comments received on the draft monitoring report. Unless otherwise noted these recommendations are supplemental to the monitoring activities contained in this report.

## 7.1. Gravel

- Spray paint strips with 10-ft hatch marks across top of constructed gravel berms at three to five regular locations to allow for rapid assessment of high flow erosion rates and particle tracking. Use different colored paint each year.
- Obtain geologic information about nourishment gravel to obtain more objective means for differentiating between native and placed gravels in the field. Perform placed vs. native tests of constructed berm gravel to get assessment of error of method.
- Continue patch maps upstream of KP 1 to pipeline crossing to familiarize field crews with "baseline" conditions before mapping commences downstream
- Continue to obtain aerial photos in spring leaf-off period if river discharge at Palmer is at or below 200 cfs.
- Visually classify the d10, d50, and d90 sediment grain size at all locations where gravel patches are mapped.
- Use electronic, GPS based mapping tool to delineate and classify gravel deposits in the field. This could greatly increase mapping accuracy and reduce monitoring expense if near survey grade GPS (+/- 1 m) can be acquired.
- Consider installing scour pins (rebar) into ELJ ballast to aid in high flow erosion assessments.
- Cross section surveys will be a primary method by which gravel deposition will be evaluated in future years. Additional methods that may be considered include regular topographic reach surveys, using technologies that provide quick absolute depth measurements, or installing some distinguishing features in the gravel that allow easy identification of the source of the deposit (coloration, magnetization, or tracking tags). The monitoring study should also investigate simple means of checking depths of deposits in the field that are not labor intensive.
- Establish cross section below Green River Gorge to determine gravel transport to and through this point.

## 7.2. Log Jams

- Consider installing gage boards or temporary level logger transducers near ELJs to assess temporal effects of gravel transport on relative stage.

## 7.3. Geomorphic Change

- Consider extending cross section surveys downstream to KP 5, 6, 8, 9, and 10 due to significant deposition that may be occurring.
- Survey main channel and side channel invert between KP 3.2 and KP 1.7. Compare with baseline, as-built, and 2004 data.
- Consider marking endpoints of ELJ logs with a spot of paint or notch to allow for easier photographic comparisons.

### 7.4. Fisheries

- Multiple spawning surveys within the season will indicate the proportion of Chinook spawning in this reach of the upper Green River over the season as well as provide information on redd scour during the spawning season.
- Conduct a redd scour study. This could be accomplished by burying marked stones as a surrogate for eggs/redds and determining the fate of the stones with respect to flow. Alternatively scour chains or rebar driven into the stream bed could be monitored to determine changes in bed elevation in response to flow.
- Future monitoring efforts should attempt to tease out the level of increased production that may be attributed to restoration processes.
- In an effort to show ecosystem response, biological monitoring could be extended to macroinvertebrates as well as fish species other than salmonids (Kauffman et al. 1997).

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