

PROJECT INFORMATION REPORT
REHABILITATION OF FLOOD CONTROL WORKS
GRN-01-14

H&H APPENDIX: Desimone Levee

Summary: Hydraulic analysis performed in support of the Desimone levee rehabilitation.

Table 1. Summary of HH Analysis

Original LOP (yr)	250
Damaged LOP (yr)	2
Landward toe loading event (yr)	<annual
Damaging event freq (yr)	2
Recommended rip rap d50 (ft)	1.5 (class 4)
Recommended blanket thickness (ft)	3 ft
Coefficient of stone uniformity d85/d15	1.5
Specific weight of stone (lb/ft ³)	165
Estimated sq ft of rock per foot of levee	300
Potential toe scour depth (ft)	25 ft

It is recommended that the scour estimate for toe protection at this site incorporate available boring data for this section of the Green River, which shows the existence of scourable material down to 25 ft below the bed. This is greater than the previous estimate provided from the local sponsor of 15 ft (NHC, 2011), and amounts to use of a greater safety factor in scour equations to account for uncertainty in bed composition. The proposed repair extends the full rip rap blanket thickness one channel top width upstream of the bend and ends at the adjacent levee at the downstream end.

Hydrology

Desimone levee is on the right bank of the Green River approximately 15 miles downstream of the USGS gage #12113000, Green River near Auburn, WA. The Green River is regulated by Howard Hanson Dam, which is operated to prevent downstream flows at Auburn from exceeding 12,000 cubic feet per second (cfs) at the USGS gage. Several high flow events exceeding flood stage occurred over the last few years: 11,100 cfs (2009), 10,400 cfs (2011) and 10,100 (2012). Recent damages were observed subsequent to a daily maximum discharge of 9,090 cfs on March 10, 2014 reported at the gage. Accounting for the drainage area of Green River between the gage and the levee, the approximate discharge at the levee was 10,000 cfs (a 2 yr event). These events are estimated to be approximately 2-yr to 10-yr return period, or 0.5 to 0.1 chance of exceedance, for a given year.

PROJECT INFORMATION REPORT
REHABILITATION OF FLOOD CONTROL WORKS
GRN-01-14

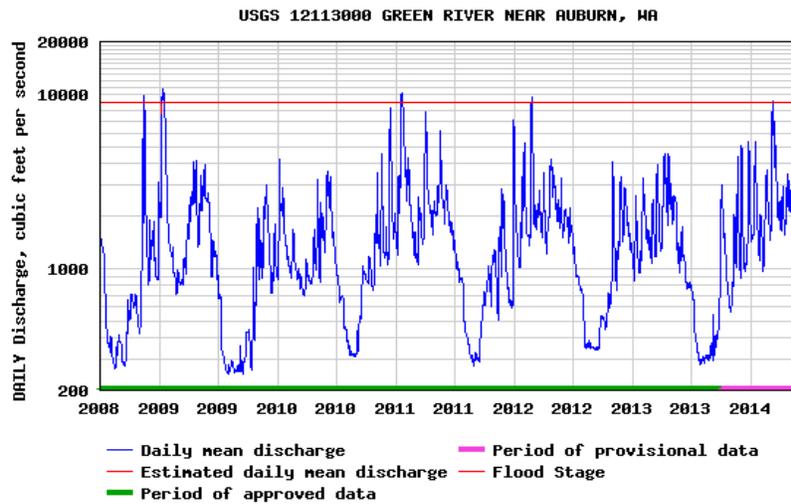


Figure 1. USGS Gage Peaks 2009 - 2014

Level of Protection

Review of hydraulic analysis suggest that the levee would be overtopped with a flood event associated with a 250-yr or greater return period (based on HEC-RAS model flood profiles). The loss of scour protection in the damaged area has compromised the pre-flood level of protection offered by the Desimone levee. Flows contacting the damaged section could erode the remaining armoring and exposed soil. Protective armoring along the toe is missing allowing scouring of in-situ material to occur causing additional sloughing. Therefore, the estimated level of protection provided by the Desimone levee in its current condition is from a flood event with a 2-yr return period and corresponds to the point where damages would occur with some certainty if the levee provided no flood mitigation. This is roughly consistent with the existing ground behind the levee (i.e. if the levee were not there the existing ground would flood from a 2 yr event). The remainder of the levee and toe is assumed to be intact as no damage was reported.

HEC-RAS Model

A HEC-RAS model was developed for this area of the Green River following the November 2006 flood event (5- to 15-yr return period). The model was updated for use in the 2012 screening of this levee for the Levee Screening Tool (LST). Cross-sections from this model directly upstream and downstream of the damaged areas were used to determine the flood profiles at each of the damaged locations.

PROJECT INFORMATION REPORT
REHABILITATION OF FLOOD CONTROL WORKS
GRN-01-14

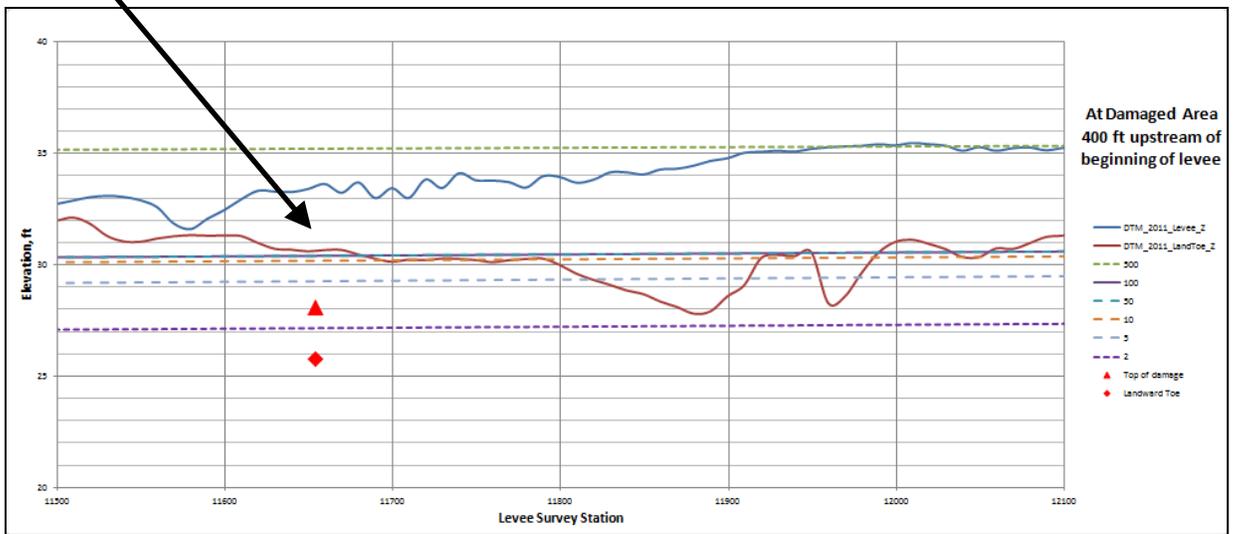
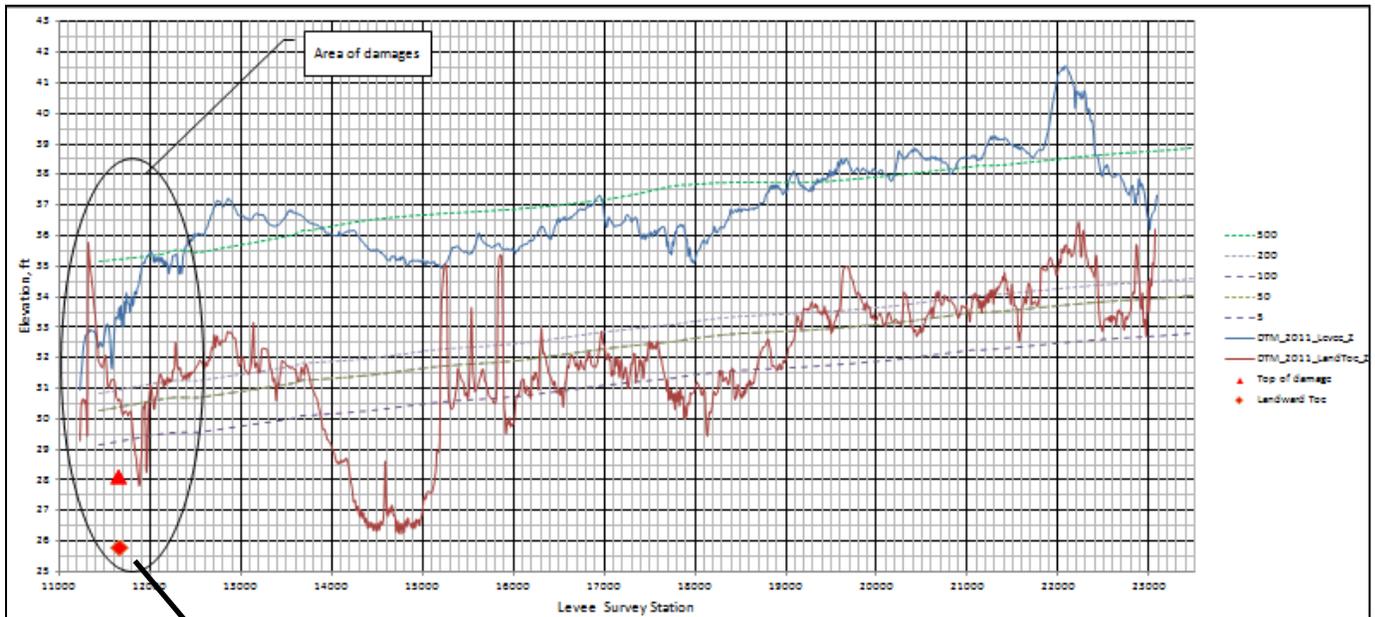
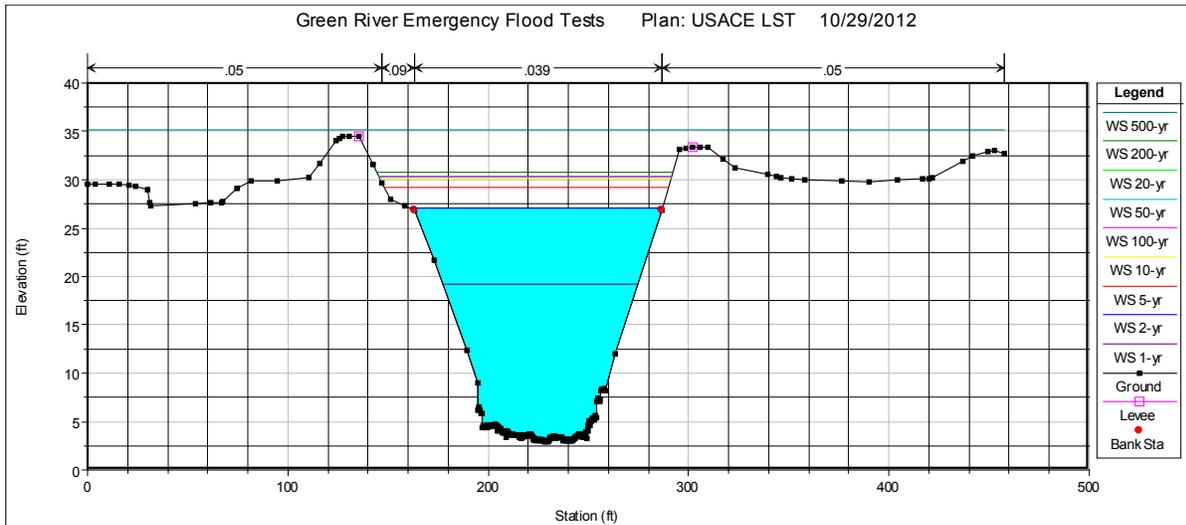


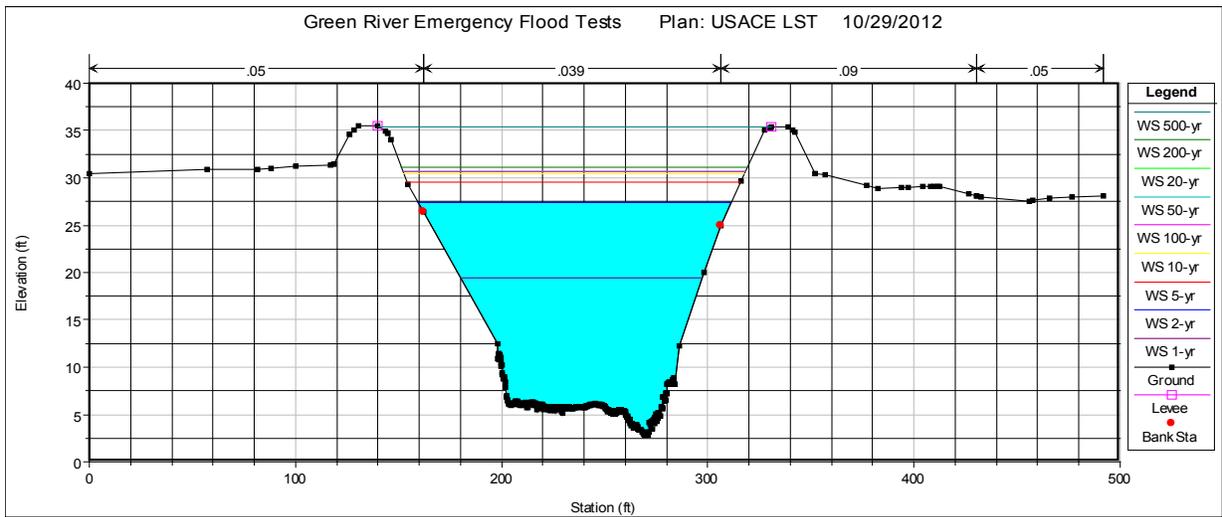
Figure 2. Desimone Levee Flood Profiles (from HEC-RAS 2012)

The HEC-RAS cross-sections near the damaged are of the Desimone levee are shown below (Figure 3).

PROJECT INFORMATION REPORT
 REHABILITATION OF FLOOD CONTROL WORKS
 GRN-01-14



RM 14.534 (Levee STA 114+34) at the bend



RM 14.659 (Levee STA 121+90) upstream straight approach

Figure 3. HEC-RAS cross-sections upstream and downstream of damaged area

PROJECT INFORMATION REPORT
 REHABILITATION OF FLOOD CONTROL WORKS
 GRN-01-14

Riprap Sizing

Hydraulic model results were used in determining the appropriate riprap size classification using the program SAMwin, version 1.0. The program follows the procedure in EM 1110-2-1601 (USACE, 1994) for cases where velocity and depth are given. Per the EM, a 1.1 safety factor was used, and a thickness coefficient of 1.0 to determine the minimum thickness. In the case of Desimone levee, a D₅₀ size of 18 inches was calculated (class 4). The top elevation of the rip rap blanket should extend to at least 32 ft NAVD88, which is the 250 yr water surface through the damaged area.

RIPRAP SIZE FOR A GIVEN VELOCITY AND DEPTH

USING GRADED RIPRAP TABLES FROM EM 1110-2-1601

LAYER #	D30CR FT	DMAXRR IN	D30 FT	D50 FT	D90 FT	WIDTH FT	CY/FT	TONS/FT	\$/FT
8	1.13	30.00	1.22	1.46	1.77	3.61	0.334	0.017	0.00

RIPRAP SIZE	=	LAYER#	8	DMAX, INCHES	=	30.
VELOCITY, FT	=	6.50	VSS/VAVG	=	1.509	
BEND RADIUS, FT	=	500.	TOP WIDTH, FT	=	180.	
R/W	=	2.778	VERT VEL CORR, Cv	=	1.194	
LOCAL DEPTH, FT	=	2.00	DESIGN DEPTH	=	1.60	
SAFETY FAC, Sf	=	1.10	STABILITY COEF, Cs	=	0.300	
THICKNESS, IN	=	30.00	THICKNESS COEF, Cv	=	2.500	
SIDE SLOPE	=	1.50	SIDE SLOPE CORR, K1	=	1.528	
SP.GR. RIPRAP	=	2.65	POROSITY, %	=	38.00	
CHANNEL TYPE	=	NATURAL	COST PER FOOT, \$/FT	=	0.00	

Figure 4. SAMwin Calculations

PROJECT INFORMATION REPORT
REHABILITATION OF FLOOD CONTROL WORKS
GRN-01-14

GENERAL GUIDANCE
FOR
RIP RAP GRADATION
(PACIFIC NORTHWEST RIVERS)
COE

Class	I	II	III	IV	V
Rip Rap Thickness	18"	24"	30"	36"	48"
100% Smaller than	150# (12")	500# (18")	800# (20")	1000# (22")	1800# (27")
50% Size	50# (8") <small>0.67 ft³</small>	200# (13") <small>1.08 ft³</small>	300# (15") <small>1.25 ft³</small>	400# (16") <small>1.33 ft³</small>	750# (20") <small>1.67 ft³</small>
90% Larger than	25# (6")	100# (10")	150# (12")	200# (13")	350# (16")
10%	25# (6")	25-100# (6-10")	25-150# (6-12")	25-200# (6-13")	25-350# (6-16")
Tolerance	+4"	+6"	+8"	+12"	+16"
Velocity fps	6-10	10-14	14-16	17	18

1. Assuming $w = 165 \text{ lb/ft}^3$
 2. Assumes 1:2 slope; for slopes up to 1:1½, use same class with double the thickness.
 3. Assumes that the L/W ratio of the rock is no greater than 3.
 4. Riprap gradation for use on the outside bank of a bend should be based on a selection velocity that is twice the average channel velocity.
 5. Riprap gradation for use on the banks of a relatively straight reach should be based on a selection velocity that is 1.5 times the average channel velocity.
 6. Riprap gradation for channel bottoms should be based on the average channel velocity.
 7. INCH (") SIZE IS MINIMUM DIMENSION
Example Class II
- 90% of stones shall range between 100 and 500 pounds. The 50% size of the gradation shall be 200 pounds. 10% of the stones may range between 25 and 100 pounds.

Figure 5. General Guidance for Riprap Gradation for Pacific Northwest Rivers

Toe Scour Estimates

This area of the Green River has been studied extensively for scour. In 2007 a COE study proposed bend scour depths of a maximum 46 ft being possible at the Tukwila 205 levee just downstream on the opposite bank (using EM 1601 methods, USACE 2007). Methods employed in the EM are known to be very conservative and typically aren't used without further calibration. In this area of the Green scour depths of this magnitude have not been seen. In 2011 NHC evaluated several sites from RM 13.5 to 17 for bend scour and calibrated the Zeller equation to the system (NHC, 2011) using a safety factor of 1.5, which predicted bend scour of 15 ft at the Desimone site. These estimates through the reach are shown in Figure 6 below. The NHC effort used extensive 2011 survey data and HEC RAS modeling to calibrate the scour estimates for this area of the Green. The results were checked and are reproducible, and the Zeller equation was found to be generally applicable to the system. The reader is referred to the NHC 2011 report for additional detail. In 2014 borings were done from RM 12.5 to 16.6 (USACE, 2014). The closest boring to the Desimone site was RM 14.748 (roughly 0.2 miles upstream) which revealed the existence of a sand/silt layer down to 25 ft below the river bottom. Borings are shown in Figure 7 below. The boring did not go below this depth so the composition of lower substrate is unknown. Synthesis of these three studies suggests that scour in excess of 15 ft may be possible. Greater scour depths may be possible during flood events. Gravel and sand bed rivers often scour at bends and structures during the rising limb of a flood hydrograph and fill in during the falling limb, revealing an observed net change less than the actual maximum that may have occurred. This phenomenon is almost entirely due to bed composition. If the depth of sub-surface layers vulnerable to scour was factored into calibration of scour

PROJECT INFORMATION REPORT
 REHABILITATION OF FLOOD CONTROL WORKS
 GRN-01-14

equations it would suggest use of a greater safety factor. Increasing the safety factor to 2.7 in the Zeller equation for example gives a scour depth of 25 ft at the site. In the absence of additional sub-surface information, the estimate of a 25 ft depth of scourable material shown in the borings is recommended. If a launching toe is used, for a launch distance greater than 15 feet the toe rock volume should be increased by 75% (EM 1601). This equates to a total launching stone volume in cubic feet of:

$$\text{Volume (cu ft)} = 3.9 \times \text{desired blanket thickness after launching (ft)} \times \text{vertical scour depth (ft)} \times \text{length of repair (ft)} = 3.9 \times 3 \text{ ft} \times 25 \text{ ft} = 293 \text{ sq ft/ ft of levee}$$

For a 25 ft scour depth this equates to approximately 300 sq ft of stone per linear foot of repair length along the levee. Constraints at the site may limit the actual launching toe size that can fit and if necessary alternative measures can be incorporated. The large volume of stone needs to be fit carefully in order to not encroach into the channel or produce a rise in the 100-yr water surface.

Channel Thalweg- Briscoe Desimone Reach (S 180th to S 200th)

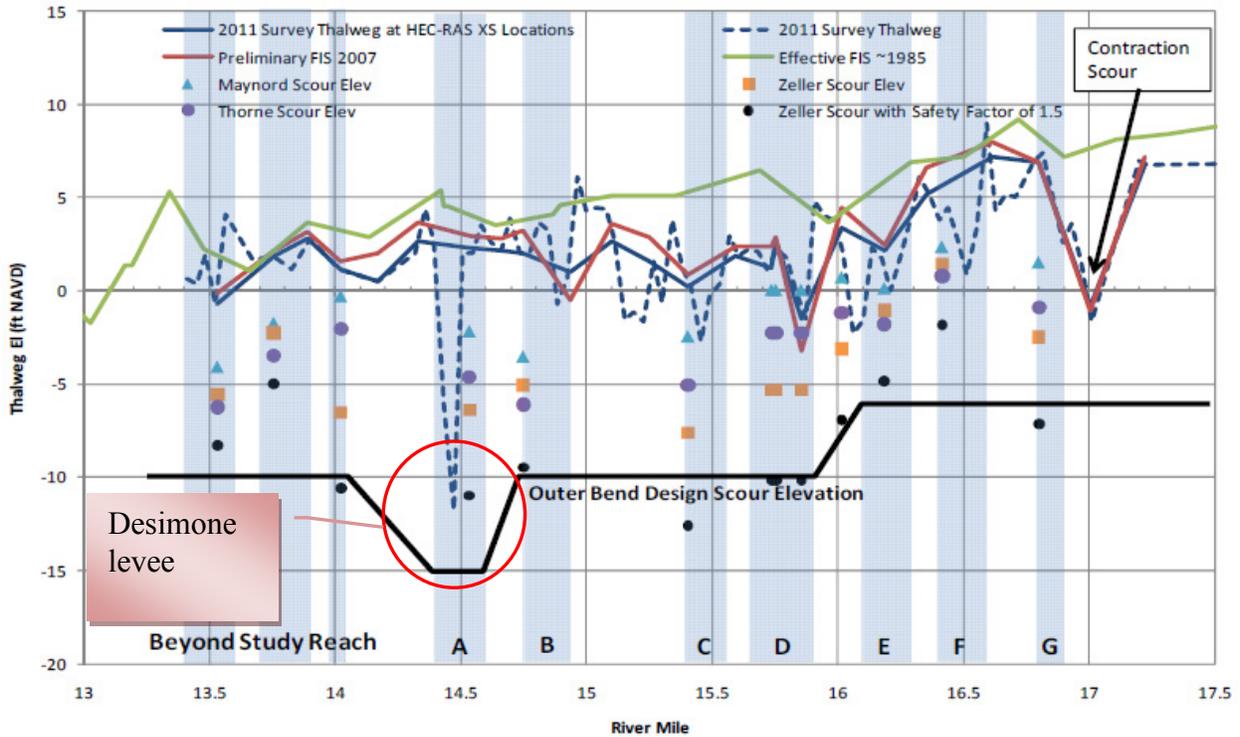


Figure 6. Recommended scour estimate (courtesy NHC 2011)

PROJECT INFORMATION REPORT
REHABILITATION OF FLOOD CONTROL WORKS
GRN-01-14

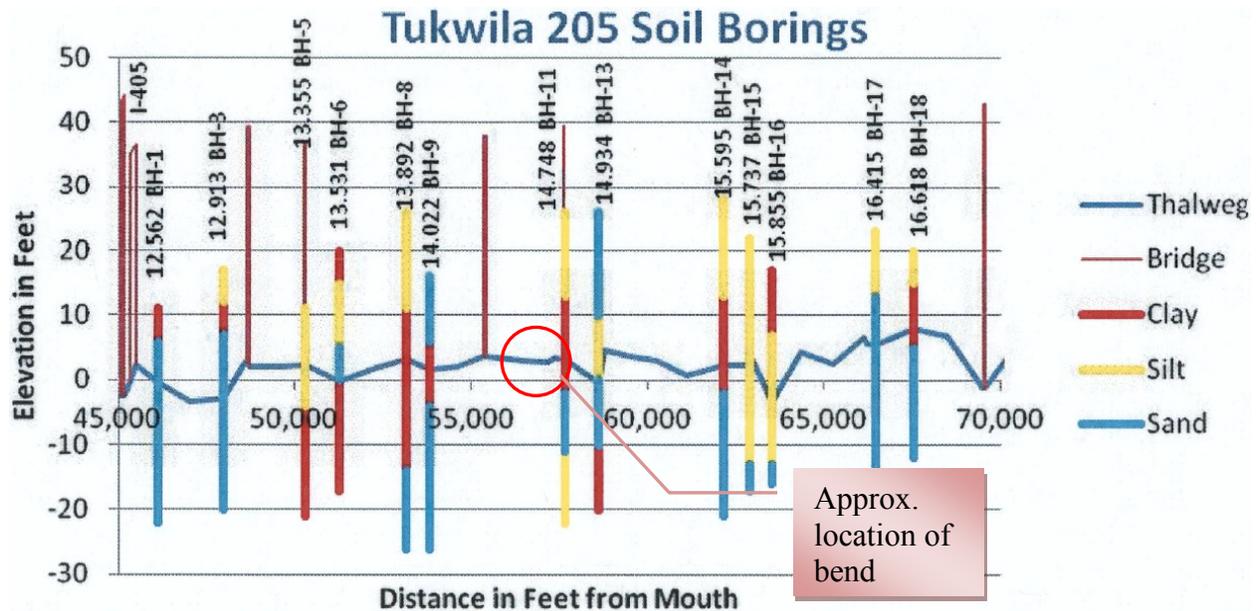


Figure 7: Boring results for levied reach (USACE, 2014)

Recommended Repair Alignment

The damaged area is directly in line with approaching flow as it enters the bend. The repair needs to be sufficiently long that: 1. The transition to the existing rock is not subject to excessive stress and, 2. The repair should be long enough that the bend is adequately protected from future erosion. Typically this involves extending the rip rap blanket at least 1 channel top width upstream from the point of curvature and at least 1 to 2 channel top widths downstream from the point of tangency (USACE, 1994). This is to prevent flanking of the repair. At this site one top width is sufficient to get out of the erosive bend. Another top width is also recommended for tapering the design into the existing levee upstream. It is important that the transition be smooth at not create a constriction along the bank. At the downstream end the repair is ended at West Valley Highway at the adjacent levee. As of this design the repair could not extend into the adjacent levee due to land ownership constraints. The repair is being terminated in an erosive zone of the bend, so it is recommended that the end be keyed into the bank with at least two times the normal blanket thickness (USACE, 1994). The downstream end should also be tapered to a smooth transition into the existing slope. At a minimum the existing slope outside of the damage area should be assessed for adequate protection.

PROJECT INFORMATION REPORT
REHABILITATION OF FLOOD CONTROL WORKS
GRN-01-14

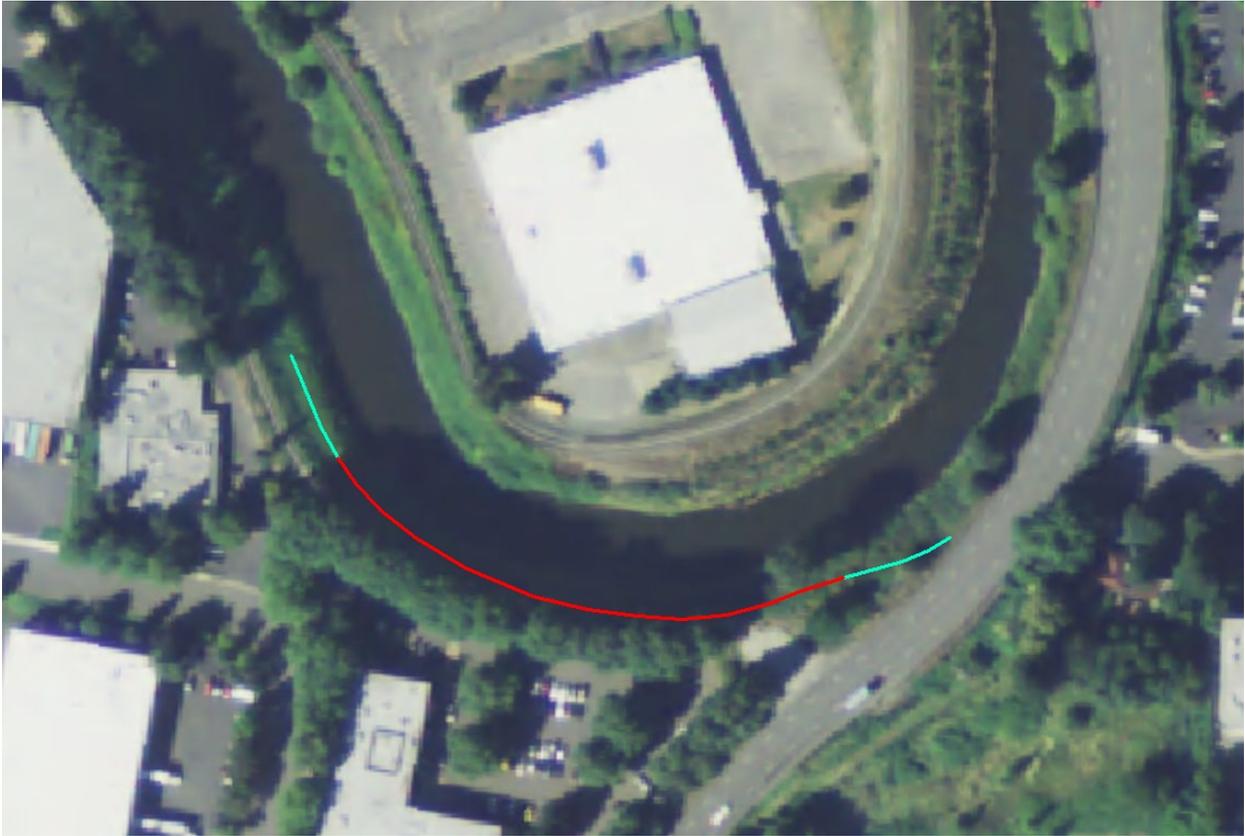


Figure 8. Recommended full rip rap layer thickness shown in red, tapered into the existing slope over the green.

PROJECT INFORMATION REPORT
REHABILITATION OF FLOOD CONTROL WORKS
GRN-01-14

References

Unpublished, USACE Seattle District HH section. General Guidance for Rip Rap Gradation (Pacific Northwest Rivers).

USACE, 2006. HEC-RAS River Analysis System – User Manual. Technical Manual CPD-68.

USACE, 1994. Engineering and Design - Hydraulic Design of Flood Control Channels”, EM-1110-2-1601, Department of the Army, Washington D.C.

WDFW, 2003. Aquatic Habitat Guidelines Program, Integrated Streambank Protection Guidelines (ISPG).

NHC, 2011. Memorandum. Kent Levee Evaluation – Scour Assessment for Geotechnical Support. 6/30/2011. Project 21867, 21877, 21880.

USACE, 2007. Memorandum. Green River Tukwila 205 Levee Toe Scour. 9/17/2007.

USACE, 2014. MEMORANDUM. Tukwila 205 Levee Toe Scour and Bank Stability.
4/29/2014.