MONITORING THE EFFECTS OF SEDIMENTATION FROM MOUNT ST. HELENS

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Abstract: Sedimentation processes from Mount St. Helens eruption affect the channel capacities and morphology of the Toutle and Cowlitz rivers in southwest Washington State. Portland District Corps of Engineers must ensure that flood protection levels are maintained on the lower Cowlitz River at the communities of Longview, Kelso, Lexington, and Castle Rock.

Levees, dredging, and Sediment Retention Structure have maintained flood protection on the lower Cowlitz River. The annual monitoring program consists of data collection to assess the current channel capacity and geomorphic state of the Toutle and Cowlitz rivers. The current monitoring activities are river gages, periodic hydrosurveys, suspended sediment and bed material sampling. The Sediment Impact Assessment Model (SIAM) incorporates all the data collected and is used to verify the observed trends. The model is used in a predictive mode to determine the effects of dry, normal and wet periods on the river system.

DATA COLLECTION

Cowlitz River Gages: The Mount St. Helens Engineering Reanalysis (Portland District, April 2002) recommended a system of 7 stage gages to monitor sediment impacts to flow levels from the mouth of the Cowlitz River to the confluence of the Cowlitz River with the Toutle River. Five water level loggers were installed on the Cowlitz River during the month of October, 2002. These five gages along with USGS gage No. 14243000 (Cowlitz River at Castle Rock) and NWS gage No. 454131 (Cowlitz River at Kelso) make up the 7-stage gage system (Portland District, October 2005).

The system of gages on the Cowlitz River is intended to track potential changes in channel capacity due to sedimentation by specific gage analysis. The data collected from the gages to date has not shown any conclusive evidence of loss or gain of channel capacity. This was expected since the gages have been in operation a short time and there have not been any significant hydrologic events which could reduce the channel capacity in the Cowiltz River.

Toutle River Basin Gages: The Corps Portland District office operates two weather stations in the Toutle River Basin; at the Sediment Retention Structure [SRS] Coldwater Ridge in the North Fork Toutle basin. The SRS weather station records air/water temperature, precipitation, wind speed/direction and the water level at the spillway. The Coldwater Ridge weather station records air temperature, precipitation and wind speed/direction. The USGS operates two important stations in the Toutle River basin; Toutle River at Tower Road (14242580) and South Fork Toutle at Toutle, WA (14242580). These two gages provide stage, discharge and suspended

sediment data. The daily sediment discharge data measured by these gages is an important tool in monitoring the operation of the SRS and sedimentation processes in the Cowlitz and Toutle Rivers.

Bed Material Sampling: Bed material samples are collected in the Toutle and Cowlitz rivers during low water period by Portland District. Field observation of geomorphic changes in the rivers system is an important component of the monitoring effort and is part of the bed material sampling effort. Once collected, the samples are processed by the USGS Cascades Volcano Observatory into sediment gradation curves. The information from the sediment gradation at each location is used to estimate the wash load and sediment transport capacity of the river reach in which it was collected. Comparisons of the sediment gradation curves from bed material are made to monitor changes. Changes in the bed material at any given location, either to coarser or finer material are an indication of changes in sedimentation processes upstream. The sediment gradation curves (Figure 1) are also used in the SIAM model.

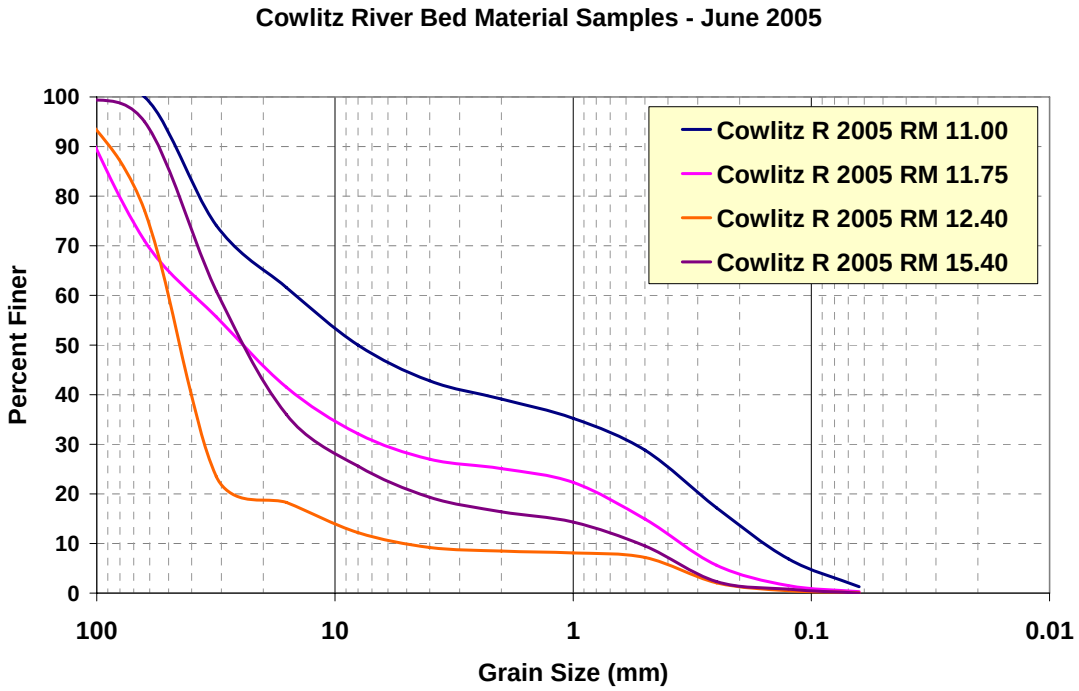

Figure 1 Sediment gradation curves - Cowlitz River bed material samples, June 2005.

SRS Deposition Monitoring: Estimates of sediment deposition (Figure 2) upstream of the SRS are made using elevation data collected using Light Detection and Ranging (LIDAR) techniques. The elevation data is used to develop a digital terrain model (DTM).

The volumetric change in the area of deposition was computed by spatial analysis of the WY 2003 and 2004 DTMs. The net deposition was estimated to be +0.7 million cubic yards (mcy) for WY 2004. This brings the total estimated sediment volume trapped behind the SRS to a total of 102.3 mcy.

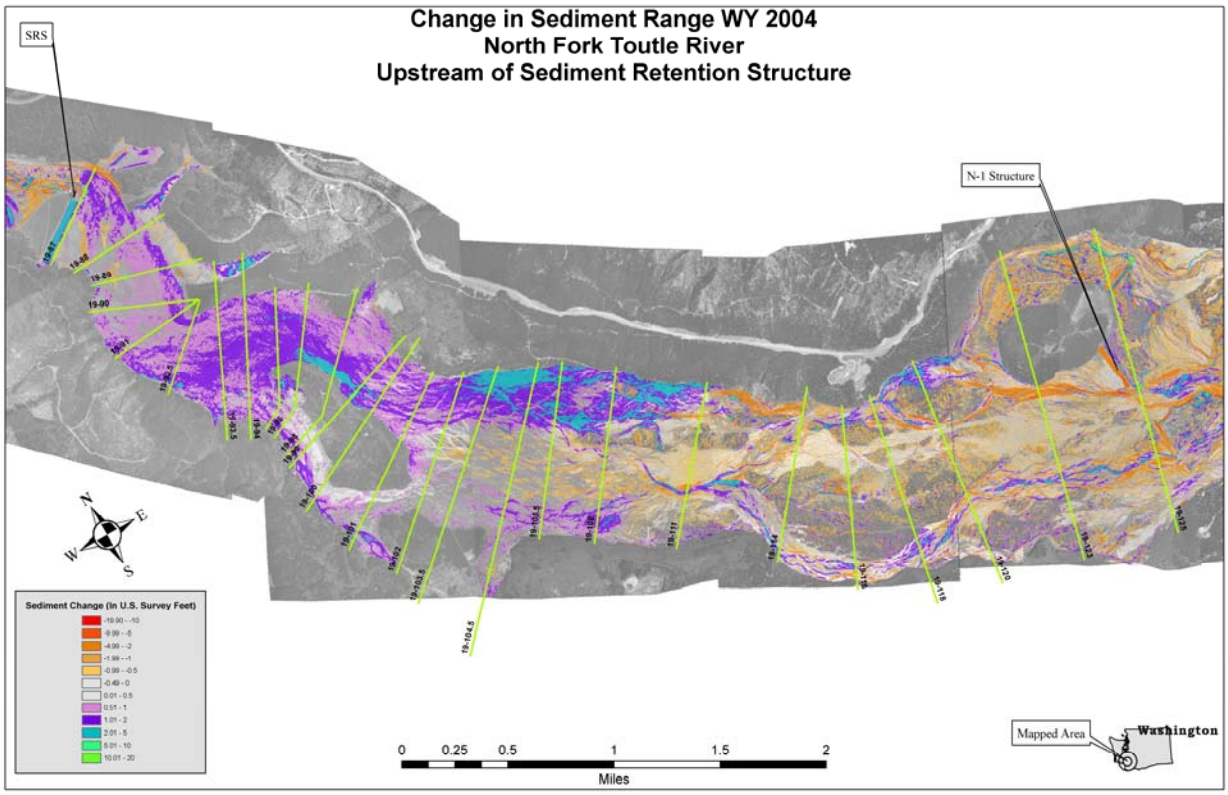

Figure 2 Sediment deposition upstream of the SRS comparing DTMs developed from LIDAR data from 2003 and 2004.

Cowlitz River Hydrosurveys: Hydrosurvey data for the lower Cowlitz River (river miles 0-20) was obtained in August 2003. The 2003 survey showed an aggradational trend in the lower 10 miles of the river from the last survey taken in 1996, and a slight degradation trend from about mile 10 to mile 20. The trend in the upper reach of the Cowlitz was confirmed by rating curve data from the USGS gage at Castle Rock (river mile 17.1).

The 2003 hydrosurvey data was used to update a HEC-RAS model developed with the 1996 survey data. The 2003 HEC RAS model for the Cowlitz was used as the basis for the WY 2004 SIAM model developed with a beta version of the software. Advances in the HEC-RAS model have greatly simplified data importation and manipulation of hydrosurvey data. The hydrosurvey data can be easily merged with data from LIDAR or conventional surveys. Portland District has recently acquired the capability to do acoustic river bed classification in conjunction with the conventional single beam hydrosurvey. The acoustical bed classification is obtained at no additional cost to provide the type of sediment on the bottom as well as the river cross sections. Bed material samples taken on the river are used to verify the sediment classification provided by the hydrosurvey. This combination of technological advances in software and data collection has greatly reduced costs making annual updates of channel bathymetry possible. This information can be used to monitor channel capacities and provide updates on levels of protection provided by the levees.

SEDIMENT IMPACT ASSESSMENT MODEL (SIAM)

ERDC and HEC (Gibson and Little, 2006) are currently developing a Sediment Impact Assessment Model (SIAM), which provides for rapid assessment of the impact of sediment management activities on downstream sedimentation trends. The model provides a framework to combine sediment sources and computed sediment transport capacities into a model that can evaluate sediment imbalances and downstream sediment yields for different alternatives. SIAM is incorporated into the Hydraulic Design module of HEC-RAS. Portland District has developed a SIAM model of the lower Cowlitz River using a beta version of the software and is participating in testing and implementation of the model.

INTEGRATION OF SIAM INTO MT ST HELENS DATA COLLECTION AND MONTIORING PROGRAM

The use of the SIAM model was recommended by the Corps Committee on Channel Stabilization during the December 2004 meeting on the Mt St Helens project at Portland District. The SIAM model utilizes all the data collected as part of the annual monitoring program and provides a platform for communication of the current and future effects of sedimentation from the eruption of Mt St Helens and the operation of the SRS. The model provides a practical means of developing a sediment budget and tracking sediment as it moves from the SRS through the Toutle and Cowlitz and into the Columbia River. Future sedimentation trends and their effect downstream based on changing hydrologic conditions may be evaluated in SIAM. The SRS has filled to the point where it may be passing more coarse sands and fine gravels downstream potentially affecting channel capacities on the lower Cowlitz.

Two SIAM models are proposed for incorporation into the Mt. St. Helens data collection and monitoring program; the Cowlitz River RM 0 to 20.8 and the SRS inflow/outflow to monitor deposition and trap efficiency. The model inputs and outputs may be used at a later date to develop a HEC-RAS mobile bed event based sediment transport model. The Cowlitz River model has been developed based on an existing HEC-RAS model updated with 2003 hydrosurvey data. The model will be updated annually with data collected for the monitoring program. Work on the SRS model will begin at a later date.

Cowlitz River SIAM model: SIAM was designed as a first order screening tool to provide reach averaged sediment transport and average annual sediment yields. Sediment yield in the program is computed on the basis of an average flow duration curve. SIAM is not an event-based sediment routing model, which limits its applicability to investigations where average annual sediment budget calculations are sufficient. The SIAM model developed for the Cowlitz River utilizes much of the data collected as part of the monitoring program. The Cowlitz River SIAM model (Figure 3) has 6 sediment reaches.

SIAM computations use an average flow duration curve which makes modeling of individual events impractical. The SIAM model for the Cowlitz uses an approach based on the annual hydrology and sediment discharge data published by the USGS. The “Water Year” approach uses a flow duration curve developed from the discharge records for the water year studied. Suspended sediment discharge data for the water year is used to estimate sediment supply. Bed

material samples and hydrosurvey data collected during the annual data collection cycle are incorporated into the model. The Cowlitz River SIAM application will be used to track sediment

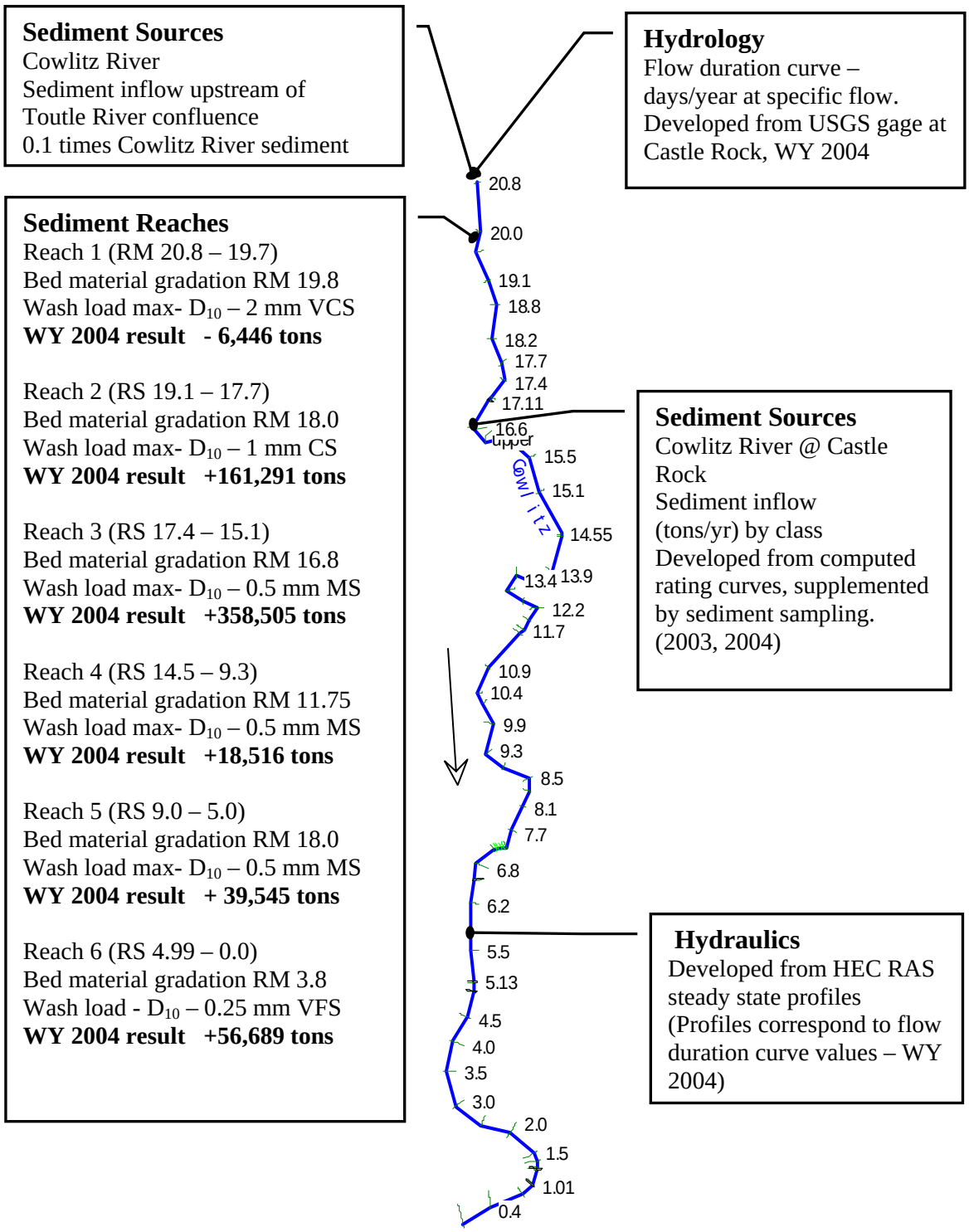

Figure 3 Cowlitz River SIAM model schematic, inputs, WY 2004 modeling results.

yield and geomorphic changes in the river on the water year cycle. Results of the model may be verified using data compiled and collected in the following water year.

WY 2004 Cowlitz River Sediment Supply: The sediment source load for WY 2004 was developed using suspended sediment data collected by the USGS at the Cowlitz River at Castle Rock, WA gage over the period from May 2003 to June 2004. The Modified Einstein method for computation of total sediment discharge was used to develop a sediment rating curve by grain size class. The total sediment supply for the water year was calculated by multiplying the sediment discharge by the fraction of the year for each flow in the SIAM flow duration curve (Figure 4).

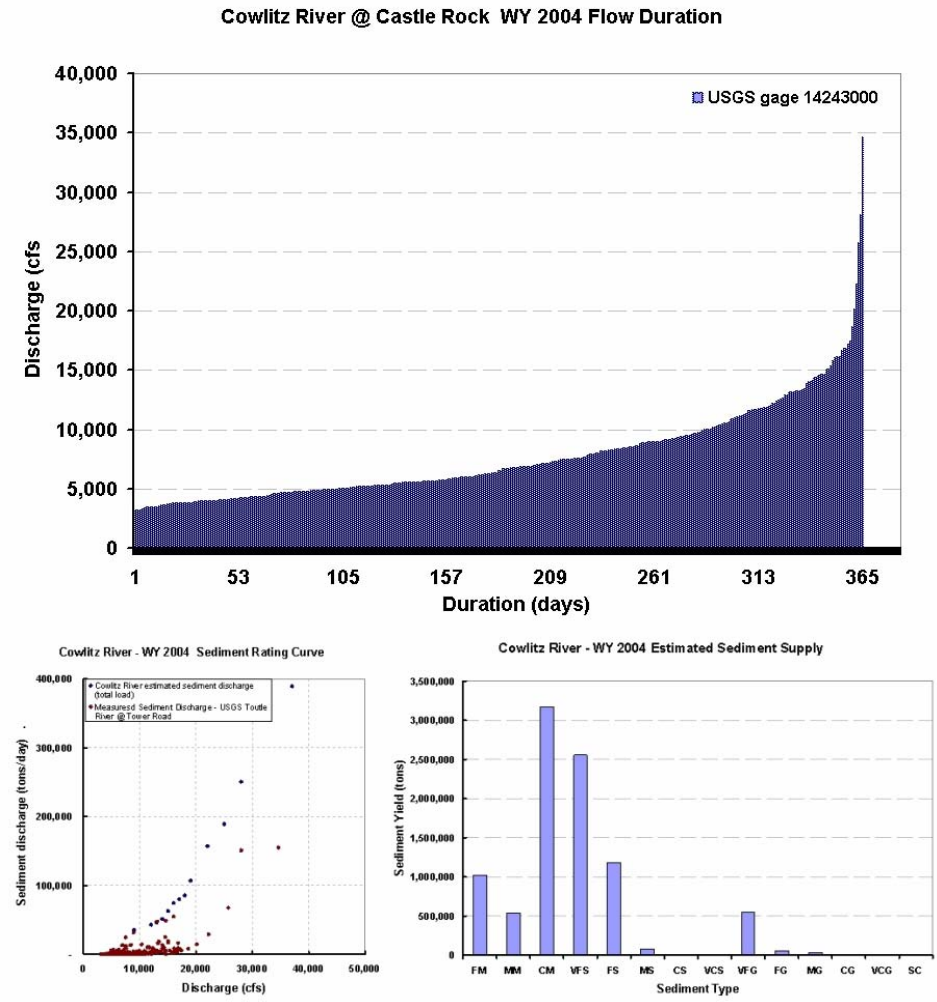

Figure 4 WY 2004 sediment supply estimation for Cowlitz River. Top - flow duration Cowlitz R @ Castle Rock, WA, WY 2004. Lower right - sediment rating curve WY 2004. Lower left - Sediment yield by grain size class for WY 2004, SIAM input.

Six sediment data sets were used to develop the sediment rating curve for WY 2004. Five contained sand – silt breaks and one contained a complete suspended sediment gradation. A bed material sample taken near the collection site was used in the computation. Total sediment

discharge estimates were made using a Modified Einstein program (O'Brien, 2000) developed in *Mathcad* (a mathematical software package).

Sediment Properties and Transport Function Used: Sediment properties are defined for each sediment reach. SIAM has six transport functions available to compute sediment transport capacity over the full range of particle sizes in the bed material gradation. For the Cowlitz River model, the Meyer-Peter Muller function was selected based on the HEC-RAS guidance given for grain size, velocity, and slope. The results are sensitive to the transport function. The maximum wash load threshold value for each sediment reach is derived from the bed material sediment gradation curves. The typical value used for maximum size class of wash load in bed material is the d_{10} fraction.

WY 2004 SIAM modeling results: The results of the initial SIAM modeling (Table 1) seem to fit with field geomorphic assessment, suspended sediment data, bed material sampling and rating curve data from the Castle Rock USGS gage.

Table 1 Cowlitz River SIAM model. Summary of WY 2004 modeling results, net of all six reaches.

Sediment type	d_g (mm)	Inflowing Sediment Supply (tons)	Bed Material Supply (tons)	Wash Material Supply (tons)	Net Deposition/ (Erosion) (tons)
FM	0.011	1,023,642		5,020,222	
MM	0.023	538,850		2,650,855	
CM	0.045	3,166,970		15,588,500	
VFS	0.088	2,556,077		12,593,000	
FS	0.177	1,181,417		5,800,600	
MS	0.354	81,500	81,500	400,834	(3,396)
CS	0.707	13,302	303,500	24,320	(25,991)
VCS	1.41	6,439	241,220	116	3,714
VFG	2.83	555,000	752,608		554,295
FG	5.66	61,050	171,608		61,057
MG	11.3	33,300	61,117		33,335
CG	22.6	3,885	3,885		3,885
VCG	45.3	250	250		250
SC	90.5	13	13		

The results shown are the net for all six reaches combined. Output by reach is available in graphical and tabular format. The model results by sediment reach (Table 2) indicate that the upper two sediment reaches of the Cowlitz (RM 19.1 to 15.1) show approximately 500,000 tons of net aggradation. The bulk of the deposition is in the fine gravel class (2 to 4 mm). Much of the material in this reach deposits in well established point bars. Although the number is large, the net effect in the 4 mile reach is small. The bulk volumetric estimate of the sediment is

400,000 cu yd. Model runs indicate that this result is sensitive to the derived estimate of supply (500,000 tons/year) used. The middle reach of the Cowlitz (RM 14.5 to 9.3) is a transport reach and had nominal deposition of 18,000 tons.

Table 2 Cowlitz River SIAM model. WY 2004 modeling results by sediment reach.

Sediment Reach (RM)	Net Deposition / (Erosion) (tons)	MS (tons)	CS (tons)	VCS (tons)	VFG (tons)	FG (tons)	MG (tons)	CG (tons)	VCG (tons)	SC (tons)
20.8 to 9.7	(6,446)	0	0	0	(4,407)	(2,100)	24	35	2	0
19.1 to 7.7	161,000	0	0	(158,000)	346,000	(33,700)	3,200	3,500	225	12
17.4 to 5.1	359,000	0	(86,600)	133,000	198,000	83,200	29,700	350	23	1
14.5 to 9.3	18,500	0	1,639	1,747	3,902	10,800	405	0	0	0
9.0 to 5.0	39,500	0	6,170	19,800	10,700	2,857	6	0	0	0
4.99 to 0.0	56,700	(3,396)	52,800	7,167	100	0	0	0	0	0

The net deposition in the lower two reaches of the Cowlitz (9.0 to 0) is approximately 100,000 tons in the coarse and very coarse sand fractions (0.5 to 2.0 mm). This indicates a slight aggradational trend in the lower Cowlitz. The amount of deposition is relatively small, but significant considering an average to below average water year. The results will be assessed during the next data collection cycle which will include new hydrosurvey data.

CONCLUSIONS

Sedimentation in the Cowlitz and Toutle Rivers below the SRS must be closely monitored so that the authorized levels of flood protection can be maintained on the Cowlitz River. The annual data collection program and SIAM modeling are cost effective measures which will ensure that these goals continue to be met.

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