# Measurements of Suspended Sediment and Streamflow Partitioning with Implications for Habitat Restoration in the Skagit River Delta, Washington

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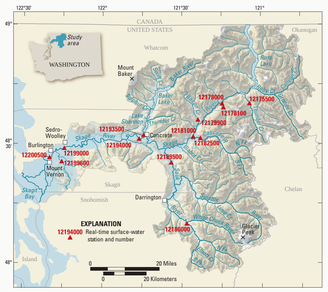
## Background

**The Skagit River Delta provides important estuarine habitat for fish, birds, invertebrates, and plants and is also an important agricultural resource. It is the product of dynamic fluvial and tidal processes that control sediment transport and deposition. Understanding sediment characteristics, delivery, and transport mechanisms to the delta resulting from natural variability, land use, and flood control are important in restoration decision-making. These fluvial processes ultimately control delta geomorphology and estuarine mixing that sustain habitat structure. Recently, the U.S. Geological Survey (USGS) Coastal Habitats in Puget Sound (CHIPS) project conducted studies to refine sediment-budget estimates and determine the partitioning of flow through the delta.**




## Refining the Sediment Budget for the Skagit River

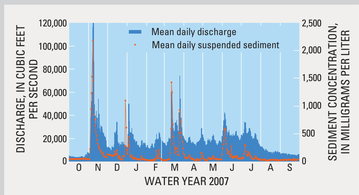
### Continuous Suspended-Sediment Monitoring

Daily suspended-sediment samples were collected from the Skagit River at the USGS streamflow gaging station (#12200500) at Mt.Vernon using an automated pump sampler from March 2006 through September 2007 and analyzed for suspended-sediment concentration.

Two pump samplers were used for the collection of daily samples and storm samples.

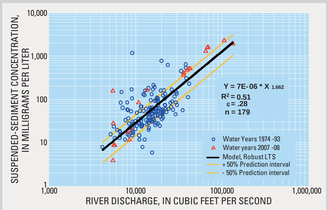
Intakes were bolted to rip-rap at the edge of the channel.

The record of suspended-sediment concentrations was combined with the instantaneous record of streamflow from the gaging station to determine daily, monthly and annual sediment loads. The annual suspended-sediment load computed for water year 2007 was 5,011,000 tons.




### Suspended-Sediment Transport Curve

The highest suspended-sediment concentrations on record were measured during a flood in November 2006 that reached a peak discharge of 138,000 ft³/s. These recent measurements and historical data collected at Mt. Vernon between 1974-93 at lower flows (<43,000 ft³/s) were used to develop a suspended-sediment transport curve, which suggests more sediment is delivered to the delta than previously thought. Recent measurements of suspended sediment were made during high flow events in November, 2008 and January, 2009 (43,000 and 70,000 ft³/s) and will be used to continue refining the transport curve.

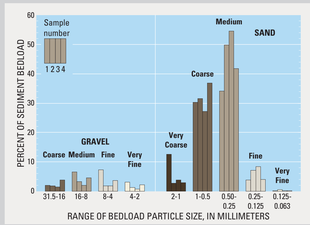



| Mean Daily Discharge Range (ft³/s) | Percent of Time in Range | Mean Sediment Concentration (mg/L) | Mean Annual Load (Tons) | Percent of Annual Load |
|---|---|---|---|---|
| > 130,000 | 0.01 | 2,353 | 25,590 | 1.1 |
| 100,000 – 130,000 | 0.03 | 1,803 | 62,622 | 2.7 |
| 80,001 – 100,000 | 0.09 | 1,200 | 100,002 | 4.3 |
| 60,001 – 80,000 | 0.28 | 790 | 154,782 | 6.7 |
| 50,001 – 60,000 | 0.67 | 529 | 192,209 | 8.3 |
| 40,001 – 50,000 | 1.49 | 379 | 250,057 | 10.8 |
| 30,001 – 40,000 | 4.73 | 250 | 407,125 | 17.6 |
| 20,001 – 30,000 | 17.41 | 143 | 612,228 | 26.4 |
| 10,001 – 20,000 | 53.14 | 61 | 479,642 | 20.7 |
| 5,001 – 10,000 | 21.36 | 19 | 30,467 | 1.3 |
| 3,101 – 5,000 | 0.77 | 7 | 210 | 0.0 |
| Mean Annual Suspended-Sediment Load = | | | 2,314,723 | |

**Percent of Sediment Load Transported During Selected Discharge Ranges. Numbers in red indicate dominant range of suspended-sediment loading.**

### Bedload Discharge at Mt Vernon

In November of 2008 and January of 2009, the USGS and Skagit River System Cooperative made the first known measurements of bedload discharge in the Skagit River at the USGS streamflow gaging station at Mt Vernon. Suspended sediment was also measured at the gage and total sediment discharge was calculated to be 65,700 tons/day on November 8, 2008. Bedload discharge was found to be 3.7 percent of total sediment discharge at a streamflow of 43,000 ft³/s. Particle-size analysis of bedload samples showed that the majority of sediment moving along the bottom of the river bed was medium to coarse sand (0.25 – 1 mm).

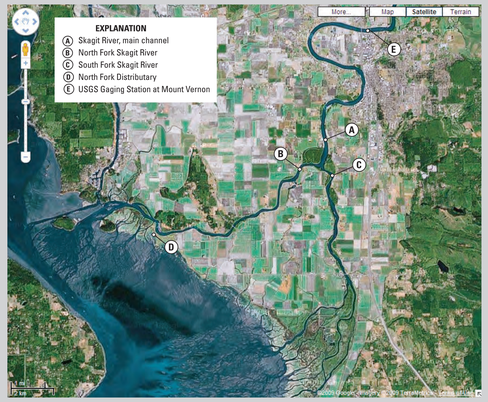


USGS and Skagit River System Cooperative personnel collect bedload samples at Mt. Vernon, WA.

### Computing the Mean Annual Sediment Budget

The regression model developed for suspended-sediment transport as a function of streamflow was used to estimate the mean annual suspended-sediment load to the Skagit Delta. A flow-duration curve based on 67 years of daily streamflow data (1941-2007) from the gaging station at Mt Vernon was combined with the suspended-sediment transport equation to estimate an annual suspended-sediment load of 2.3 million tons. Seventy-five percent of the long-term suspended sediment load occurs during the streamflow range of 10,000 – 50,000 ft³/s.

## Determining The Distribution of Flow and Sediment




### Measuring Streamflow and Sediment Through a Distributary

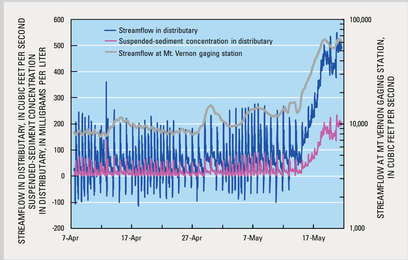
A newly formed distributary (D) provides insights into the natural process of channel formation in the Skagit Delta. Distributaries influence fish migratory pathways, sediment and nutrient delivery, and freshwater mixing along the heavily armored bayfront of the delta. By measuring the flux of water and sediment through the distributary, the function of these types of channels can be better understood and lessons can be incorporatated into developing restoration scenarios.

A tethered ADCP was used for measuring streamflow in the distributary over a tidal cycle.

An upward-looking acoustic velocity meter was installed in the distributary channel for measuring streamflow.

A bottom mounted ADCP was used to measure a continuous record of flow through the newly formed distributary on the North Fork Skagit River in April and May of 2008. Results indicate that as much as 0.5-1 percent of the Skagit River discharge can be rerouted through the delta to the bay within a few years of the inception of a new channel.

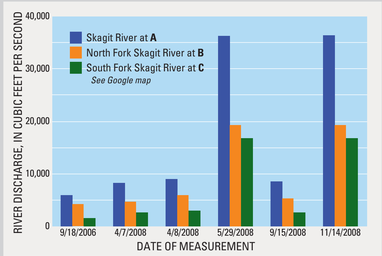
Flow measurements using a tethered ADCP were made over the course of changing tides and were used to calibrate the bottom-mounted device. Suspended-sediment concentrations were also measured and used to model concentration over time.



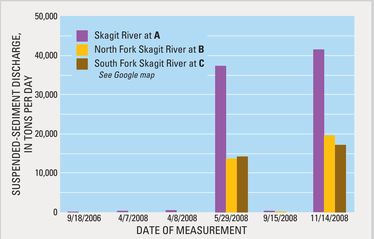

### Streamflow and Sediment Partitioning in the Lower Skagit River

Measurements of flow and suspended-sediment concentration were made at locations on the lower river to determine the partitioning of streamflow and sediment between the North and South Forks of the Skagit River. The purpose of this effort was to develop an understanding of streamflow and sediment routing through the delta in support of restoration designs requiring information about the locations of estuarine mixing and sediment deposition.

The measurements showed that as streamflow increases in the main channel, a larger percentage of the total flow enters the South Fork of the Skagit River. For example, at streamflows less than 10,000 ft³/s, the North and South Forks carry 65 and 35 percent of the total flow, respectively. At streamflows of 36,000 ft³/s, they carry 55 and 45 percent of the total flow, respectively.

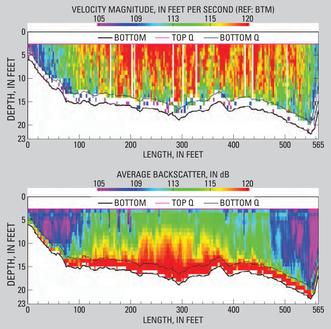



Suspended-sediment concentrations were measured concurrently with streamflow using the Equal-Discharge Increment method with an ADCP. The measurements were combined to calculate suspended-sediment discharge. Results show that the suspended-sediment load is reasonably well-mixed. In May and November of 2008, flow conditions and suspended-sediment discharge were similar, even though the May flow was dominated by snowmelt and the November flow was dominated by rainfall runoff.

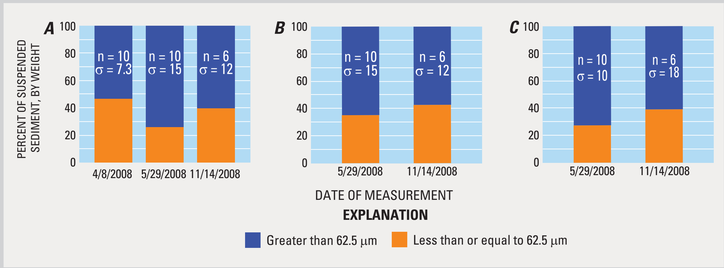



Limited particle-size analyses of suspended-sediment samples from site A,B, and C suggest 50 percent or more of the suspended-sediment load by weight is sand. Some seasonal variation was observed suggesting a higher percentage of sand in May than in November.

USGS boat used for the collection of sediment samples and measurement of streamflow on the Skagit River.




ADCP measurements reveal velocity flow cells in the channel as well as areas of high backscatter, suggesting higher suspended-sediment concentrations in the center of the channel.

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