DETERMINATION OF TOTAL AND CLAY SUSPENDED-SEDIMENT LOADS FROM INSTREAM TURBIDITY DATA IN THE NORTH SANTIAM RIVER BASIN, OREGON; 1998-2000

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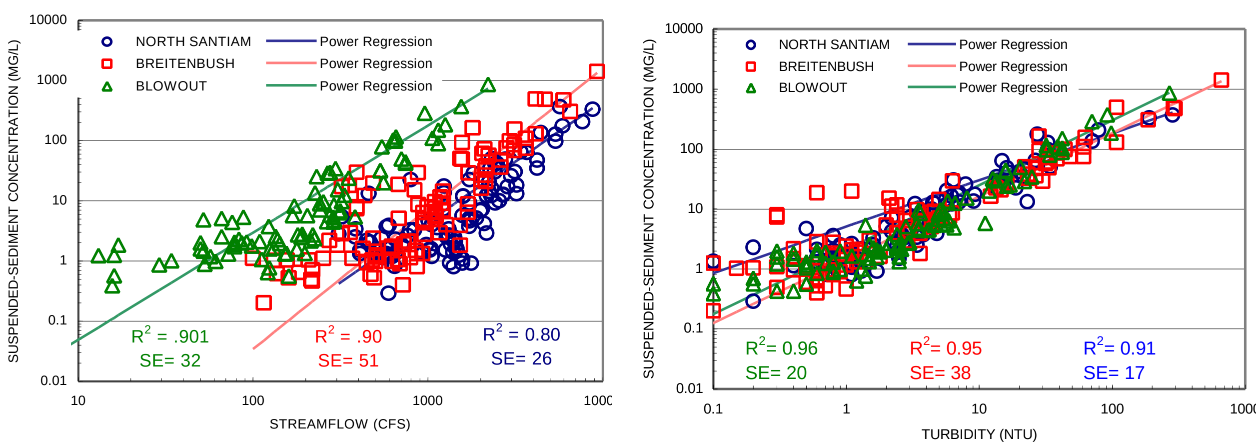
A method to estimate suspended-sediment load was developed using linear regression to correlate continuous turbidity-monitor data and suspended-sediment concentrations (SSC). In 1998, the U.S. Geological Survey began a cooperative study with the City of Salem, in Oregon to investigate the sources and dynamics of turbidity and suspended sediment within the North Santiam River-reservoir system. Three real-time sampling sites were established in October 1998 in the upper North Santiam River Basin upstream of Detroit Lake, a large, controlled reservoir, to collect water samples and continuously monitor turbidity, streamflow, water temperature, specific conductance, and pH from the three main tributary inputs to the lake. The sites were interrogated via telemetry every 3 to 4 hours, providing data in 30-minute increments. Approximately 75 equal-width-increment (EWI) and 15 dip samples (dipped and composited at vertical points in the cross-section similar to the EWI samples) were collected from October 1998 through September 2001 at the three sites.

Estimating Suspended-Sediment Concentrations from Turbidity

Regression correlations were developed for each site using the average instream turbidity values recorded during the sample collection and the sample SSCs. Estimates of SSCs were determined from the continuous turbidity data for each 30-minute reading. As a comparison, power transformed streamflow also was regressed with SSCs. The power regression equations for both turbidity and streamflow were each assessed as potential surrogates for SSC in the North Santiam River Basin (fig. 1). The turbidity and SSC plot clearly shows less scatter than the streamflow and SSC plot, as indicated by the higher coefficient of determination values (R^2) and lower standard error of estimate (SE). One reason for the higher scatter when using streamflow as the surrogate is erosion in the North Santiam River Basin, caused by glacial and landslide activity, can affect suspended sediment production disproportionately to streamflow, making streamflow unreliable for estimating SSC.

Figure 1. Comparison of streamflow and turbidity measurements versus suspended-sediment concentrations for three sites upstream of Detroit Lake (1998-2001).



Suspended-Sediment Load Calculations

Suspended-sediment loads (SSL) were computed from the estimated SSCs and corresponding streamflow data. The resulting 48 estimates per day were averaged and provided as the estimated mean daily SSL reported in tons per day (Porterfield, 1972). A graph of 1999 and 2000 annual SSLs using power equations between both instream turbidity and SSC and streamflow and SSC are presented in figure 2A. Most SSLs using streamflow as a surrogate for SSC were greater than the estimates using turbidity as the surrogate, except for Breitenbush in 2000 which was less, and Blowout which was about the same for both years, varying less than 10 percent between the surrogates. SSLs using better-fit regressions (usually not power equations) with turbidity as the surrogate were less than the SSLs using power regressions with turbidity for all sites and years (fig. 2B).

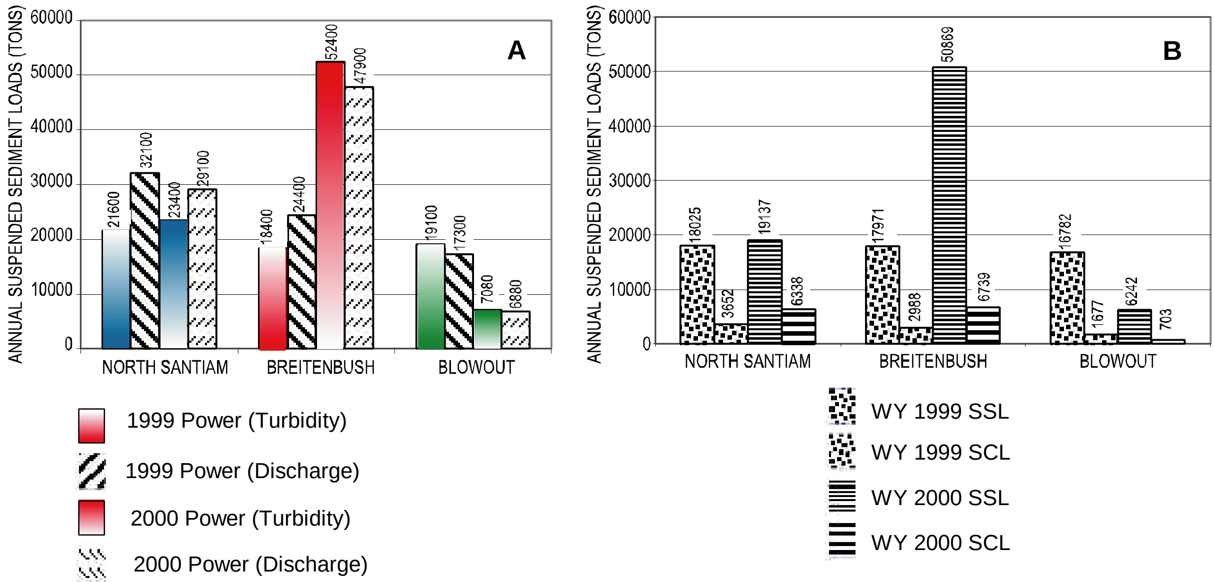


Figure 2. Estimated suspended-sediment loads using power equations with streamflow and turbidity as surrogates (A) and estimated suspended-sediment load (SSL) and suspended-clay load (SCL) using better-fit equations with turbidity as the surrogate (B).

Estimating Persistent Turbidity (Suspended-Clay Concentrations) from Turbidity

Colloidal particles held in suspension have been difficult and expensive to remove by the City of Salem slow-sand filtration system, which supplies drinking water from the North Santiam Basin. A method for predicting suspended-clay load from the persistent or residual turbidity was developed. Separate samples evaluating the change in turbidity over time were collected during the suspended-sediment sampling. Clay fraction (≤ 2 μm diameter) estimates were derived from regression analysis of the turbidity decay curves and particle fall times computed using Stoke's Law (see equation 1, below).

$$\textbf{1. Fall time (in sec)} = \frac{\textbf{(0.1113) (viscosity at sample temp, in °C) (fall distance, in mm)}}{\textbf{(diameter of spherical particle, in mm)}^2}$$

The method used to determine persistent turbidity of fine sediments is similar to the pipet method for particle-size analysis (Guy, 1969), except that dispersion agents and mechanical agitation are not used, and the settling medium is native water. Aliquots are withdrawn from the same depth below the sample water surface at specific time intervals that correspond to the fall times of defined particle sizes (samples are refrigerated and settle at 4° C, the average winter temperature of Detroit Lake, Table 1).

Table 1. Fall times for persistent-turbidity samples (at 4 °C)

Class Name	Particle Size Diameter	Fall Time for 2.75 cm (in lab)	Lab Aliquot Schedule	Fall Time for 70 feet (in lake)
Coarse to medium silt	.062 mm	34 seconds	Initial after shaking	2.7 minutes
Fine to very fine silt	.008 mm	32 minutes	30 minutes	6.7 days
Very fine silt to coarse clay	.004 mm	2.1 hours	2 hours	26.9 days
Coarse clay	.003 mm	3.8 hours	4 hours	47.8 days
Medium to fine clay	.002 mm	8.5 hours	8 hours	107.7 days (3.5 months)
Fine clay	.001 mm	34 hours	28-34 hours	1.2 years
Very fine clay	.0005 mm	5.7 days	5-6 days	4.7 years

Using table 1, persistent turbidity in Detroit Lake is defined as the time it takes 0.002 mm size particles (silt-clay breakpoint) and smaller to settle 70 feet in Detroit Lake to the penstock outlet port, approximately 3.5 months or longer at 4° C. In the laboratory, if we select the 0.002 mm diameter particle as the defining clay size, then the turbidity value after 8.5 hours of settling is considered the persistent turbidity value.

Persistent-Turbidity (Clay Load) Calculations

Suspended-clay loads (SCL) can be estimated using these correlations and corresponding streamflow. Regression equations were developed using the initial (or whole water) turbidity (independent variable) and the turbidity after 8.5 hours of particle settling (dependant variable). That is, the instream turbidity values are converted to persistent-turbidity values and used to compute suspended-clay concentration in the same manner as with computing suspended-sediment concentration. SCLs are computed using the suspended-clay concentrations. A comparison of annual SSLs and SCLs is shown in Figure 2B. The SCLs were 10 to 20 percent of the SSLs for all sites and years.

Data presented from this study will assist the City of Salem water treatment planners in understanding the water quality of their watershed and municipal managers in allocating drinking-water supplies from surface-water sources with persistent turbidity problems.

References

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