Report as of FY2007 for 2006WA157B: "Developing a Sediment Model for Use in the TMDL Processes in the Inland Northwest"

Publications

Project 2006WA157B has resulted in no reported publications as of FY2007.

Report Follows

PROBLEM AND RESEARCH OBJECTIVES

Washington State is still facing water quality issues as nearly 650 water bodies in the state are failing to meet water quality standards due primarily to end of pipe discharges from point sources within cities and industries and diffuse runoff from non-point sources. The Total Maximum Daily Load (TMDL) program was established by the Clean Water Act as a process to regulate both point sources and non-point sources so that the integrity of the water quality could be protected. A TMDL is a calculation of both the maximum amount of a pollutant that a water body can receive and still meet water quality standards and an allocation of that amount to the pollutant's sources. The Washington Department of Ecology has until 2013 to develop and implement TMDLs for the state's nearly 650 polluted water bodies.

Most impaired water bodies are affected by more than one pollutant, among which sediment has been identified as a primary pollutant. Besides direct environmental impact, sediment is often the carrier for other pollutants such as nutrients and bacteria. Sediment allocation is thus an important component in many efforts of TMDL development, including that in Washington State. Because of difficulties in direct measurement of sediment amount, science based technical tools such as mathematical models have become essential in the TMDL process, as well as in the planning, design, and implementation of watershed projects. Unfortunately, mathematical models that are well accepted for sediment prediction required in TMDL development are limited. For example, in the models listed by the Washington Department of Ecology for TMDL studies (http://www.ecy.wa.gov/programs/eap/models/), sediment models that are considered applicable to Washington are lacking. This is mainly due to the fact that the land use and climatic uniqueness of the region cause models developed for other regions to not perform well in this region without modifications.

The limitations in using other regional models such as USLE/RUSEL for the Inland Northwest become clear by noting the needs of the TMDL process as well as the unique conditions under which erosion events occur. First, the application of an annual based model for TMDL development is questionable, as the major erosion events of the Inland Northwest occur primarily in winter time. Second, the use of an event erosivity factor, EI_{30}, is not suitable, as a large portion of the erosion events of this region occur as a result of snow melt or rain on snow and with low rain intensity. Third, although by changing the annual based erosion prediction to event based prediction, and by considering runoff volume, MUSLE represents an improvement to USLE/ RUSLE for application in TMDL development, rain on snow and/or melting under frozen soil conditions in this region will have a significant impact on the sediment produced from a watershed compared with rain on unfrozen soil. Therefore, verification and modification of the above models is necessary for their applications to this region. The primary objective of this project is collecting data from a watershed in the Inland Pacific Northwest to verify the practicality of the existing model in this region and prepare the data set for modifying the model.

METHODOLOGY

The study was conducted on Dartford Creek Watershed, a subwatershed of the Little Spokane River Watershed. Data collection focused on runoff hydrography and sediment yield. A sampling station was installed at the outlet of the Dartford Creek Watershed. The station included a continuous flow sensor and an automatic sampler. An ISCO automatic water sampler (6712) was installed for sediment sample collection, flow water level and rainfall recording. Samples were automatically collected after each storm event. Manual (hand grab) samples were also collected as reference and complementary. All the samples were transported back to the Water Quality and Waste Analysis Lab at WSU for analysis of sediment concentration. Two sampling programs, A and B, were implemented. Program A was for the event period and the interval of sampling was every two hours. Program B was for the background/baseflow period, the interval sampling was every three days. Sampling criterion was adjusted according to the water level change to obtain the sediment samples with different water levels (different flow rate). Additional devices were installed for water level measurements. The continuous flow recorder installed was self-contained pressure transducers and loggers that record the water depth at an interval of every 15 minutes. It consisted of the Water Level Logger (WL15) from Global Water Instrumentation. The data were downloaded to a PC periodically. A correlation between flow rate and water depth called a "rating curve" (a stage-discharge relationship) was established using the data obtained from a series discharge measurements made according to the USGS midsection method.

A weather station was also installed at the watershed, where precipitation, wind speed and direction, air and soil temperatures were the major parameters monitored.

The field data was processed to derive important relationships on sediment yield. The data processing mainly involved the conversion of measured water levels to discharge rate, the delineation of storm events from the discharge rate, and the estimation of total sediment yield from the discharge data and the sediment concentration. After the data was processed, mathematical manipulations were performed to verify the Modified Universal Soil Loss Equation (MUSLE):

$$SY_e = X_e KLSC_e P_e \qquad (1)$$

where SY_e is the event total sediment yield. Additionally,

$$X_e = \alpha(Q_e q_p)^{0.56} \qquad (2)$$

where α is an empirical coefficient which is independent of climate, soil, vegetation, conservation practice, or management; Q_e is runoff amount and q_p is the peak runoff rate obtained during the erosion event; and *K*¸ *L*, and *S* are as defined for the USLE with *C*e and *P*e being event *C* and *P* values.

Due to the fact Equation (2) is the key of MUSLE, the data analysis was focused on verifying the relationship. With taking natural logarithm to both sides of Equation (2), the following equations were obtained:

$$\mathrm{Ln}(SY_e)=0.56\mathrm{Ln}(Q_e q_p) + M \qquad (3)$$

$$\mathrm{Ln}(SY_e)=a\mathrm{Ln}(Q_e q_p) + M \qquad (4)$$

For each event, SY_e value was calculated from the flow and sediment data collected at the outlet of the watershed. The values of Q_e and q_p were also measured at the outlet. The slope of the linear regression of Equation (4) will define the coefficient "a" which in turn can be compared with the existing value (0.56) used in the current MUSEL model.

PRINCIPAL FINDINGS AND SIGNIFICANCE

Major findings of the project results can be summarized in three aspects, including (1) sediment yields, (2) discrepancy with the existing MUSEL model, and (3) analysis of relative impact of discharge versus peak flow rate upon sediment yield.

Sediment yields

Total 14 events were measured during the 2006-2007 winter season with discharge rate ranging from 319,510 ft^3 to 3154760 ft^3. The peak discharges ranged from 3.11 ft^3/s to 6.86 ft^3/s. Significant amount of sediments was produced from each of these events, ranging from 0.4 to 16 metric tons.

Comparisons with MUSEL

The relationship between sediment yield and the product of total event discharge and peak flow is illustrated in Figure 1. Regression equation indicates that the value of "a" as in Equation (4) is 0.934. The current value used in MUSEL is 0.56. The results obtained in this study suggest that a modification to the MUSEL model may be necessary for use in TMDL in the Inland Pacific Northwest in terms of the coefficient.

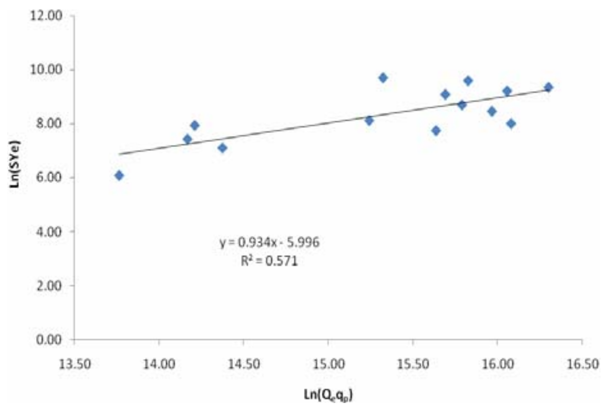

Figure 1. Correlation between sediment yield and product of total event discharge and peak flow

It can be noted that the R^2 value of the above correlation was not high. One contributing factor to the variations might be the fact that these events were different in ways they occurred. According to the weather station data and field records, some of these events were caused by rain, some by snow melt, and some by rain on snow. The soil conditions also varied, as for some events the field was frozen and non-frozen for others.

Impact of discharge versus peak flow rate upon sediment yield

The relative impact of the total event discharge on sediment yield is presented in Figure 2 in comparison with that of peak flow (Figure 3). It can be seen from the coefficients of the correlation equations that peak flow had more significant impact on the total sediment yield than that of total discharge of the event. These results may provide some insight as to the nature of the erosion process of the watershed, whether the process is limited by the detachment or transport of the soil particles in the upland areas.

It needs to be pointed out that multi-year data are required for watershed modeling studies. Due to the limitation of the project scope, data from a single season was collected and used for the above analysis. Therefore, the results presented here are preliminary in nature. Further verifications are recommended before the results are used for this and other similar watersheds.

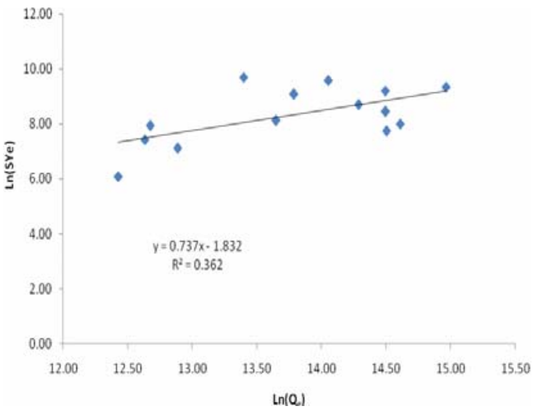

Figure 2. Sediment yield versus total discharge

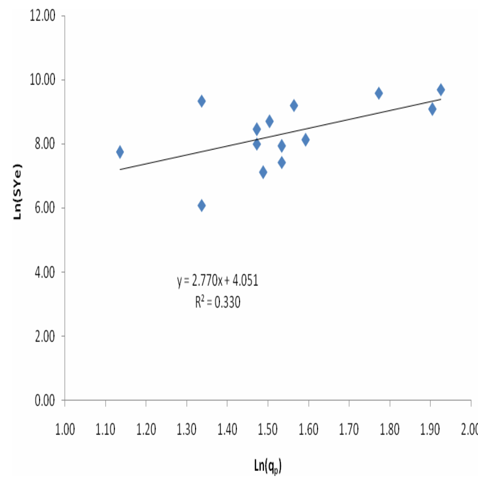

Figure 3. Sediment yield versus peak flow