U.S. Department of Transportation
Federal Highway Administration

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The Stochastic Empirical Loading and Dilution Model (SELDM)

The new Federal Highway Administration runoff-quality model

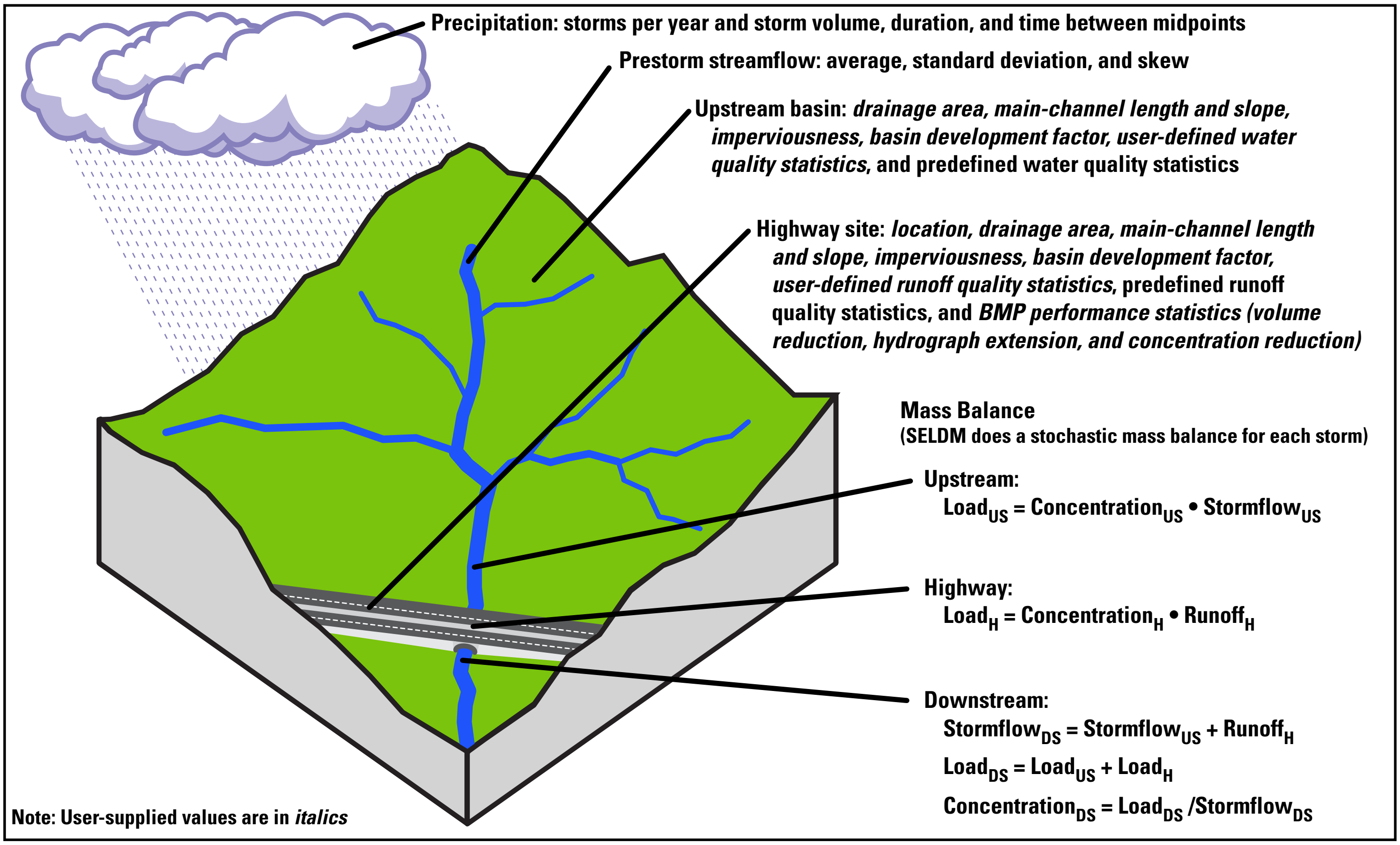

Figure 1. Schematic diagram showing an upstream basin, a highway site, and the hydrologic variables used to do a SELDM analysis.

The Stochastic Empirical Loading and Dilution Model (SELDM) is designed to transform complex scientific data into meaningful information about the risk of adverse effects of runoff on receiving waters, the potential need for mitigation measures, and the potential effectiveness of such management measures for reducing these risks. The U.S. Geological Survey developed SELDM in cooperation with the Federal Highway Administration to help develop planning-level estimates of event mean concentrations, flows, and loads in stormwater from a site of interest and from an upstream basin. Planning-level estimates are defined as the results of analyses used to evaluate alternative management measures; planning-level estimates are recognized to include substantial uncertainties. SELDM uses information about a highway site, the associated receiving-water basin, precipitation events, stormflow, water quality, and the performance of mitigation measures to produce a stochastic population of runoff-quality variables. SELDM provides input statistics for precipitation, prestorm flow, runoff coefficients, and concentrations of selected water-quality constituents from National datasets. Input statistics may be selected on the basis of the latitude, longitude, and physical characteristics of the site of interest and the upstream basin. The user also may derive and input statistics for each variable that are specific to a given site of interest or a given area.

SELDM is a stochastic model because it uses Monte Carlo methods to produce the random combinations of input variables needed to generate the stochastic population for each input and output variable. SELDM uses the individual concentrations, flows, and loads to calculate the dilution of runoff in the receiving waters and the resulting downstream event mean concentrations. SELDM groups individual events by year to calculate a population of annual loads. SELDM uses annual flows and loads with constituent-specific attenuation factors to calculate annual average lake concentrations. Results are ranked, and plotting positions are calculated, to indicate the level of risk for adverse effects in receiving waters by storm and by year. The BMP module can be used to assess the potential for minimizing such risks. Unlike deterministic hydrologic models, SELDM is not calibrated by changing values of input variables to match a historical record of values. Instead, input values for SELDM are based on site characteristics and representative statistics for each hydrologic variable. Thus, SELDM is an empirical model based on data and statistics rather than theoretical physiochemical equations.

SELDM is a lumped parameter model because the highway site, the upstream basin, and the lake basin each are represented as a single homogeneous unit. Each of these source areas are represented by average basin properties, and results from

SELDM are calculated as point estimates for the site of interest. Use of the lumped parameter approach facilitates rapid specification of model parameters to develop planning-level estimates with available data. The approach allows for parsimony in the required inputs to and outputs from the model and flexibility in the use of the model. For example, SELDM can be used to model runoff from various land covers or land uses by using the highway-site definition as long as representative water quality and impervious-fraction data are available. In addition, the highway-site definition can be used to form conceptual runoff models with a unit drainage area and an impervious fraction to calculate annual loads for different highway sites or land covers. For example, if data for constituent concentrations representing runoff from different road classes or land covers are generated for a generic one-acre site, then the estimated annual loads per unit area can be used with a geographic information system (GIS) program to estimate total loads from the sum of different contributing areas in a watershed.

To calculate the concentrations, flows, and loads required for the mass-balance analyses (figure. 1), SELDM calculates values for 17 primary environmental variables, 15 of which are modeled as stochastic variables. For each storm, the volume of highway-runoff is calculated by using precipitation and highway runoff coefficient statistics. The timing of runoff from the highway is calculated as a function of site characteristics, a fixed hydrograph-recession ratio equal to one, and storm duration. If BMP modifications to the highway runoff are specified, then the timing and volume of runoff from the BMP also is calculated. The volume of upstream stormflows is calculated by using prestorm-flow, precipitation, and runoff coefficient statistics for the upstream basin. The timing of runoff from the upstream basin is calculated as a function of site characteristics, a stochastic hydrograph-recession ratio, and the storm duration. Dilution in the receiving water is calculated by using the volume of upstream flow that coincides with untreated highway runoff and the BMP discharge. The concentrations of highway-runoff and upstream constituents are stochastic variables that can be calculated as purely random variables or dependent variables (defined as a function of another constituent). Upstream concentrations also may be modeled as a function of upstream stormflow (the transport curve).

The primary hydrologic variables are precipitation, runoff coefficients, prestorm streamflow, and water quality. SELDM uses Monte Carlo methods to calculate the precipitation volume, precipitation duration, and the time to the next storm-event midpoint for each storm as a stochastic variable. The statistics available in SELDM for storm-event characteristics were based on data from the 2,610 selected National Weather Service hourly-precipitation data stations in the conterminous United States. Runoff coefficients are used with the randomly generated precipitation volumes to calculate the volume of runoff from the highway site and the upstream basin for each storm. Runoff coefficient statistics were calculated by using rainfall-runoff data from 58 highway-runoff monitoring sites and 167 other storm-runoff monitoring sites with 9 or more storm events. SELDM is designed to calculate prestorm streamflow volumes from the basin upstream of the highway-runoff mixing point for each storm as a stochastic variable. The prestorm streamflow statistics available in SELDM were calculated by using data from the 2,783 selected U.S. Geological Survey streamgages in the conterminous United States. Estimates of highway and upstream stormwater concentrations and loads are needed for using a mass-balance approach to predict the potential effects of runoff on receiving waters. Highway-runoff quality data and statistics are available in the Highway Runoff Database (HRDB) developed as part of this project. The latest version of the HRDB has 54,384 EMC measurements of 194 water-quality constituents monitored at 117 sites during 4,186 storm events. The SELDM-development project also provided upstream-water quality data; in this project data-mining and analysis techniques to identify and compile more than 1,876,000 paired streamflow and water-quality measurements that included 21 constituents commonly measured in highway and urban runoff studies. These data and statistics are available for modeling the potential effects of runoff on receiving waters of the United States.

References: (Please see the project web page: http://webdmamrl.er.usgs.gov/g1/fhwa/SELDM.htm)

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Training:

There will be classroom training on the model for FHWA, state DOTs, and regulators in Washington DC during April 2014 and in Portland OR during May 2014. There will be on-line training sessions throughout 2014 that are open to everyone.