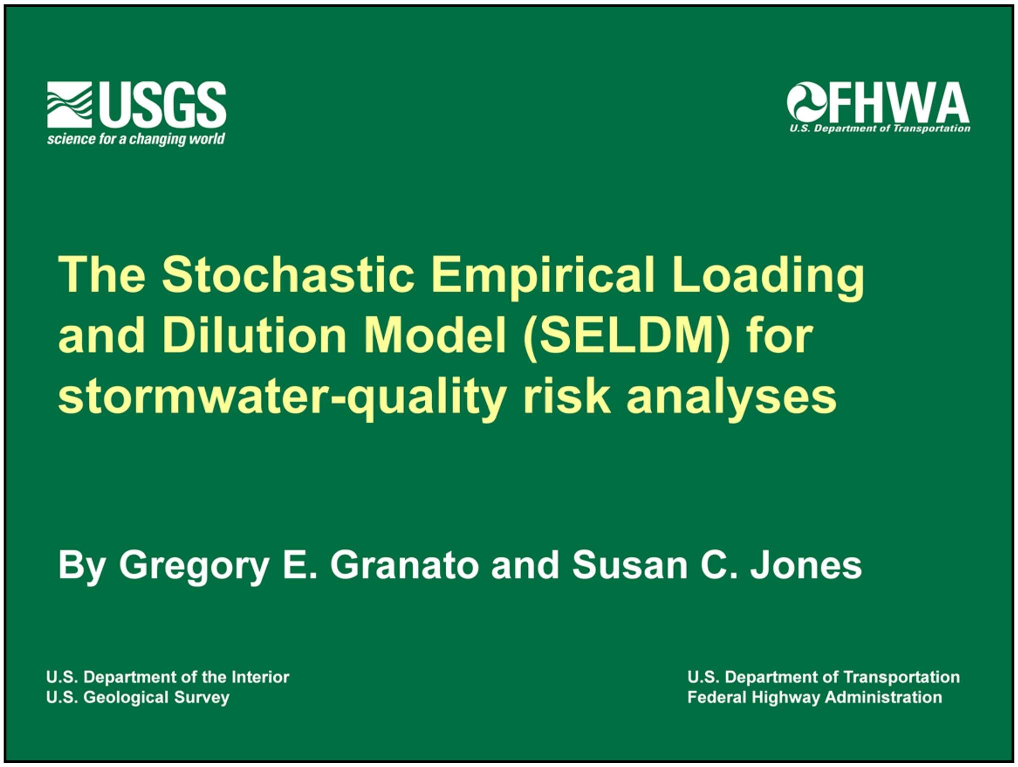

The Stochastic Empirical Loading and Dilution Model (SELDM) was designed for analysis of stormwater quality from a site of interest, its upstream basin, and the receiving water downstream of the outfall. SELDM was developed by the US Geological Survey in cooperation with the Federal Highway Administration to provide a tool for estimating the risk for adverse effects of runoff on receiving waters and the potential effectiveness of best management practices for reducing those risks. Nominally, SELDM is a highway runoff model, but it can be used to model runoff from diverse sites by using representative water-quality data and a few simple basin characteristics.

Today, I'll provide a brief overview of the model and illustrate its use with a case study

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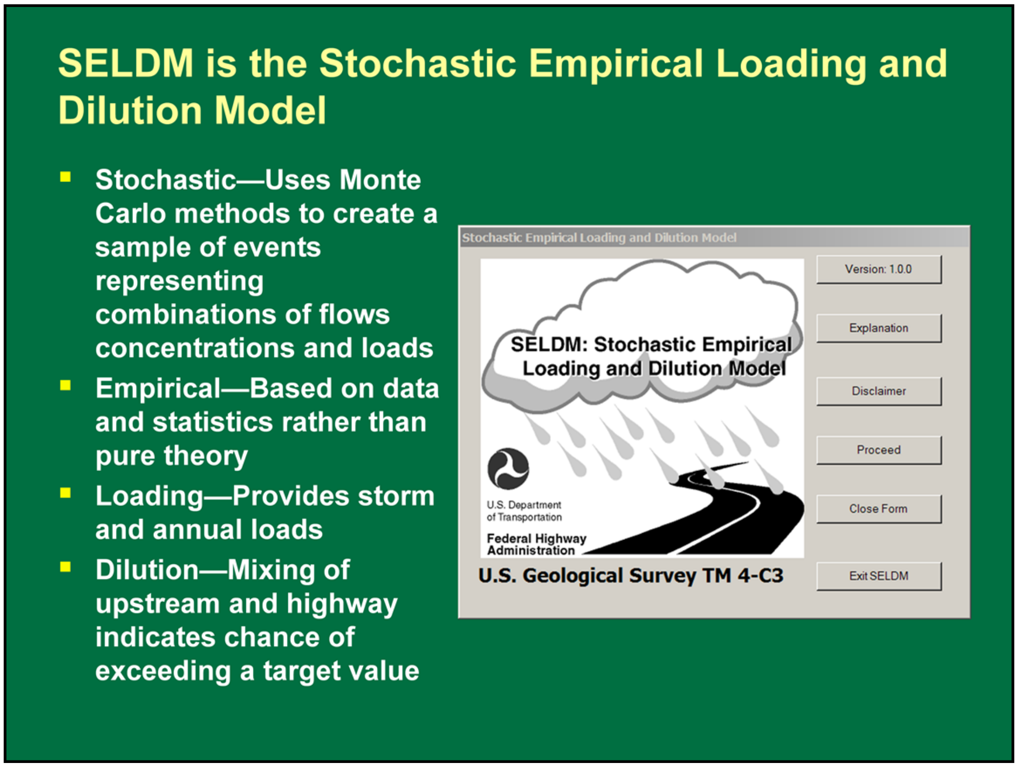


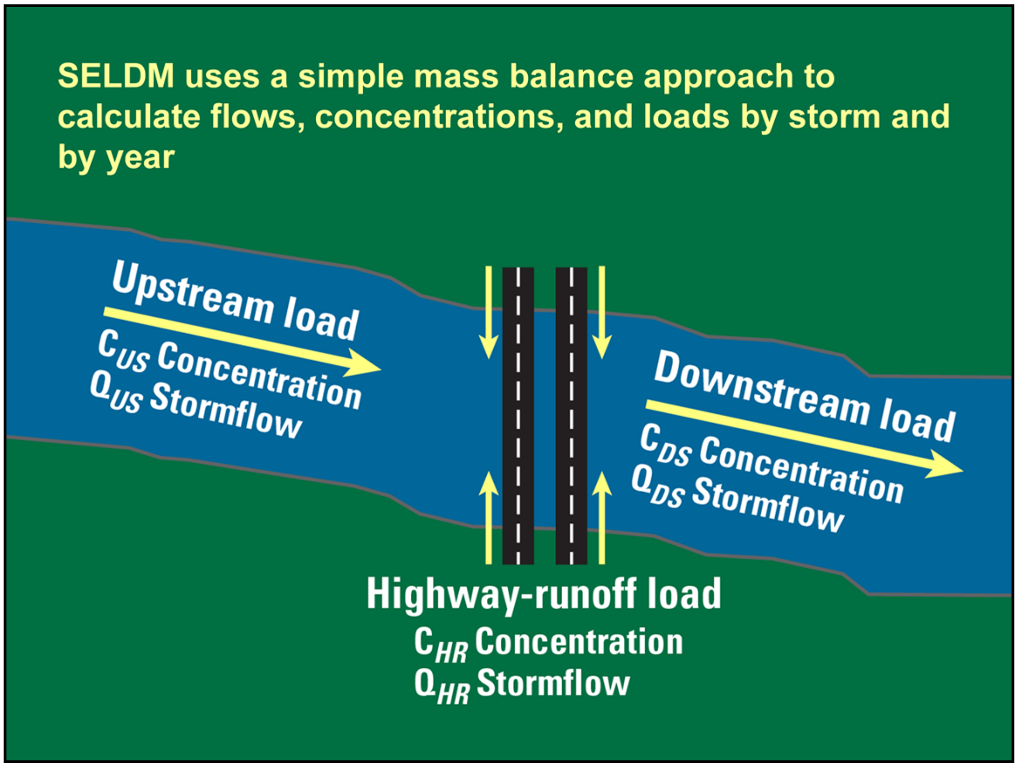
SELDM is

- A stochastic model because it uses Monte Carlo methods to create a sample of events representing combinations of flows, concentrations, and loads. It randomly generates the variables needed to model hundreds to thousands of storm events and provides probabilistic information that can be used to assess the risks for adverse effects of runoff and the potential effectiveness of mitigation measures

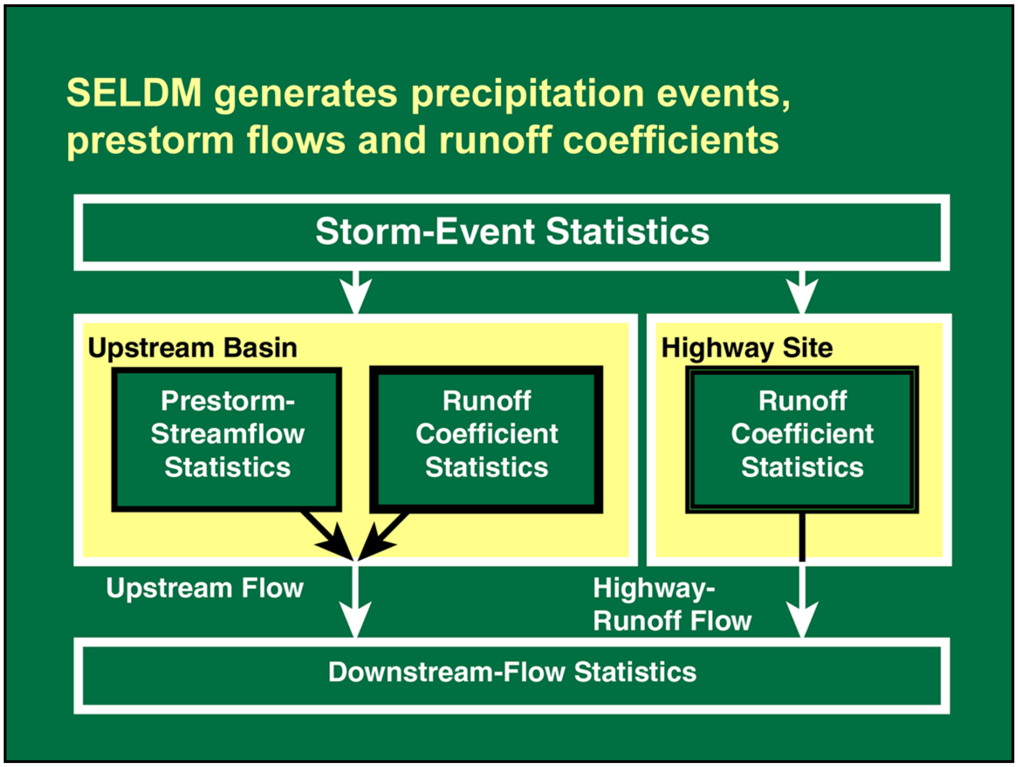
* It is an empirical model because it is based on data and statistics rather than pure theory; for example the amount of runoff is calculated by using runoff-coefficient statistics developed with data from hundreds of sites rather than by simulating surface storage, infiltration, and evaporation during each storm

* It is a loading model because it provides storm and annual loads

* It is a dilution model because it calculates the mixing of upstream and highway runoff to indicate chance of exceeding a target concentration or load downstream of the outfall.



SELDM uses a stochastic mass balance approach to calculate flows, concentrations, and loads by storm and by year. This schematic diagram represents the mass balance at the highway-runoff outfall. SELDM generates and outputs a population of hundreds to thousands of individual storm events. The loads for each storm are the product of concentrations and flows. If a BMP is specified, the volume, duration, and quality of the runoff that enters the stream is modified for each storm. The upstream flows, concentrations, and loads are calculated to be concurrent to the highway runoff and BMP discharge. The downstream flow and load for each storm event is the sum of the upstream and highway values for that storm. Downstream concentrations are calculated by dividing the downstream load by the downstream flow.



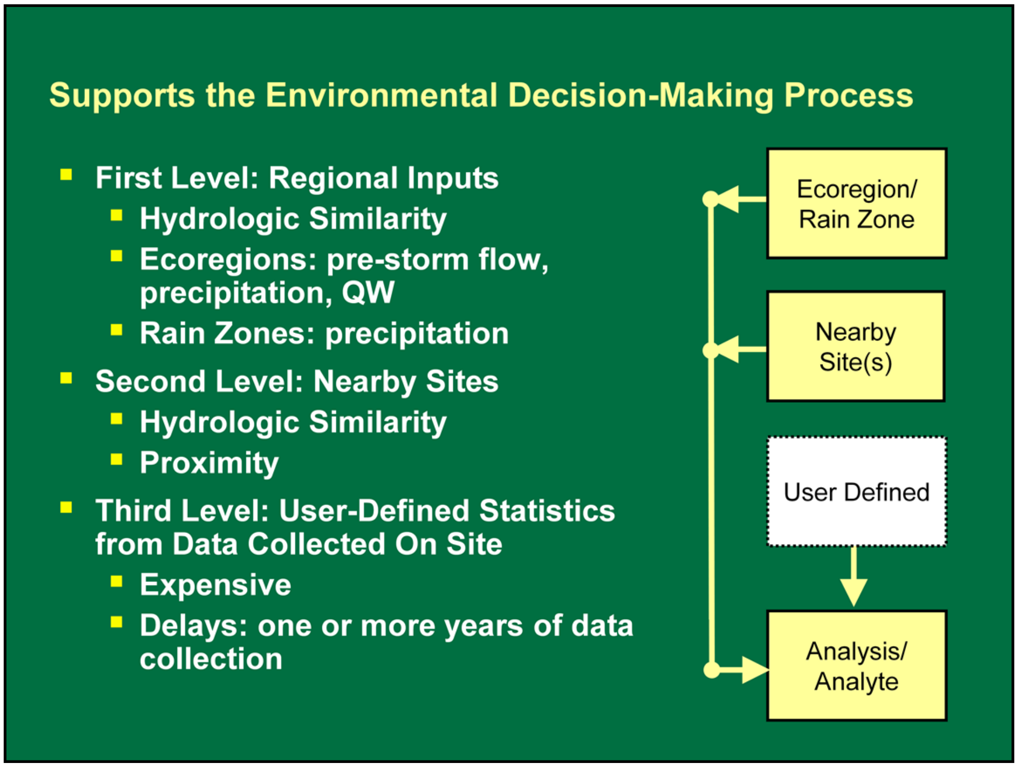
This diagram shows the components of upstream flows and highway-runoff flows that combine to define the downstream flow statistics. The precipitation, prestorm flow, and runoff-coefficient statistics are preloaded in SELDM for you.

The storm event statistics determine the duration, volume, and time between event midpoints for each generated storm. The times between midpoints are used to aggregate storms into annual load accounting years.

The stormflows from the upstream basin are comprised of prestorm flows and storm-event runoff volumes. For each storm, the prestorm flow is generated by using streamflow statistics from USGS gaging stations. The runoff is calculated by multiplying the drainage area by the stochastic precipitation volume and the stochastic runoff coefficient. The runoff coefficient statistics are calculated from the imperviousness of the upstream basin.

The stormflows from the highway site are calculated by multiplying the drainage area by the stochastic precipitation volume and the stochastic runoff coefficient for each storm. The runoff coefficient statistics are calculated from the imperviousness of the highway site. The timing and volume of runoff from the highway site may be modified by use of BMP treatment statistics, which we are calculating from data in the international BMP database.

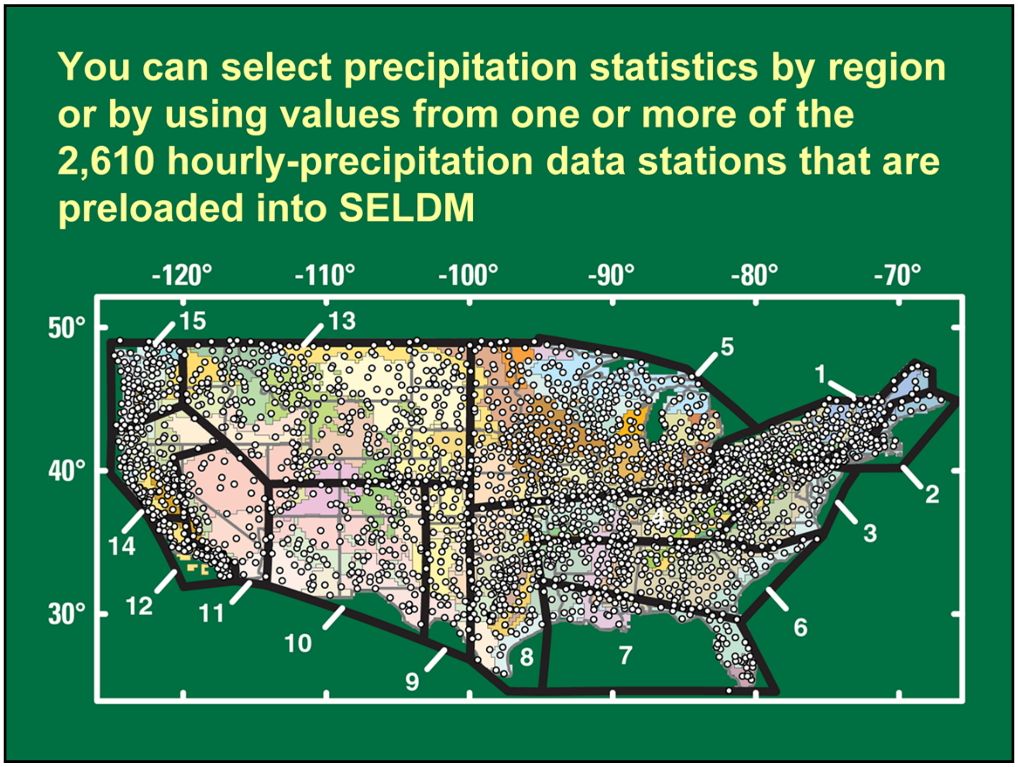
The concurrent highway and upstream flows are added together to determine the downstream stormflow volumes.



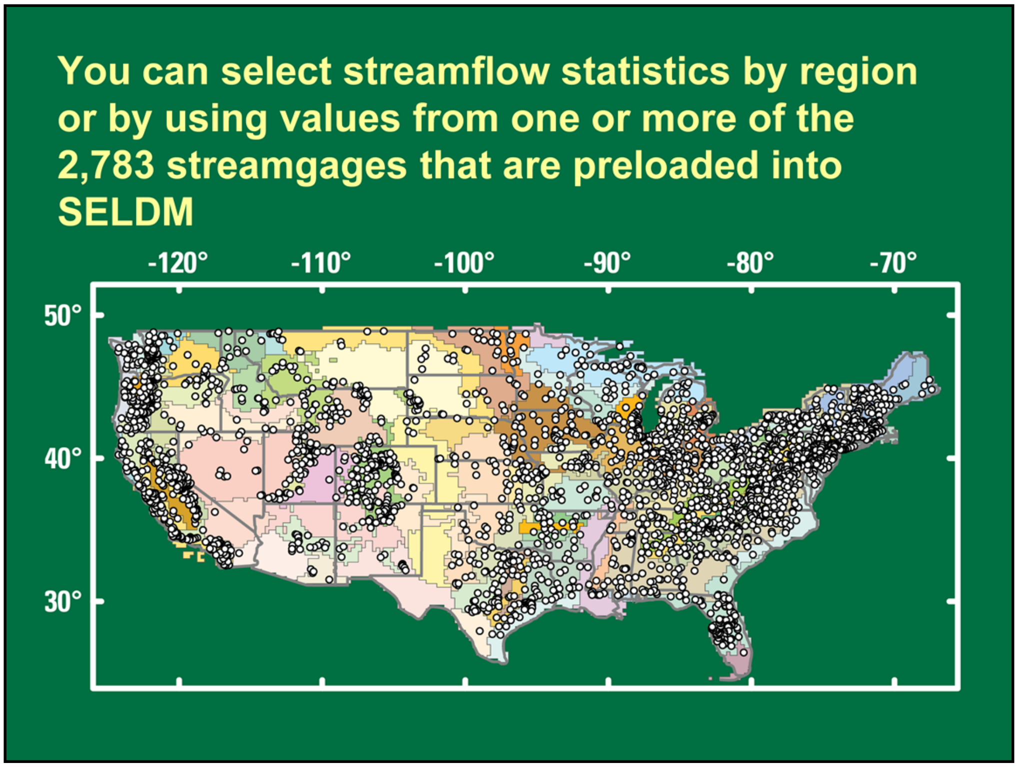
SELDM supports the environmental decision-making process because it is preloaded with many of the statistics needed to do a planning-level analysis. When faced with questions about potential effects of runoff at a site we can do a first level analysis by entering a few simple site characteristics and the latitude and longitude of the site. For a level 1 analysis, we can select the precipitation statistics by ecoregions or rain zones and we can select prestorm flow statistics and water-quality statistics by ecoregion. If the risks for adverse effects are very low, we may stop with a level 1 analysis.

If there is some concern, we can proceed with a level 2 analysis. In this case we can use the site coordinates to select statistics from one or more nearby sites. If this analysis indicates that the risks for adverse effects are very low, we may stop with a level 2 analysis. If the risks are deemed to be too high, we can accept these results and use SELDM to asses the potential for mitigating the adverse effects with various BMPs or move on to a level 3 analysis.

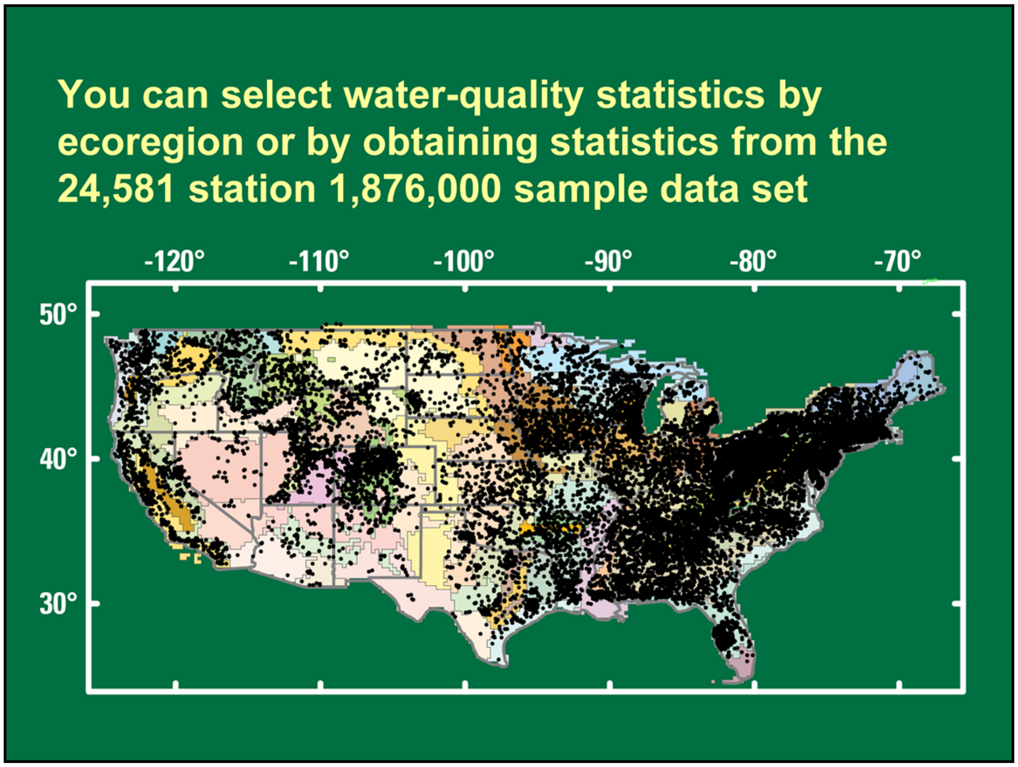
If the site is highly sensitive or if decisionmakers are not comfortable with results from predefined statistics we may need to proceed with a level 3 analysis, which includes data collection and use of at-site statistics calculated and entered by the user. A level 3 analysis could include use of some predefined statistics and some user-defined statistics as appropriate. If you have to collect defensible data at a site of interest, this will cause substantial delays and cost increases that will be orders of magnitude greater than the initial modeling effort.



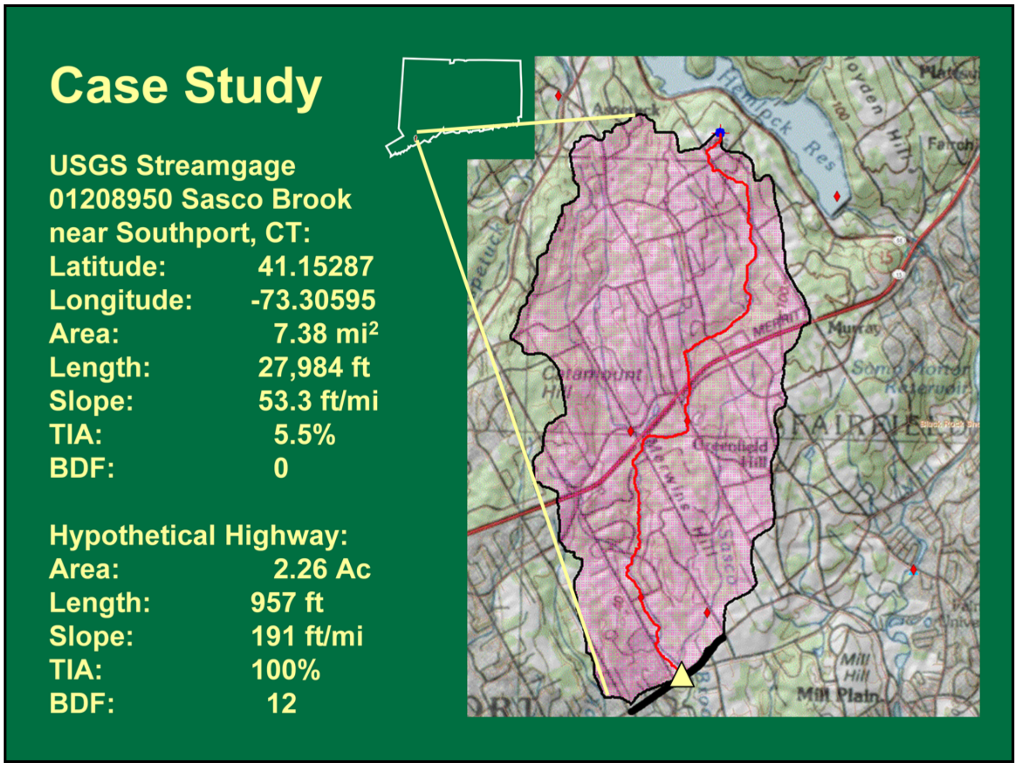
This is a map showing the ecoregions, the rain zones and the location of selected precipitation data stations that are preloaded into SELDM for calculating precipitation statistics. The dark black lines are the boundaries of the 15 EPA rain zones. The colored polygons are the EPA ecoregions. If I was doing a level 1 analysis in northern Nevada I may choose Rain zone 11 or ecoregion 13, which is the dark pink area. If I wanted to do a level 2 analysis, I could use statistics from one or more nearby sites. For example if my site was located here, I could use statistics from one or more of these three sites.



This is a map showing the ecoregions and the location of the selected USGS streamgages used to calculate prestorm flow statistics. As with the precipitation statistics, I can select the regional values or values from one or more nearby sites.



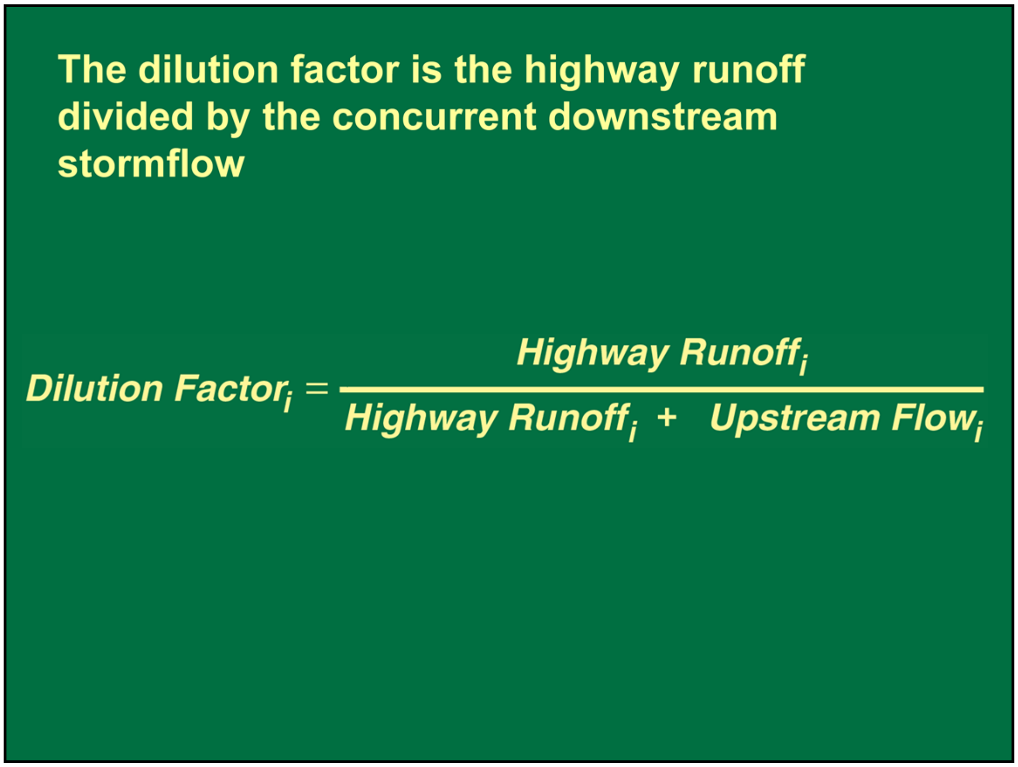
This is a map showing the ecoregions and the location of USGS water quality monitoring sites with paired streamflow and water-quality measurements. The data for 24 constituents commonly measured in highway- and urban-runoff studies were compiled for use with SELDM. Water-quality transport curves, which are relations between flow and concentration were developed by ecoregion for sediment, total phosphorus, and total hardness. Random water-quality statistics were developed by ecoregion for pH.



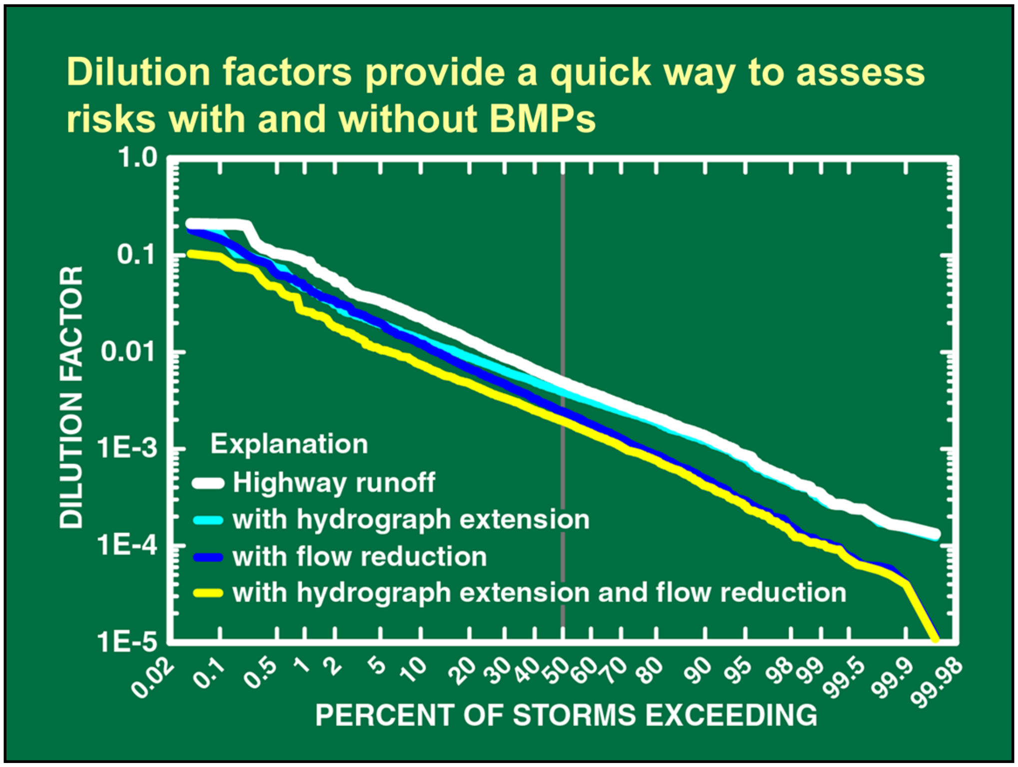
To demonstrate the information that SELDM can provide, I'll use data from the Sasco Brook basin to look at results for total phosphorus. We picked this basin because it is small, largely rural, and does not have point-sources. Also, it has water-quality data collected over a large range of flows.

In this hypothetical scenario we will model the road as if it is a 4-lane highway with a trunkline drainage system. To use SELDM you need representative water-quality data, the latitude and longitude of the road crossing, and 5 simple basin characteristics. These characteristics are the drainage area, the main channel length, the main channel slope, the total impervious area, and the BDF which is the basin development factor. The BDF ranges from 0, which represents a completely natural drainage system to 12, which indicates that 50 percent or more of the area has engineered drainage features.

The index map shows the location in southwestern CT. The basin map, which was generated with the USGS streamstats application shows the drainage divide in black and the area in red. The main channel is shown as the dark red line from the gaging station, which is the yellow triangle at the bottom to the drainage divide. The black line at the bottom is the hypothetical highway site, which runs from topographic divide to topographic divide.



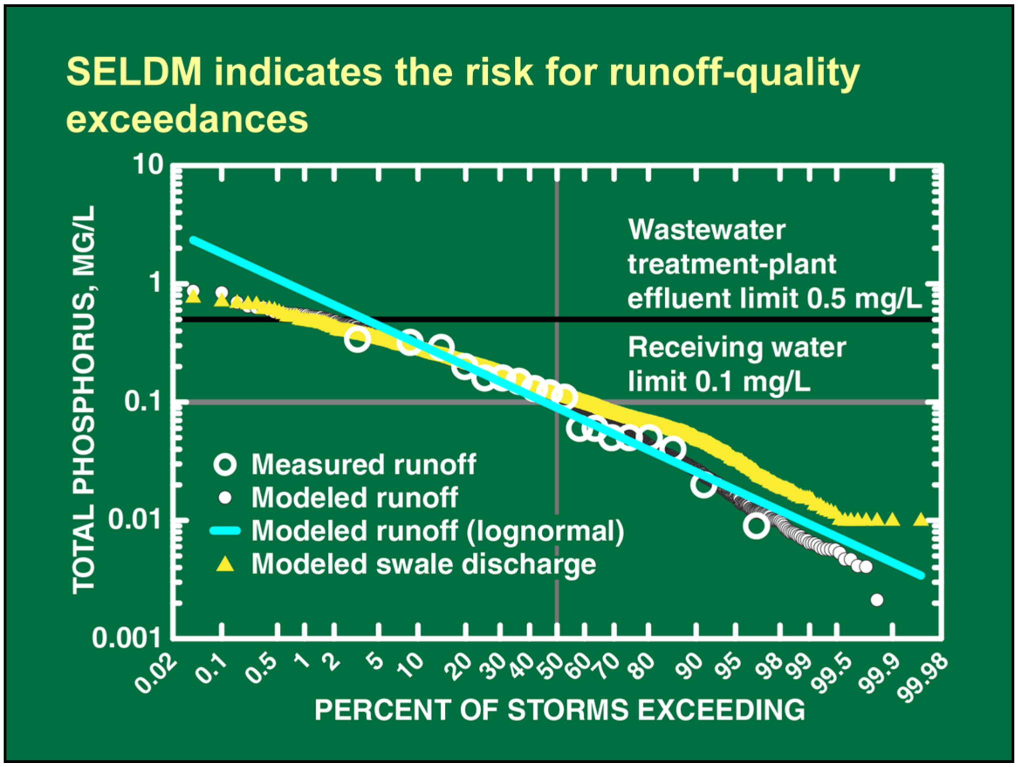
One output from SELDM is a file of dilution factors for each storm. The dilution factor is the highway runoff divided by the concurrent downstream stormflow. The dilution factor provides a quick assessment of the potential for adverse effects of runoff in receiving waters. A dilution factor of one indicates that the downstream flow is all highway runoff. A dilution factor near zero indicates that the highway runoff is a negligible portion of the downstream flow.



SELDM provides a population of dilution factors with and without use of BMPs. The dilution factors provide a way to quickly assess risks for water-quality exceedances. If an engineer must look at many outfalls the dilution factors can be used to focus on the most vulnerable sites. This graph shows the potential effectiveness of a grassy swale for modifying downstream stormflows. The vertical axis is the dilution factor on a logarithmic scale ranging over five orders of magnitude. The horizontal axis is a probability scale indicating the percentage of storms with dilution factors that equal or exceed a given value. The white line shows the dilution factors from highway runoff that would occur at the outfall without BMP treatment. During this 28 year simulation, these dilution factors range from about 10 to the -4 to 0.2 (or 20 percent). Highway runoff is about 11 percent of the downstream flow at the 0.5 percent exceedance, which is the commonly used 3-year exceedance period.

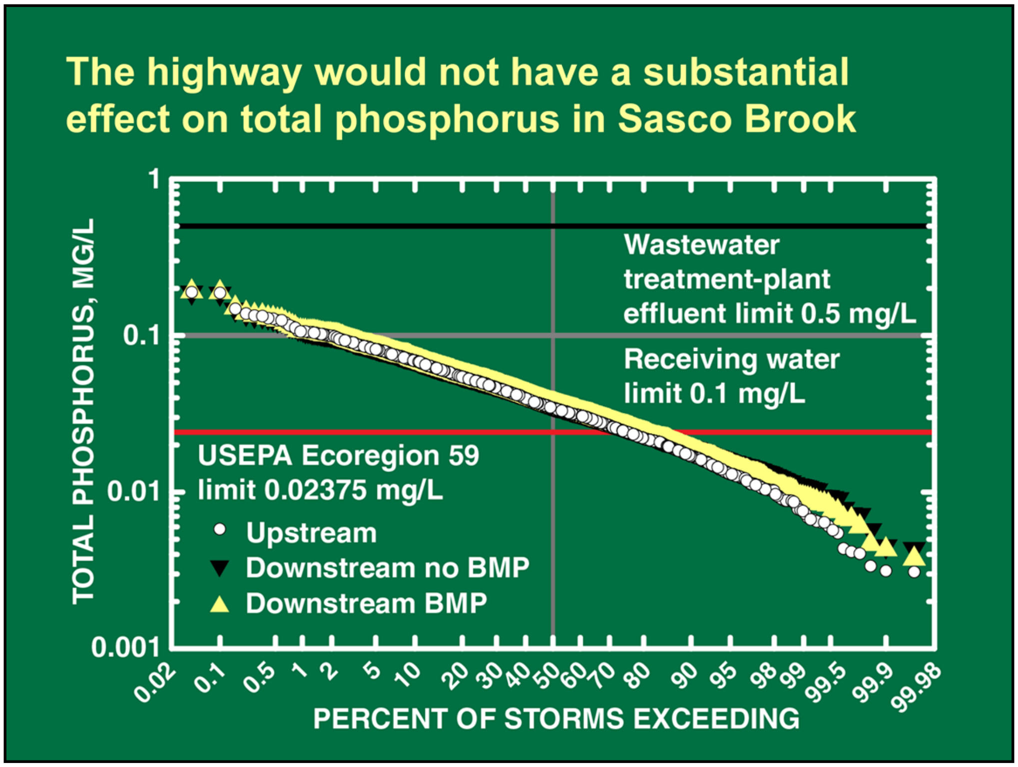
The light blue line represents potential effects of stochastic hydrograph extension values from a swale. When you extend the outflow hydrograph you dilute the highway runoff into a larger proportion of the upstream stormflow. The dark blue line represents potential effects of stochastic flow reduction. The yellow line shows the dilution factors that would result if both extension and reductions are modeled. The grassy swale dilution factors range from about 10 to the -5 to 0.11 (or 11 percent). At the 0.5 percent exceedance BMP discharge is about 5.2 percent of the downstream flow.

This dilution factor analysis indicates that on average, grassy swales may reduce the proportion of highway runoff in downstream flows by more than half. As indicated by the blue lines most of this benefit results from the flow reduction. This is because the residence time in a swale is short. Similar analyses using statistics for other BMP types would indicate the relative effectiveness of those BMPs for reducing the proportion of highway runoff in concurrent downstream stormflows.



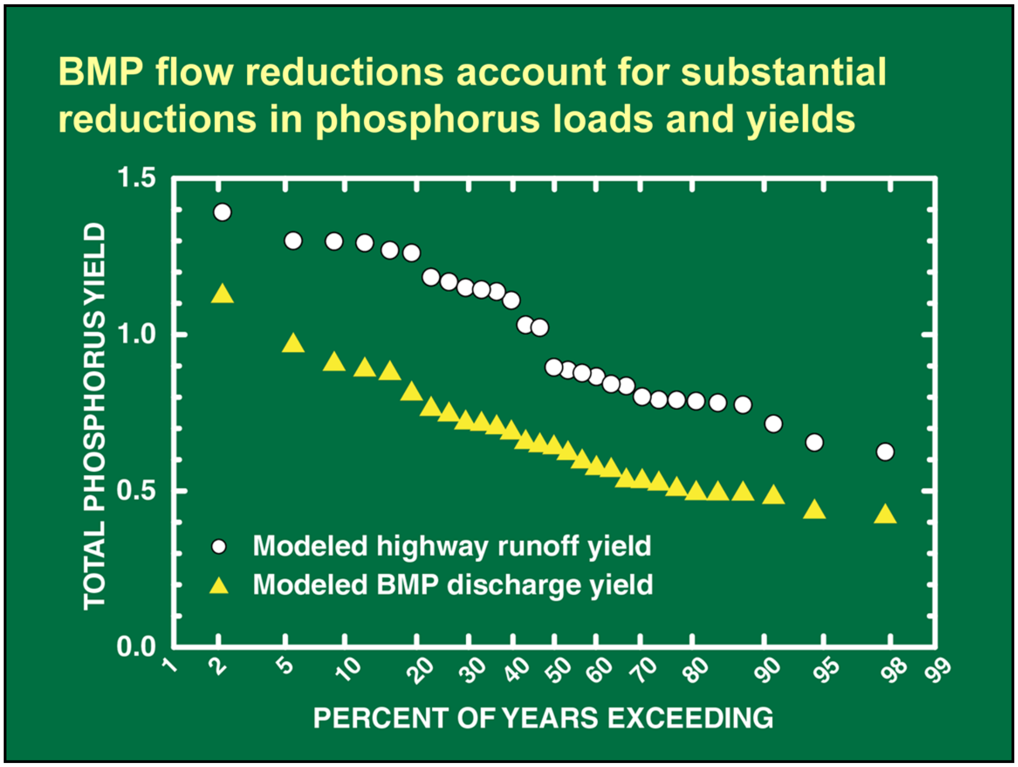
This graph shows how SELDM can be used to assess the risk for runoff quality exceedances. In this graph, the vertical axis is the total phosphorus concentrations on a logarithmic scale ranging over four orders of magnitude. The horizontal axis is a probability scale indicating the percentage of storms with concentrations that equal or exceed a given value. The large white circles are concentrations measured along State Route 2 in Massachusetts. The small white circles are the 1,645 values generated by using the mean, standard deviation, and skew of the logarithms of measured concentration. Use of the negative skew term from the data results in a modeled population that is concave down. In comparison, the light blue line is the theoretical lognormal distribution of highway runoff concentrations. In comparison to the measured and modeled data, use of the straight-line lognormal distribution overestimates values at the ends of the distribution. The yellow triangles are the modeled swale-effluent concentrations, which are greater than the pavement runoff values in about 70 percent of storms. The minimum irreducible concentration for the swale, which represents the best possible effluent concentration, appears as the horizontal line of storm values at 0.01 mg/L on the right side of the plot. The grassy swale concentrations may be greater than pavement-runoff concentrations during many storms because the vegetation and other organic matter in the swale can contribute phosphorus to the runoff.

The two horizontal lines on this graph are water-quality guidelines for total phosphorus. The upper black line at 0.5 mg/L was a commonly used wastewater effluent limit. This simulation indicates that the risk of exceeding the 0.5 mg/L value is about 1.68 percent for modeled runoff, 3.85 percent for lognormal, and 0.9 percent for swale effluent concentrations. The gray line at 0.1 mg/L is a water-quality guideline for running waters. This simulation indicates that the risk of exceeding the 0.1 mg/L value is about 51 percent for modeled runoff, 45 percent for lognormal, and 59 percent for swale effluent concentrations.



This graph shows the modeled concentrations of total phosphorus in Sasco Brook upstream and downstream of the hypothetical highway outfall. As with the last graph, concentrations are on the vertical axis and storm-event exceedance probabilities are on the horizontal axis. The upstream concentrations, which were calculated by using a site-specific water-quality transport curve are shown as white circles. The black triangles are the downstream concentrations without the BMP. The yellow triangles are the downstream concentrations with the BMP. The upstream concentrations range from about 0.003 to 0.19 mg/l. The downstream concentrations range from about 0.004 to 0.19 mg/l. In this scenario highway runoff does not have a substantial effect on phosphorus concentrations in the stream

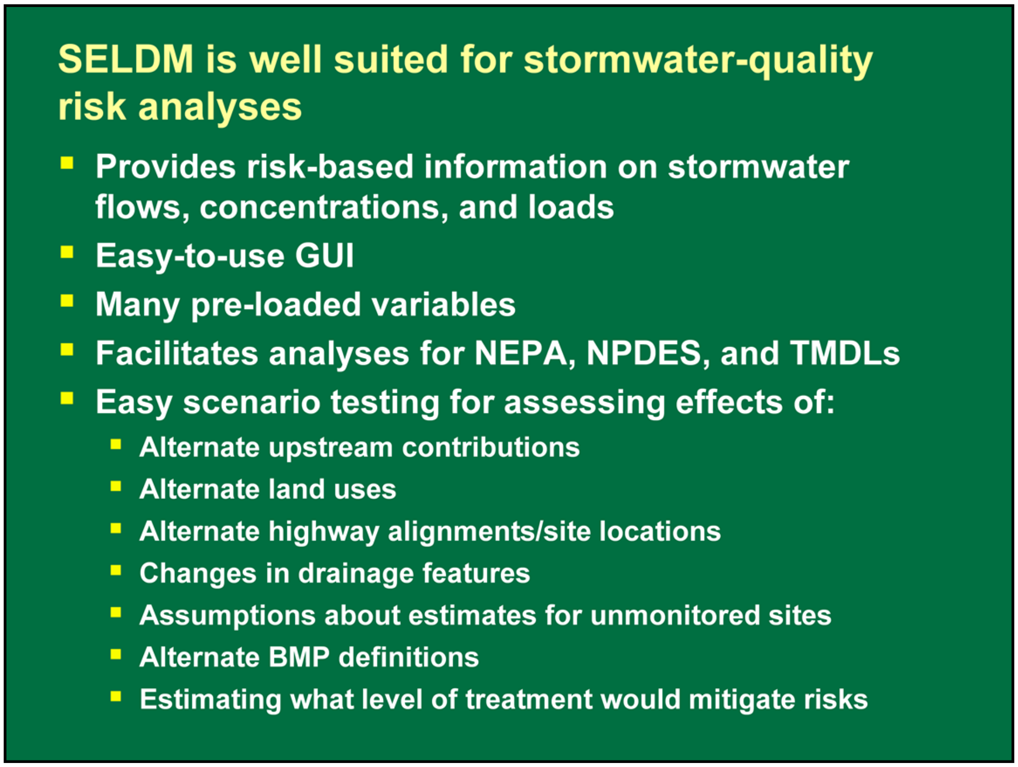
The three horizontal lines on this graph are current or historic water-quality guidelines. None of the upstream or downstream values come close to the 0.5 mg/L effluent limit. About 1.8 percent of upstream values, and about 2.1 percent of downstream values exceed the 0.1 mg/L guideline. The lowest red line is the suggested EPA criterion for ecoregion 59, the northeastern coastal zone. About 68 percent of upstream values exceed this criterion. Among the downstream concentrations about 73 percent without the BMP and 71 percent with the BMP exceed this criterion. This is an example from a largely rural basin in CT, it is 5.5 percent impervious, more than 50 percent forested, and has less than 2 percent agricultural land use, the rest is low-intensity suburban development. Results from this and other largely forested basins indicate that the EPA's method, which is based on the 25th percentile of all nutrient data, may not be well suited for regulation of wet weather conditions for basins in ecoregion 59.



This graph demonstrates the risk-based loading information provided by SELDM. It shows the modeled yield of total phosphorus from simulated highway runoff and BMP effluent. The yields are in pounds per acre of highway per year. Yields are on a linear scale on the vertical axis and the percentages of years equaling or exceeding a given yield are on a probability scale on the horizontal axis. Highway-runoff yields, shown as white circles, range from 1.4 to 0.63 with a median of about 0.9 pounds per acre per year. BMP effluent yields, shown as yellow triangles, range from 1.12 to 0.43 with a median of about 0.64 pounds per acre per year.

The graph of highway-runoff concentrations indicated that the grassy swale was almost ineffective for reducing total phosphorus concentrations. This graph, however, indicates the effectiveness of the swale in reducing annual phosphorus loads. These reductions are primarily achieved via reductions in runoff volumes.

The distribution of annual loads or yields can be used to address a total maximum daily load allocation for highways in a basin. SELDM can be used to demonstrate the effectiveness or ineffectiveness of one or more BMPs for achieving a desired result. Once these yields are calculated by using SELDM they can be applied to all the highway area in a basin that contributes runoff to the surface waters.



In conclusion, we think that SELDM is well suited for stormwater-quality risk analyses because it provides risk-based information on stormwater flows, concentrations, and loads. It is easy to use because it has a simple graphical-user interface and it is preloaded with many of the variables needed to do a runoff-quality analysis. Therefore, it can be used to facilitate analyses for NEPA, NPDES, and TMDLs.

Furthermore, the ability to easily change variables and rerun the model in a matter of minutes facilitates scenario testing for assessing potential effects of

- Alternate upstream contributions
- Alternate land uses
- Alternate highway alignments or site locations
- Changes in drainage features
- Assumptions about estimates for the quality or quantity of runoff from unmonitored sites
- Alternate BMP definitions, and
- Estimating what level of BMP treatment would be necessary to mitigate risks

Thanks for listening to this talk. Are there any questions?