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# Project Summary

# Combined Sewer Overflow Sediment Transport Model: Documentation and Evaluation

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**A modeling package was developed to study the movement and fate of combined sewer overflow (CSO) sediment in receiving waters. The package contains a linear, implicit, finite-difference flow model and an explicit, finite-difference sediment transport model. The sediment model is coupled to the flow model by means of a file containing velocity, depth, and discharge at each model cross-section at each time step. The operation and utility of the model package were tested using data from a 20-km reach of the Scioto River below the Whittier Street outfall in Columbus, Ohio. A preliminary field investigation of the study reach in July 1980 collected sufficient data to calibrate the flow model partially. Data from a CSO event in September 1981 were used to further calibrate the flow model and evaluate the sediment transport model operation. The flow model reproduced stages and discharges with sufficient accuracy for linkage with the sediment model. The sediment model produced smoothed estimates of sediment concentrations that fell within the scatter of observed data in most instances. CSO sediment sizes and the armored nature of the Scioto River channel were such that all solids discharged from the CSO were convected through the reach with no deposition, even at low flow. Experiments with the sediment model indicate that it can be used for qualitative assessments of the fate of various sediment size fractions if properly calibrated.**

***This Project Summary was developed by EPA's Water Engineering Research Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).***

## Introduction

A major portion of the pollutant load from combined sewer overflow (CSO) events consists of suspended particulate matter. The water quality impacts of these materials depend on their size distribution and on the hydraulic and sediment transport properties of the stream channel into which they are discharged. Mathematical models of transient stream flow and sediment transport are useful in predicting the fate of CSO materials under a wide variety of hydrological events and CSO control options.

This report documents the development and application of a computerized flow routing and sediment transport model package especially adapted to consider CSO releases. The computer code is a refinement of an earlier experimental version. The report contains a description of the theory behind the models and provides detailed instructions on using the associated computer program. A complete listing of the FORTRAN source code is included. The report also contains a description of attempts to apply the model package to field data collected during CSO events on the Scioto River downstream of Columbus, Ohio.

## Model Theory

The time-dependent flow model discussed in the report is based on the conservation of mass and momentum equations for a one-dimensional channel,

$$u\frac{\partial A}{\partial x} + A\frac{\partial u}{\partial x} + \frac{\partial A}{\partial t} - q = 0$$

$$\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} + g(\frac{\partial y}{\partial x} - \frac{\partial Z}{\partial x} + S_f) = 0$$

where u is the average flow velocity, A is the cross-sectional area, x is the longitudinal distance, t is time, q is lateral inflow, g is the acceleration of gravity, y is the depth of flow, Z is the elevation of the channel bed, and $S_f$ is the friction slope.

The solution technique for these equations employs a linear, implicit, four-point, finite difference scheme. The following features are built into the computer program that implements the solution:

- Up to 40 cross-sections and 20 tributaries can be handled.
- Flow resistance at each cross-section can be specified as a polynomial function of depth.
- An arbitrary spacing of cross-sections can be used.
- Initial conditions are automatically computed based on a prescribed set of upstream, lateral, and tributary flows at time zero.
- A variety of upstream and downstream boundary conditions are available.
- The program output provides estimates of velocity, depth, discharge, and water surface elevation at each cross-section and each time step of the simulated flow period.

The program also stores velocity, depth, and discharge results on a disk file that is later accessed by the sediment transport portion of the package.

The sediment transport model is based on the conservation of mass equation,

$$\frac{\partial G_s}{\partial x} + \frac{\partial cA}{\partial t} + \frac{\partial Pz}{\partial t} = g_s$$

where $G_s$ is the total sediment transport rate by volume, c is the sediment concentration by volume (equal to $G_s/(uA)$), z is the net depth of loose soil, P is the wetted perimeter of the cross-section, $g_s$ is the lateral sediment inflow, and all other terms are as defined earlier.

An equation of this form is written for each size fraction of sediment particles. The set of equations is solved with an explicit finite difference scheme. At each time step, the sediment transport capacity of each channel section is computed. The bed load portion of this capacity is based on the Meyer-Peter Muller equation, and the suspended load portion is computed using a modified Einstein procedure. The resulting transport capacity is substituted into the conservation of mass equation, and the equation is solved for the potential change in loose soil. The depth of loose soil is adjusted accordingly, and the computations are repeated for the next time step.

The computer program that implements this solution accesses the data file created by the flow model to obtain the necessary hydraulic input. The sediment transport computer code contains the following features:

- Up to 10 size fractions of sediment, 40 stream cross-sections, and 5 sources of sediment inflow can be handled.
- A variety of channel boundary conditions and sediment inflow conditions (including the use of rating curves) are permitted.
- A variable soil detachment coefficient may be used.
- Aggradation/degradation of the bed is assumed not to affect cross-section geometry.
- The model is designed for non-cohesive, biologically inert sediment materials with constant specific gravity and sizes larger than 0.063 mm.
- Program output consists of total transport rate, bed aggradation/degradation, and sediment concentration by size class for each stream section and time step of the simulation.

## Field Application

The model package was tested using data from a 20-km reach of the Scioto River below the Whittier Street combined sewer outfall in Columbus, Ohio. Data collected during a dry-weather period in July 1980 provided a preliminary calibration of the flow model under steady-state conditions. The resulting bed profile elevations and cross-section locations appear in Figure 1. Two storm events were then sampled—one in November 1980, and another in September 1981. Only the latter event provided sufficient data to use with the model.

The results of calibrating the flow model to the September 1981 event are shown in Figure 2. The model was capable of reproducing the observed variations in stage with a maximum error of 1 ft and a mean error between 4 to 6 in. The ability of the sediment model to match the observed suspended solids concentrations was less successful, as shown in Figure 3. The predicted concentrations qualitatively followed the measured ones with errors of 20% to 50%. Part of the discrepancies can be attributed to the difficulty and eratic nature of obtaining sediment concentration measurements.

In addition, most of the sediment from the CSO outfall was smaller than 0.063 mm, the lower size limit of the current state of the art in sediment transport modeling. Because of this small particle size and the armored nature of the channel, CSO sediments are flushed through

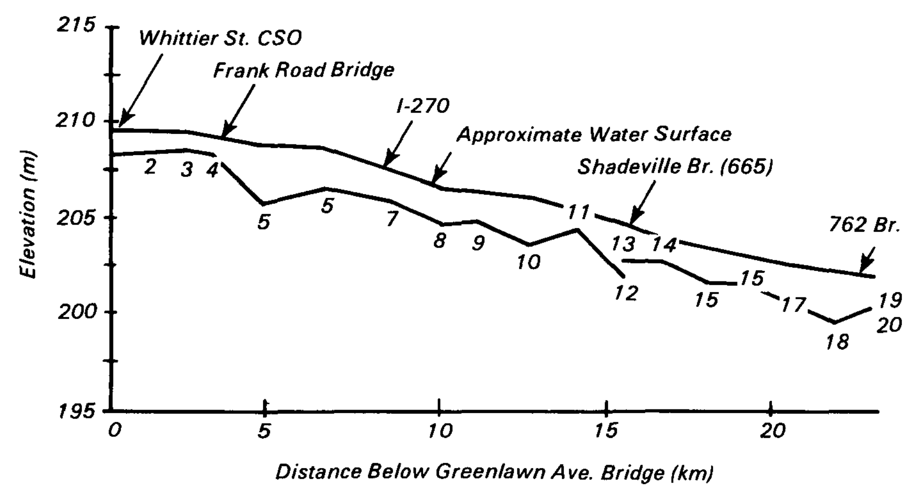


*Figure 1.* *Bottom profile of Scioto River and model cross section locations.*

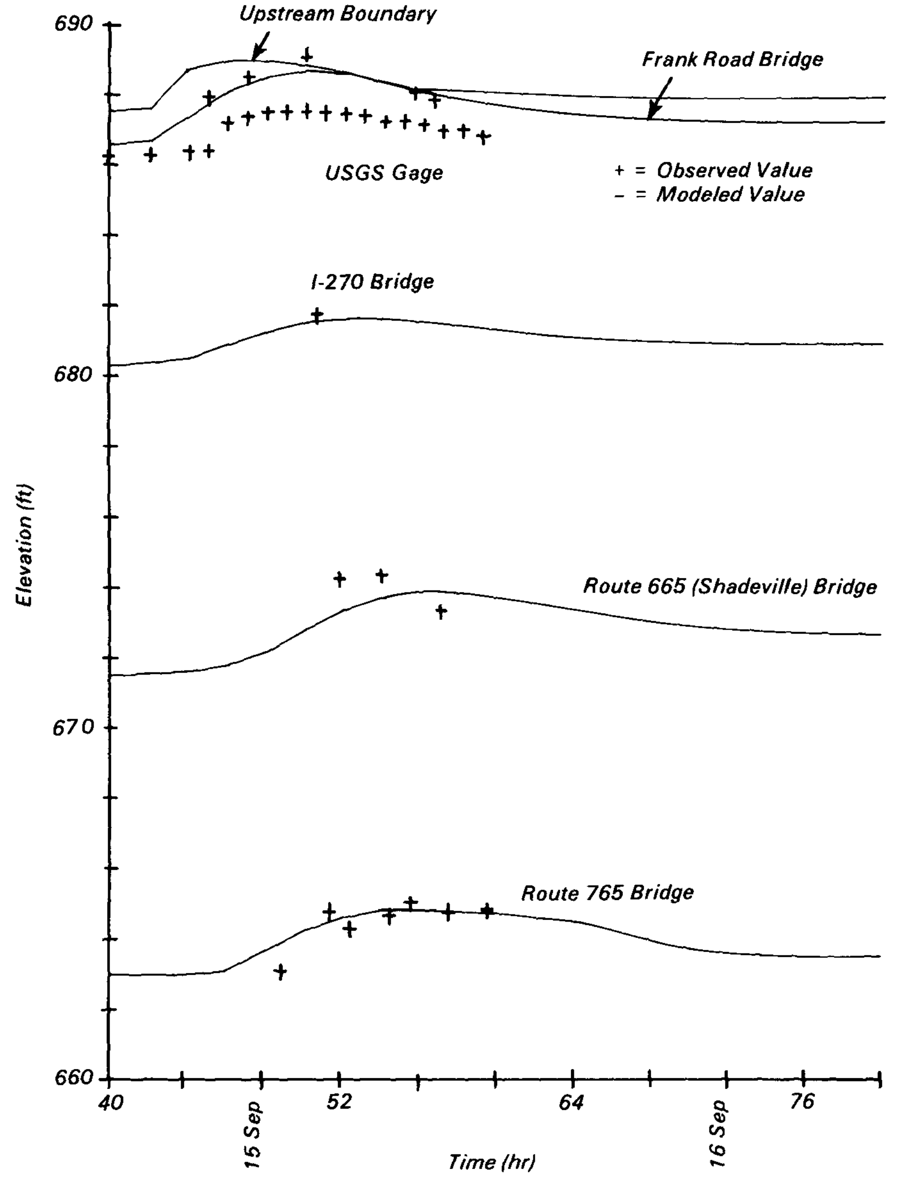


***Figure 2.*** *Scioto River stage hydrographs between 4 p.m. on September 14 and 8 a.m. on September 16, 1981.*

the Scioto River reach with no aggradation occurring, even at low flows.

## Conclusions

The following conclusions were drawn with respect to the model package and its application:

- The model package is a useful tool for qualitative assessment of the movement of nonporous, noncohesive, biologically inert sediments in receiving waters.
- Considerable knowledge of hydraulics and hydrology may be required to set up, run, and interpret the model.
- The sediment transport in the Scioto River is similar to that in a rigid boundary channel.
- All the sediment material from the Whittier Street outfall is fine enough to be transported by the Scioto River, even at low flow.
- Sufficient correlation exists between variations in sediment transport and variations in other water quality parameters measured during the CSO event to suggest a close connection between the two.

The full report was submitted in fulfillment of Contract No. 68-03-2869 by the Sutron Corporation under the sponsorship of the U.S. Environmental Protection Agency.

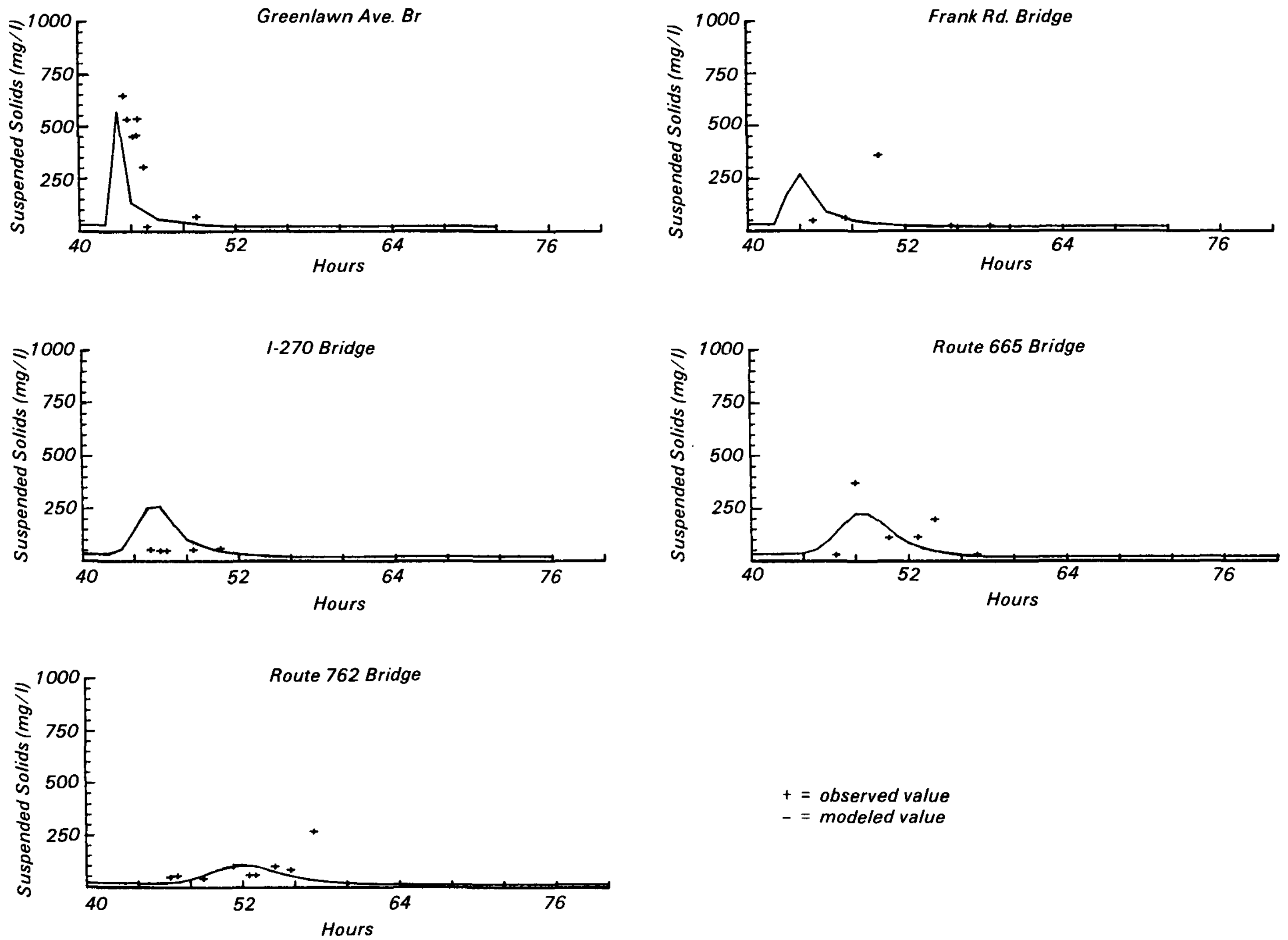


***Figure 3.*** *Variation of suspended solids with time.*

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*The complete report, entitled "Combined Sewer Overflow Sediment Transport Model: Documentation and Evaluation," (Order No. PB 85-180 859/AS; Cost: $20.50, subject to change) will be available only from:*
*National Technical Information Service*
*5285 Port Royal Road*
*Springfield, VA 22161*
*Telephone: 703-487-4650*
*The EPA Project Officer can be contacted at:*
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