Sediment and Radionuclide Transport in Rivers

Radionuclide Transport Modeling for Cattaraugus and Buttermilk Creeks, New York

Prepared by Y. Onishi, S.B. Yabusaki, C. T. Kincaid
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Pacific Northwest Laboratory
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Battelle Northwest Laboratory

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Radionuclide Transport Modeling for Cattaraugus and Buttermilk Creeks, New York

Manuscript Completed: September 1982
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Sediment and Radionuclide Transport in Rivers

Radionuclide Transport Modeling for Cassadaga and Burt Lake Creeks, New York

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ABSTRACT

SERATRA, a transient, two-dimensional (laterally-averaged) computer model of sediment-contaminant transport in rivers, satisfactorily resolved the distribution of sediment and radionuclide concentrations in the Cattaraugus Creek stream system in New York. By modeling the physical processes of advection, diffusion, erosion, deposition, and bed armoring, SERATRA routed three sediment size fractions, including cohesive soils, to simulate three dynamic flow events. In conjunction with the sediment transport, SERATRA computed radionuclide levels in dissolved, suspended sediment, and bed sediment forms for four radionuclides ($^{137}$Cs, $^{90}$Sr, $^{239,240}$Pu, and $^3$H). By accounting for time-dependent sediment-radionuclide interaction in the water column and bed, SERATRA is a physically explicit model of radionuclide fate and migration. Sediment and radionuclide concentrations calculated by SERATRA in the Cattaraugus Creek stream system are in reasonable agreement with measured values.

SERATRA is in the field performance phase of an extensive testing program designed to establish the utility of the model as a site assessment tool. The model handles not only radionuclides but other contaminants such as pesticides, heavy metals and other toxic chemicals. Now that the model has been applied to four field sites, including the latest study of the Cattaraugus Creek stream system, we recommend a final model validation through comparison of predicted results with field data from a carefully controlled tracer test at a field site. We also recommend a detailed laboratory flume testing to study cohesive sediment transport, deposition and erosion characteristics. The lack of current understanding of these characteristics is one of the weakest areas hindering the accurate assessment of the migration of radionuclides sorbed by fine sediments of silt and clay.
ABSTRACT

SERATA is a flexible, low-compliance, consumer-oriented computer model. The
SERATA 12, in the field programming phase, is a state-assignment tool. The
model handles our only computer language but also can handle other languages such as
pseudo-code, which makes it easier to port to other computers. How shall the model be used?
Topics include semantics, etc. An introduction to the computer line stream
involved with SERATA, a critical concept, is presented. The project of
SERATA is to provide a single computer program that can interact with
and control a variety of computer configurations. The core of
this approach is to interact with and utilize the full range of
computer configurations, including the user interface, and to
provide a comprehensive framework for the development of
computer programs. The model allows for the interaction of a
variety of computer programs and can be used to develop
applications that can interact with the user.
SUMMARY

The migration and fate of radionuclides in surface waters are controlled by four complex mechanisms. These mechanisms are radionuclide transport due to water and sediment movements; intermedia transfer due to adsorption/desorption, precipitation/dissolution, and volatilization; decay and degradation due to radionuclide decay or chemical and biological degradation (where applicable); and transformation due to the yield of daughter, degradation, or chemical-reaction products (where applicable). SERATRA, a two-dimensional (laterally-averaged) finite element model of sediment-radionuclide transport, was formulated to account for these mechanisms in a physically explicit manner.

SERATRA predicts time-varying longitudinal and vertical distributions of sediments and radionuclides in nontidal rivers and some impoundments. The model consists of three coupled transport submodels, sediment transport, dissolved radionuclide transport, and particulate radionuclide transport, which are capable of time-dependent sediment-radionuclide interaction in the riverbed and water column.

The potential of SERATRA as a site assessment tool has led to a lengthy testing program designed to validate the model over a variety of field conditions. Initially, numerical experiments, i.e., mass balance checks and comparisons with analytical solutions, were performed to confirm the accuracy of the model. Next, SERATRA was taken to the field where it was applied to large rivers with steady flow conditions under several previous projects. SERATRA is currently in the final stage of the testing program where smaller rivers with dynamic flow events are being modeled.

Hence under this study, SERATRA was applied to a system of two small, highly dynamic streams in New York: Cattaraugus and Buttermilk Creeks. Radionuclides found in this system are due in part to a radioactive waste burial site near Franks Creek, a tributary of Buttermilk Creek. An extensive field data collection program provided time- and space-dependent measurements of discharges, sediments, and radionuclides for the modeling of three flow events. Particular attention in the field sampling program was given to the behavior of radionuclides associated with the various size fractions of bed and suspended sediment. Laboratory analyses of collected samples under separate projects yielded data on 30 radionuclides including equilibrium distributions of dissolved and sorbed radionuclide forms. The depths and discharges required as input to SERATRA were obtained by hydrodynamic models with measured and synthesized flow data. Radionuclide information for an application of SERATRA was sufficient in four cases: $^{137}$Cs, $^{90}$Sr, $^{239,240}$Pu, and $^3$H.

Sediment and radionuclide concentrations predicted by SERATRA on the three flow events were in reasonable agreement with values measured in the field. SERATRA performed best where the most field data were available, underscoring the importance of complete and accurate input data when describing a complex modeling system.
SERATRA has now been tested on four field sites of widely varying flow and topographic characteristics. We recommend a comparison of predicted results with field data from a carefully controlled tracer test as the final validation of SERATRA. Since the confidence of radionuclide transport modeling is severely impaired by the general lack of the understanding of cohesive sediment transport characteristics, we strongly recommend that detailed laboratory flume testing be performed to increase the understanding of the basic mechanisms of transport, deposition and erosion of cohesive sediment in fresh and saline waters.
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ACKNOWLEDGMENTS

This report summarizes the results of research conducted by Pacific Northwest Laboratory for the U.S. Nuclear Regulatory Commission on Cattaraugus and Buttermilk Creeks, New York. The authors wish to acknowledge the guidance provided by Dr. Phillip R. Reed of the U.S. Nuclear Regulatory Commission.

Most of the measured radionuclide activities used in this study were counted by the University of Washington, Laboratory of Radiation Ecology for radiological analyses under a separate project.
A report summaries the results of research conducted by the artist and scientist J. C. B. S. A. and the National Geographic Society. The study was supported by the United States Atomic Energy Commission.

The main objective of this research is to investigate the effects of radiation on the human body. The results indicate that prolonged exposure to radiation can cause significant health issues. The study also highlights the importance of understanding the mechanisms of radiation damage and developing methods to mitigate its effects.
1.0 INTRODUCTION

Four complex mechanisms govern the migration and fate of contaminants in surface waters: 1) transport, 2) intermedia transfer, 3) decay and degradation, and 4) transformation.

Transport refers to the mixing and advection of contaminants by the water flow. This includes the transport of sorbed and precipitated contaminants by the movement of solids entrained in the flow. Intermedia transfer involves the exchange of contaminant across the solid-liquid and liquid-gas interfaces. In the bed and water column, particulate-contaminant interaction occurs through precipitation/dissolution and adsorption/desorption. At the water surface, contaminants are volatilized to the atmosphere. Decay and degradation mechanisms attenuate the contaminant severity. Processes included in this category are radionuclide decay, and degradation due to hydrolysis, oxidation, photolysis, and biological activities. Transformation, on the other hand, creates new forms of potentially hazardous substances through the yield of daughter, degradation, or chemical-reaction products.

Historically, contaminant modeling in surface waters has been performed without considering the nonaqueous forms a contaminant may exist in or evolve to. Although a contaminant may be substantially precipitated, volatilized, or sorbed to a solid matrix, the aqueous-only modeling approach remains popular because of the conservative concentrations predicted for dissolved contaminants in most cases. Recent concern for the accumulation of contaminants in the environment in addition to the dissolved contaminant levels has prompted the development of more sophisticated surface water models.

SERATRA, a computer model of sediment-contaminant (e.g., radionuclides, pesticides, heavy metals) transport was developed in response to the need for a site assessment methodology which realistically addresses the governing mechanisms of contaminant migration and fate in surface waters. SERATRA uses the finite element computational approach to predict time-varying longitudinal and vertical distributions of sediments and contaminants in rivers and some impoundments.

The model consists of the following three coupled submodels, which describe sediment-contaminant interactions and migration:

- a sediment transport submodel
- a dissolved contaminant transport submodel
- a particulate contaminant transport submodel.

The sediment transport submodel simulates transport, deposition, scouring and armoring for three size fractions of cohesive and noncohesive sediments. The transport of particulate contaminant (i.e., contaminants adsorbed by sediment) is also simulated for each sediment size. Dissolved contaminants are linked by the adsorption/desorption process to the particulate contaminants. The contaminant submodels account for 1) advection and dispersion of dissolved and particulate contaminants; 2) radionuclide decay and chemical and
biological degradation resulting from hydrolysis, oxidation, photolysis, biological activities where applicable; 3) volatilization; 4) adsorption/desorption; and 5) deposition and scouring of particulate contaminants. SERATRA also computes changes in riverbed conditions for sediment and contaminant distributions.

In an effort to prepare SERATRA for dissemination, a lengthy program of testing has been followed. Initially, numerical experiments were performed to confirm the accuracy of the model. These experiments consisted of simulating problems which have analytical solutions to compare against, and checking the mass balance by isolating the various mechanisms in the model formulation. Upon the successful completion of these experiments, SERATRA was then applied to actual field sites.

Prior to this study, sediment and radionuclide transport in the Columbia River in Washington and the Clinch River in Tennessee, were simulated by SERATRA under steady flow conditions (Onishi and Wise 1979, Onishi et al. 1980). The reasonably good results produced by SERATRA in these two applications paved the way for the final phase of model testing: unsteady flow conditions.

In an ensuing study, contamination in Four Mile and Wolf Creeks in Iowa was simulated over a three year period during which highly dynamic runoff events occurred (Onishi et al. 1979). Although the concentrations of alachlor (a pesticide) predicted by SERATRA were reasonable, no measured data were available for comparison.

SERATRA had now been successfully applied to three diverse stream systems, modeling both radionuclides and pesticides. Despite the satisfactory performance of SERATRA in the field, the time-dependent computation of particulate radionuclide transport remained unverified because of data limitations in these earlier studies.

In an effort to investigate the importance of fluvial sediment in the transport of radionuclides, the U.S. NRC requested PNL to conduct a comprehensive data collection program to provide SERATRA with suitable information for the verification study. The field site selected by the U.S. NRC is located within the watershed of Cattaraugus Creek in rural western New York. Radionuclides found in Cattaraugus Creek and its tributary, Buttermilk Creek, have originated in part from the past operation of a low-level radioactive waste disposal facility at West Valley, New York (Ecker and Onishi 1978, Walters et al. 1982, Ecker et al. 1982).

During each of the years 1977 to 1979, Pacific Northwest Laboratory (PNL) monitored one, week-long flow event on Cattaraugus and Buttermilk Creeks for discharges, sediments, and radionuclides. Hydrodynamics on these three phases of data collection were extremely varied, from a high, unsteady flow in Phase 1 to a low, steady flow in Phase 2 with an intermediate flow in Phase 3. PNL determined the physical characteristics of the water and sediment samples, e.g., temperature, concentrations, sediment size fractions, densities, etc.
before sending the samples mostly to the University of Washington where the radiochemical analyses were performed. A total of 30 radionuclides were analyzed, of which $^{137}$Cs, $^{90}$Sr, $^{239,240}$Pu, and $^3$H had adequate data bases for a reasonable modeling effort. Fortunately, these four radionuclides have distinctly different geochemical attributes allowing the full breadth of model capability to be tested.

Complex models such as SERATRA have extensive data requirements to be properly applied in a predictive mode. Inadequate data sets have the effect of reducing the analysis to an exercise in curve fitting due to the number of model parameters which can be adjusted. In this study of the Cattaraugus Creek watershed, all parameters were predetermined prior to the model application except for the cohesive sediment transport parameters and vertical dispersion coefficient. To avoid the danger of curve fitting, these latter parameters were calibrated on one flow event and applied unchanged to the other two flow events.

This report discusses the performance testing of SERATRA on three flow events in Cattaraugus and Buttermilk Creeks where four radionuclides are simulated. Included in the report is a model description, summary of previous SERATRA applications, results from the application to Cattaraugus and Buttermilk Creeks, hypothetical case studies and the computer print out of SERATRA code.
Complex models, such as SERATARA, have extensive data requirements to be
products of applying a predictive model. The models' data requirements vary the direct
effect of parameter estimation on the model's fit. The number of
parameters in the model can be quite large. In this study of the interactions
between parameters and the model's performance, we analyze the effects of
parameters on the model's fit. This involves identifying parameters that
significantly affect the model's performance and selecting models
that improve fit without overfitting.

This report discusses the performance of SERATARA on three farms:
the results presented here are based on simulations on these farms.
SERATARA is a data-driven approach to modeling crop and soil growth,
which uses statistical methods to predict crop yields for
specific locations. The report includes a detailed description of
SERATARA's methodology and its application to agricultural
research. The report concludes with a discussion of
SERATARA's limitations and future directions.
CONCLUSIONS

The sediment-radionuclide transport model SERATRA is undergoing a testing program which will lead to its distribution as a site assessment tool. The final phase of this testing program is the field verification of the model. In the latest of a series of field applications, the Cattaraugus Creek stream system in New York was modeled to simulate the transport, deposition and resuspension of sediment and particulate radionuclides; the transport of dissolved radionuclides; and sediment-radionuclide interactions. Radionuclides simulated by SERATRA were $^{137}$Cs, $^{90}$Sr, $^{239,240}$Pu, and $^3$H. Results from this modeling study indicate that SERATRA can reproduce with reasonable accuracy the mechanisms which affect the migration and fate of radionuclides in rivers.

SERATRA generated the best results where known boundary conditions and verification values were both time- and space-dependent. This study emphasizes the importance of providing an adequate data set to model a complex phenomenon.

RECOMMENDATIONS

1. SERATRA has now been tested at four sites (Columbia River; Clinch River; Four Mile and Wolf Creeks; and Buttermilk and Cattaraugus Creeks) where its ability to handle a wide range of flow, sediment, and contaminant behavior has been demonstrated under current and previous studies. As a final step in the validation of SERATRA, we recommend that SERATRA be applied to a field site where a carefully controlled tracer test (e.g., a neutron activation test) can be performed.

2. Due to the radiochemical nature of the radionuclide transport problem, a critical dependence on laboratory analyses is unavoidable. Radionuclide distribution coefficients are, to a certain extent, affected by factors which cannot always be accounted for in the laboratory. In particular, the dynamics of field phenomena are impossible to duplicate. We recommend additional research into the present method of modeling a dynamic adsorption phenomenon.

3. We also recommend coupling a geochemical model with the transport model, SERATRA, so that adsorption mechanisms and precipitation are more accurately estimated by a geochemical model to obtain more accurate concentrations and forms of radionuclides in surface waters.

4. Basic characteristics of transport, deposition and erosion of cohesive sediment (e.g., silt and clay) should be investigated in a carefully controlled laboratory flume. The current lack of understanding of these characteristics inhibits a reliable prediction of particulate and dissolved radionuclides in surface waters.
3.0 CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The segment logon/call target model is being adopted for use in the AAR/RTA CAC model. The model is being used to test potential new call target models and to provide a basis for the development of new call target models. The model is also being used to test new call target models.

RECOMMENDATIONS

I. SCENARIO "A" AND "B" call targets are used for the following cases:

1. Highest priority, high call volume, and long call duration.

2. Medium priority, medium call volume, and medium call duration.

3. Lowest priority, low call volume, and short call duration.

II. SCENARIO "C" call targets are used for the following cases:

1. Highest priority, high call volume, and long call duration.

2. Medium priority, medium call volume, and medium call duration.

3. Lowest priority, low call volume, and short call duration.

III. SCENARIO "D" call targets are used for the following cases:

1. Highest priority, high call volume, and long call duration.

2. Medium priority, medium call volume, and medium call duration.

3. Lowest priority, low call volume, and short call duration.

IV. SCENARIO "E" call targets are used for the following cases:

1. Highest priority, high call volume, and long call duration.

2. Medium priority, medium call volume, and medium call duration.

3. Lowest priority, low call volume, and short call duration.

V. SCENARIO "F" call targets are used for the following cases:

1. Highest priority, high call volume, and long call duration.

2. Medium priority, medium call volume, and medium call duration.

3. Lowest priority, low call volume, and short call duration.
3.0 FORMULATION OF MODEL, SERATRA

The SERATRA code uses the finite element computation method with the Galerkin weighted residual technique. It consists of three submodels coupled to include the effects of sediment-contaminant interaction. The submodels are: 1) a sediment transport submodel, 2) a dissolved contaminant transport submodel, and 3) a particulate contaminant (contaminants adsorbed by sediment) transport submodel. SERATRA not only calculates distributions of sediment and contaminant concentrations in water, but also predicts river bed conditions, including bed elevation change, sediment size distribution within the bed, and distribution of particulate contaminant concentration in the river bed. The detailed model formulation is discussed below:

3.1 SEDIMENT TRANSPORT SUBMODEL

Since the movements and adsorption capacities of sediments vary significantly with sediment sizes, the sediment transport submodel solves the migration of sediment (transport, deposition and scouring) for three size fractions of cohesive and non-cohesive sediments.

The model includes the mechanisms of:
1. Advection and dispersion of sediments
2. Fall velocity and cohesiveness
3. Deposition on the river bed
4. Resuspension from the river bed (bed erosion and armoring)
5. Sediment contributions from tributaries and point/nonpoint sources into the system and subsequent mixing.

Sediment mineralogy and water quality effects are implicitly included through the above mentioned mechanisms 2, 3, and 4.

Mass conservation of sediment passing through the control volume leads to the following expression for the transport of sediments:

\[
\frac{3}{\delta t} \left( C_j B_j \right) + (U_j C_j B - U_i C_i B) + \frac{3}{\delta z} \left\{ C_j (W - W_{sj}) B_j \right\} = \frac{3}{\delta z} \left( \epsilon \frac{3}{\delta z} A_j B_j \right) + \frac{1}{h} \left( S_{Rj} - S_{Dj} \right) \]

where:
- \( \frac{3}{\delta t} \) is the rate of accumulation
- \( \frac{3}{\delta z} \) is the vertical advection
- \( \frac{3}{\delta z} \) is the horizontal advection
- \( \epsilon \) is the vertical diffusion
- \( h \) is the water depth
- \( S_{Rj} \) is the river bed slope
- \( S_{Dj} \) is the deposition rate

For \( j = 1, 2, \ldots, N \)
The symbols defined above remain the same throughout the report.
where

\[ \gamma = \text{coefficient, i.e., probability that particle settling to the bed is deposited.} \]

Sediment erosion and deposition rates, \( S_{Rj} \) and \( S_{Dj} \), are also evaluated separately for each sediment size fraction because erosion and deposition characteristics are significantly different for cohesive and noncohesive sediments.

Erosion and deposition of noncohesive sediments are affected by the amount of sediment the flow is capable of carrying. For example, if the amount of sand being transported is less than the flow can carry for given hydrodynamic conditions, the river will scour sediment from the stream bed to increase the sediment transport rate. This occurs until the actual sediment transport rate becomes equal to the carrying capacity of the flow or until the available bed sediments are all scoured, whichever occurs first. Conversely, the river deposits sand if its actual sediment transport rate is above the flow's capacity to carry sediment. Sediment transport capacity of flow, \( Q_T \), in this model, was calculated by either the Toffaleti or the Colby formulas (Vanoni 1975), whichever a user assigns. The computer program of the Colby method used in SERATRA was that developed by Mahmood and Ponce (Mahmood and Ponce 1975). The sediment transport capacity of flow, \( Q_T \), was then compared with the actual amount of sand, \( Q_{Ta} \), being transported in a river water. Hence:

\[
S_{Rj} = \frac{Q_T - Q_{Ta}}{A} \quad (4)
\]

\[
S_{Dj} = \frac{Q_{Ta} - Q_T}{A} \quad (5)
\]

where

\[ A = \text{the river bed surface area.} \]

The availability of bed sediments to be resuspended was also examined to determine the actual amount of sediment erosion.

For sediment erosion and deposition rates of cohesive sediments (silt and clay), the following Partheniades (1962) and Krone (1962) formulas, respectively, were adopted in this study:

\[
S_{Rj} = M_j \left( \frac{\tau_b}{\tau_{cRj}} - 1 \right) \quad (6)
\]

\[
S_{Dj} = W_{sj} C_j \left( 1 - \frac{\tau_b}{\tau_{cDj}} \right) \quad (7)
\]
where

\[ M_j = \text{erodibility coefficient for sediment of jth size fraction} \]

\[ \tau_b = \text{bed shear stress} \]

\[ \tau_{cDj} = \text{critical shear stress for sediment deposition for jth sediment size fraction} \]

\[ \tau_{cRj} = \text{critical shear stress for sediment erosion for jth sediment size fraction}. \]

Values of \( M_j \), \( \tau_{cDj} \) and \( \tau_{cRj} \) must be determined by field and/or laboratory tests for a particular river regime. The model examines the availability of cohesive sediments in the river bed to determine the actual amount of sediment erosion.

When the fall velocity, \( W_{sj} \), depends on sediment concentration and no aggregation occurs, Krone (1962) recommends:

\[ W_{sj} = K_j C_j^{4/3} \]

where

\[ K_j = \text{an empirical constant depending on the sediment type}. \]

3.2 DISSOLVED CONTAMINANT TRANSPORT SUBMODEL

The dissolved contaminant transport submodel includes the mechanisms of:

1. Advection and dispersion of dissolved contaminants (pesticides, radionuclides, and other toxic substances) within the river

2. Adsorption (uptake) of dissolved contaminants by sediments (suspended and bed sediments) or desorption from sediments into water

3. Radionuclide decay

4. Degradation of dissolved contaminants due to hydrolysis, oxidation, photolysis and biological activities

5. Volatilization

6. Contributions of dissolved contaminants from tributaries and point/nonpoint sources into the system, and subsequent mixing.

Effects of water quality (e.g., pH, water temperature, salinity, etc.) and clay minerals are indirectly taken into account through changes in the distribution coefficients for adsorption and desorption, \( K_{dj}, K_{dj}' \), respectively. In this.
model, distribution coefficients for adsorption can be assigned to a value different from that of desorption to be able to handle not-completely-reversible adsorption/desorption processes. Mass conservation of dissolved contaminants may be expressed as:

\[
\frac{2}{\tau} \left( \frac{G_{Bi}}{G_{W}} \right) + \frac{2}{\tau} \left( \frac{U_{G_{Bi}}}{U_{G_{W}}} \right) + \frac{3}{\tau} \left( \frac{W_{G_{Bi}}}{W_{G_{W}}} \right)
\]

rate of horizontal advection
rate of vertical advection
rate of accumulation

\[
= \frac{3}{\tau} \left( \frac{G_{W}}{G_{W}} \right) - \frac{3}{\tau} \left( \frac{G_{W}}{G_{W}} \right) - \sum_{i=1}^{5} K_{ci} G_{Bi}
\]

vertical diffusion
radionuclide decay
chemical and biological degradation
and volatilization

\[
= \sum_{j} K_{j} (K_{dj} G_{W} - G_{j}) B_{2j} - \sum_{j} K'_{j} (K'_{dj} G_{W} - G_{j}) B_{2j}
\]

adsorption to moving sediment
adsorption from moving sediment

\[
- \sum_{j} \gamma_{j} (1 - POR) D_{j} K_{bj} (K'_{dj} G_{W} - G_{bj}) - \sum_{j} \gamma_{j} (1 - POR) D_{j} K'_{bj} (K'_{dj} G_{W} - G_{bj})
\]

adsorption to sediment in bed
adsorption from sediment in bed

\[
\quad j = 1, 2, 3
\]

(9)

It was assumed that a contaminant has the same distribution coefficient values \(K_{dj}\) or \(K'_{dj}\), for the moving (suspended and bed load sediments) and non-moving (bed sediment without any motion) \(j\)th sediment. However, these two types of sediments have two different transfer rates, \(K_{j}\) or \(K'_{j}\) and \(K_{bj}\) or \(K'_{bj}\), as expressed in Equation 9.

In addition to the previously defined symbols:

\(D_{j}\) = diameter of \(j\)th sediment

\(G_{bj}\) = particulate contaminant concentration per unit weight of sediment in \(j\)th sediment size fraction in river bed

\(\gamma_{j}\) = specific weight of \(j\)th sediment

\(G_{W}\) = dissolved contaminant concentration per unit volume of water
$G_{wi}$ = dissolved contaminant concentration in horizontal inflow

$G_j$ = particulate contaminant concentration per unit volume of water

$K_{Ci}$ = the first order reaction rate of contaminant degradation due to hydrolysis, oxidation, photolysis, biological activities, and volatilization

$K_{b,j}, K_{b,j}'$ = transfer rates of contaminants for adsorption and desorption, respectively, with $j$th non-moving sediment in bed

$K_{d,j}, K_{d,j}'$ = distribution coefficients rate of adsorption and desorption, respectively, between dissolved contaminant and moving sediment (suspended and bed load sediments) of $j$th size fraction, respectively

$K_j, K_j'$ = transfer rates of contaminants for adsorption and desorption, respectively, with $j$th sediment in motion

$\lambda$ = decay rate of radioactive material.

$POR$ = porosity of bed sediment

The distribution coefficients, $K_{d,j}$ and $K_{d,j}'$, are defined by:

$$K_{d,j} = \frac{f_{sj}}{f_w} \frac{M_j}{V_w} \quad \text{and} \quad K_{d,j}' = \frac{f_{sj}}{f_w} \frac{C_j}{G_{wi}}$$

where

- $f_{sj} = \text{fraction of contaminant sorbed by } j\text{th sediment}$
- $f_w = \text{fraction of contaminant left in solution}$
- $M_j = \text{weight of } j\text{th sediment}$
- $V_w = \text{volume of water}$

Hence Equation 10 may be rewritten as:

$$G_j = K_{d,j} C_j G_{w} \quad \text{or} \quad G_j = K_{d,j}' C_j G_{w}$$

The adsorption of contaminant by sediments or desorption from the sediments is assumed to occur toward an equilibrium condition with the transfer rate, $K_j$ or $K_j'$ (with the unit of the reciprocal of time), if the particulate contaminant concentration differs from its equilibrium values as expressed in Equation 11. Longitudinal dispersion of dissolved contaminant is considered to be negligible when compared to convection. Longitudinal spread of contaminants due to vertical variation of longitudinal velocity is, however, simulated in this study.
Boundary conditions at the water surface and river bed are:

\[ \text{at } z = h \]
\[ W G_w - \varepsilon_z \frac{\partial G_w}{\partial z} = 0 \]

\[ \varepsilon_z \frac{\partial G_w}{\partial z} = 0 \quad \text{at } z = 0 \] (13)

One of the important mechanisms of transport and fate of contaminants is the degradation and volatilization of contaminants in an aquatic environment. The contaminant degradation includes both chemical and biological reactions. Major mechanisms of chemical degradation are due to reactions of: 1) hydrolysis, 2) oxidation, and 3) photolysis (Smith et al. 1977). Due to the present lack of knowledge on degradation and volatilization of particulate contaminants (Smith et al. 1977), these degradation mechanisms were considered only for the dissolved contaminants. These degradation and volatilization rates are included in Equation 9 as the first order kinetic reaction rates, \( K_i; i = 1, 2, 3, 4 \text{ and } 5 \). Actual formulations of chemical and biological degradation, and volatilization were obtained from pesticide studies conducted by Smith et al. 1977, Zepp and Cline 1977 and Falco et al. 1976. These formulations will be discussed below:

**Chemical Degradation Due to Hydrolysis:**

The fundamental concept of chemical reactivity is based on the quest to improve stability in the configuration of the outer shells. A contaminant in solution will react with other species in solution and form a complex if there is a large increase in stability. Hydrolysis reactions are a specialized type of complex formation in which the \([\text{OH}^-]\) anion acts as the ligand. They are quite sensitive to pH changes. The rate of change of dissolved contaminant concentration due to hydrolysis is expressed by the following equation (Smith et al. 1977):

\[ \frac{dG_w}{dt} = K_A [H^+]G_w + K_B [OH^+] GW + K_N G_w \]

\[ = (K_A [H^+] + \frac{K_B G_w}{[H^+] + K_N}) G_w \]

\[ = (K_A \cdot 10^{-pH} + K_B \cdot 10^{pH-14} + K_N) G_w \]

\[ = K_{Cl} G_w \] (14)
where

\[ K_{C1} = K_A \cdot 10^{-pH} + K_B \cdot 10^{pH-14} + K_N \]

\[ K_W = [H^+] \cdot [OH^-] = 10^{-14} \]

\[ pH = - \log [H^+] \]

\[ K_A, K_B, K_N = \text{acid, base and neutral hydrolysis rates; respectively.} \]

Rate coefficients, \( K_A, K_B \) and \( K_N \) can be determined from laboratory tests (Smith et al. 1977).

**Chemical Degradation Due to Oxidation**

Oxidation of contaminants by free radical processes may become important under some environmental conditions. The rate of oxidation of contaminant may be expressed by the second order reactions depending on the concentration, of free and radical oxygen, and dissolved contaminant as shown below (Smith et al. 1977):

\[ \frac{dG_w}{dt} = K_{ox}[RO_2^\cdot]G_w + K_{AB}[RO^\cdot]G_w \]

It is assumed that only a small concentration of dissolved contaminants is oxidized, and that the second term in the right hand side may be deleted (Smith et al. 1977). Hence:

\[ \frac{dG_w}{dt} = K_{ox}[RO_2^\cdot]G_w = K_{C2}G_w \]

where

\( K_{ox}, K_{AB} = \text{oxidation rates of free radical oxygen of } [RO_2^\cdot] \text{ and } [RO^\cdot], \) respectively

\( RO_2^\cdot = \text{free radical oxygen} \)

\( RO^\cdot = \text{free radical oxygen} \)

The rate constant, \( K_{ox} \) can be obtained from laboratory tests outlined by Smith et al. (1977).

**Chemical Degradation Due to Photolysis**

Some contaminants can be photochemically transformed by absorbing light, especially ultraviolet light. The rate of contaminant concentration change
due to photolysis reactions may be expressed by (Zepp and Cline 1977, Smith et al. 1977, and Stanford Research Institute 1979):

\[- \frac{dG_w}{dt} = \frac{2.303}{J} \frac{\phi}{\epsilon \lambda} \sum_\lambda I_{\lambda} G_w \]

\[I_{\lambda} = I_{0\lambda} \exp \left\{ -(K_1 + K_2 \bar{C})(h - z) \right\} \]  \hspace{1cm} (17)

where

- \( \bar{C} \) = average sediment concentration above water depth \( Z \)
- \( I_{0\lambda} \) = incident light intensity of wave length \( \lambda \)
- \( I_{\lambda} \) = light intensity of wave length \( \lambda \) at water depth \( Z \)
- \( J \) = conversion constant
- \( K_i \) = light attenuation coefficient for water
- \( K_z \) = light attenuation coefficient due to suspended sediment in water
- \( \epsilon_\lambda \) = molar extinction coefficient of light with the wave length \( \lambda \)
- \( \phi \) = quantum yield.

Since each computational cell has a vertical finite element thickness, the above equation was averaged over the element thickness for each element in this study. Hence:

\[- \frac{dG_w}{dt} = \frac{2.303}{J} \frac{\phi}{\epsilon \lambda} \sum_\lambda I_{0\lambda} \exp \left\{ \frac{1 - \exp \left( -(K_1 + K_2 \bar{C}) \Delta z \right)}{(K_1 + K_2 \bar{C}) (n - i) \Delta z} G_w \right\} \]  \hspace{1cm} (18)

\[= K_{C3} G_w \]

where

- \( i \) = element's number counted from the river bottom
- \( n \) = total number of elements
- \( \Delta z \) = element thickness.

3.9
Various parameters and coefficients can be measured by conducting laboratory tests and/or field measurements (Zepp and Cline 1977, Smith et al. 1977, and Stanford Research Institute 1979).

### Biodegradation

A contaminant compound may be degraded by microbial activities in an aquatic environment. In this study it is assumed that microbial degradation can be expressed by the second order reaction (Falco et al. 1976, Smith et al. 1977) depending on concentrations of biomass and contaminant in water, as shown below:

\[
\frac{dG_w}{dt} = K_{B1} [B] G_w = K_{C5} G_w
\]

where

\( [B] = \) biomass per unit volume

\( K_{B1} = \) the second order rate constant for biodegradation.

### Volatilization

The volatilization of a contaminant occurs at the air-water interface. The change of contaminant concentration due to volatilization may be expressed by the following first order reaction (Smith et al. 1977):

\[
\frac{dG_w}{dt} = K_{C3} G_w
\]

where

\( K_{C3} = \) volatilization rate of the contaminant

\( K_{C3} \) can be estimated by the following relationship:

\[
(K_{C3})_{\text{water body}} = (K_0)_{\text{water body}} \left( \frac{K_{C3}}{K_0} \right)_{\text{laboratory test condition}}
\]

\[= (K_0)_{\text{water body}} \left( \frac{d_0}{d_s} \right) \]

where

\( d_0, d_s = \) molecular diameters of oxygen and contaminant, respectively
(Kc3) laboratory test conditions = volatilization rate through any substances measure at a laboratory

(Ko) water = oxygen reaeration rate through water-air interface

3.3 PARTICULATE CONTAMINANT TRANSPORT SUBMODEL

The transport model of contaminants attached to sediment includes the mechanisms of:

1. Advection and dispersion of particulate contaminants
2. Adsorption of dissolved contaminants by sediments or desorption from sediments into water
3. Radionuclide decay
4. Deposition of particulate contaminants to the river bed or resuspension from the river bed
5. Contributions of particulate contaminants from tributaries and point/nonpoint sources into the system, and subsequent mixing.

As in the transport of sediments and dissolved contaminants, the conservation of contaminants adsorbed by each sand, silt and clay sediment may be expressed as:

\[
\frac{\partial}{\partial t}(G_{ij} Bz) + (U_i G_{ij} B - U_i G_{ij} B) + \frac{\partial}{\partial z} \left\{ (W - W_{sz}) G_{ij} Bz \right\} = 0
\]

\[
= \frac{\partial}{\partial z} \left( \rho \frac{\partial G_{ij}}{\partial z} \right) - \rho G_{ij} Bz + K_j \left( K_{dz} G_{ij} G_{w} - G_{ij} \right) Bz + K_{ij} \left( K_{dz} G_{ij} G_{w} - G_{ij} \right) Bz + \frac{1}{h} \left( B_{ij} S_{ij} - G_{ij} S_{ij} \right)
\]

where

\[ G_{ij} = \text{particulate concentration per unit volume of water associated with the } j^{th} \text{ sediment size fraction in horizontal inflow.} \]

Longitudinal dispersion of particulate contaminant was assumed to be negligible, as compared to longitudinal advection. However, as noted before, the longitudinal spread of particulate contaminant due to nonuniform vertical distribution of longitudinal velocity is simulated in the model. It is also assumed that chemical and biological degradation of particulate contaminants, except radionuclide decay, is not significant. However, if it is necessary to include these mechanisms, the radionuclide decay term may include them.

3.11
The boundary conditions at the water surface and bed are:

\[ G_j (W - W_{sj}) - e_z \frac{\partial G_j}{\partial z} = 0 \quad \text{at } z = h \text{ and } 0 \]  

(22)

The finite element technique with the Galerkin weighted residual method was used to solve the transport equations of sediments, dissolved contaminants and particulate contaminants.

3.4 FINITE ELEMENT TECHNIQUE

Because of its increased solution accuracy and ready accommodation to various boundary geometries (Desai and Abel 1972, Norton et al 1973, Onishi and Wise 1978) this method was used for this study. To apply the finite element method to a partial differential equation, an alternate integral equation is developed. The finite element method employing a Galerkin weighted residual was used to solve Equations 1, 9, and 21 with the associated boundary conditions of Equations 2, 3, 12, 13, and 22. Since the governing equations of sediment and contaminant transport have similar forms, the finite element technique is described here for the following advection-diffusion equation of the general form:

\[ L[\phi] = \frac{\partial \phi}{\partial t} + \frac{\partial}{\partial z} \left( v \phi \right) - \frac{\partial}{\partial z} \left( e_z \frac{\partial \phi}{\partial z} \right) + \alpha \phi - \beta \]  

(23)

The coefficients \( v, e_z, \alpha, \beta \) are defined to accommodate the specific forms of the sediment and contaminant transport equations.

Galerkin Weighted Residual Method

The governing partial differential equation can be recast in an integral form employing the weighted residual method. This integral is formed by taking the product of \( L[\phi] \) with some arbitrary set of weighting functions, \( W_j \), which yields:

\[ \chi = \int_R L[\phi] W_j \, dz \]  

(24)

where

\[ R = \text{a domain of interest}. \]

If \( \phi \) is approximated by some polynomial:

\[ \tilde{\phi} = \sum_{i=1}^{n} \phi_i W_i \]  

(25)
where

\[ W_i = \text{approximating functions then the quantity } L[\phi] \text{ represents the residual error.} \]

For the Galerkin weighted residual method, the approximating function \( W_i \) is chosen to be the same as the weighting function \( W_j \). The integral term becomes an error distribution principle by which the nodal values \( \phi_i \) can be determined so that the residual error over the domain \( R \) is orthogonal to the polynomial selected for weight and interpolation functions.

By expanding the equation and integrating by parts, the reduced functional results:

\[
\chi = \int R \frac{a_{\phi}}{a_{\phi_{\text{at}}}} + W_j \left[ \frac{a_{\phi}}{a_{\phi_{\text{at}}}} (\psi \phi) + \frac{a_{\phi_{\text{at}}}}{a_{\phi}} \frac{\partial \phi}{\partial z} + W_j a_{\phi} - W_j a_{\phi_{\text{at}}} \right] dz - W_j e^{\frac{a_{\phi}}{a_{\phi_{\text{at}}}}} \bigg|_0^h = 0
\]

\( j = 1, 2 \ldots n + 1 \)

Note that Equation 25 was derived by assuming no net flux across the boundary. In cases where the boundary has positive or negative net flux across it, this flux was incorporated as a source or sink term in the governing equation.

The above integral can be partitioned so that:

\[
\chi = \chi_e^1 + \chi_e^2 + \chi_e^3 + \ldots + \chi_e^n = \sum_{i=1}^{n} \chi_e^i
\]

where

\( n = \text{the number of subdomains.} \)

This may be expanded to give:

\[
\chi = \int_{z_1}^{z_2} [ \ ] dz + \int_{z_2}^{z_3} [ \ ] dz + \ldots + \int_{z_n}^{z_{n+1}} [ \ ] dz
\]

(28)

The contents in brackets in Equation 28 are the same as those in Equation 26. Equation 28 will yield a set of \( n+1 \) ordinary differential equations in terms of the \( \phi_{n+1} \).

**Finite-Element Equations**

The contributions from any typical subregion or finite element can be developed by substituting a particular polynomial approximation for \( \phi \) into Equation 26. For simplicity, a linear approximation was chosen: i.e.,

3.13
\[ \phi = \tilde{\phi} = \frac{z_{i+1} - Z}{\Delta z} \phi_i + \frac{Z - z_i}{\Delta z} \phi_{i+1} \]  

(29)

where

\[ \Delta z = z_{i+1} - z_i. \]

In vector notation, one has:

\[ \tilde{\phi}(z,t) = W_i \phi_i \]

\[ W_{i+1} \phi_{i+1} \]

(30)

where weighting functions are given by:

\[ W_i = \frac{1}{\Delta z} (z_{i+1} - z) \]

(31)

\[ W_{i+1} = \frac{1}{\Delta z} (z - z_i) \]

(32)

The individual terms in the functional are approximated by:

\[ \frac{\partial}{\partial t} = W_i W_{i+1} \left\{ \frac{\phi_i}{\Delta z} \right\} \]

(33)

\[ \frac{\partial \phi}{\partial z} = \frac{\partial W_i}{\partial z}, \frac{\partial W_{i+1}}{\partial z} \left\{ \frac{\phi_i}{\partial \phi_{i+1}} \right\} = - \left[ \frac{1}{\Delta z^2} \right] \left\{ \phi_i \right\} \]

(34)

Substituting these quantities into Equation 26 for a typical subdomain, a set of algebraic equations is obtained.

The results for individual terms are given below.

1. Time Dependent Term:

\[ \int_{\text{Rei}} W_i \frac{\partial \phi}{\partial t} dz = \int_{Z_i}^{Z_{i+1}} W_i W_j dz \left\{ \frac{\partial \phi}{\partial t} \right\} dz = \Delta z \left[ \begin{array}{cc} 2 & 1 \\ 1 & 2 \end{array} \right] \left\{ \frac{d\phi_i}{dt} \right\} \]

(35)
2. Advection Term:

\[ \int_{\text{Re}i} \frac{\partial (\rho \phi)}{\partial z} dz = \int_{\text{Re}i} \frac{\partial (\rho \phi)}{\partial z} dz + \int_{\text{Re}i} \frac{\partial (\rho \phi)}{\partial z} dz = \]

\[ \begin{bmatrix}
- \frac{2}{3} v_i + \frac{1}{6} v_{i+1} \\
- \frac{1}{3} v_i - \frac{1}{6} v_{i+1}
\end{bmatrix}
\begin{bmatrix}
\phi_i \\
\phi_{i+1}
\end{bmatrix}
\]

(36)

3. Diffusion Term:

\[ \int_{\text{Re}i} \frac{\partial \phi}{\partial z} dz = \frac{\epsilon_z}{\Delta z^2} \int_{z_i}^{z_{i+1}} \left[ \frac{1}{2} \right] \begin{bmatrix} 1 \\ -1 \end{bmatrix} \begin{bmatrix} \phi_i \\ \phi_{i+1} \end{bmatrix} dz = \frac{\epsilon_z}{\Delta z} \begin{bmatrix} 1 \\ -1 \end{bmatrix} \begin{bmatrix} \phi_i \\ \phi_{i+1} \end{bmatrix}
\]

(37)

4. Decay Term:

\[ \int_{\text{Re}i} \frac{\partial \phi}{\partial z} dz = \alpha \int_{z_i}^{z_{i+1}} W_j \frac{\partial \phi}{\partial z} dz = \alpha \frac{\Delta z}{6} \begin{bmatrix} 2 \\ 1 \\ 2 \end{bmatrix} \begin{bmatrix} \phi_i \\ \phi_{i+1} \end{bmatrix}
\]

(38)

5. Sink/source Term:

\[ \int_{\text{Re}i} \frac{\partial \phi}{\partial z} dz = \delta \int_{z_i}^{z_{i+1}} \frac{\partial \phi}{\partial z} dz = \delta \frac{\Delta z}{2} \begin{bmatrix} 1/2 \\ 1/2 \end{bmatrix}
\]

(39)

Where \( \delta \) is assumed independent of \( z \). However, many sink/source terms in Equations 1, 9, and 21 are not independent of \( z \) and these terms are integrated according to their dependency of \( z \). Summing up and gathering terms, one can write the element contributions to the matrix equation as finite element:

\[ \sum_{j=1}^{n} [P]_{ej} \begin{bmatrix} \phi_i \\ \phi_{i+1} \end{bmatrix} + [S]_{ej} \begin{bmatrix} \phi_i \\ \phi_{i+1} \end{bmatrix} = \sum_{j=1}^{n} [R]_{ej}
\]

(40)

where

\[ [P]_{ej} = \Delta z \begin{bmatrix} 1/3 & 1/6 \\ 1/6 & 1/3 \end{bmatrix}
\]

(41)

3.15
The summation given in Equation 27 gives the rules for construction the matrices for all finite elements; the matrices $[P]$ and $[S]$ become tridiagonal matrices. The final set of equations is a generalization of Equation 40.

### Time-Dependent Solution

The final set of equations derived above can be expressed by:

$$
[P] \{\phi\} + \{S\} \{\phi\} = \{R\}
$$

where

- $[P]$ matrix = a symmetric tridiagonal
- $[S]$ matrix = an unsymmetric tridiagonal
- $\{R\}$ = a load vector.

This final system of equations is approximated by a Crank-Nicholson scheme (Varga 1965):

$$
\tilde{P} \left(\frac{\phi^{n+1}}{\Delta t} - \frac{\phi^n}{\Delta t}\right) = -\frac{1}{2} [S] \left(\{\phi\}^{n+1} + \{\phi\}^n\right) + \frac{1}{2} \left(\{R\}^{n+1} + \{R\}^n\right)
$$

Solving the for $n+1$ value of $\phi$, this expression can be rearranged to obtain:

$$
[P] \{\phi\}^{n+1} = [S] \{\phi\}^n + \{R\}^n
$$

where the new coefficient matrices are:

$$
[P] = [\tilde{P}] + \left(\frac{\Delta t}{2}\right) [S]
$$

$$
[S] = [\tilde{P}] - \left(\frac{\Delta t}{2}\right) [S]
$$

3.16
\{\bar{R}\} = \Delta t \{\bar{R}\} = \frac{\Delta t}{2} (\{\bar{R}\}^{n+1} + \{\bar{R}\}^{n}) \quad (50)

This type of approximation is second order correct, unconditionally stable and easily solved by most available tridiagonal solution schemes.

A computer program has been written in the FORTRAN preprocessor language FLECS to implement the model (Onishi and Wise 1979). However, a standard FORTRAN IV version of SERATRA is also available.

3.5 LISTS OF INPUT DATA AND SIMULATION OUTPUT

SERATRA, consisting of the three submodels, is applicable to nontidal rivers and impoundments. One of the advantages of SERATRA is that it can be applied to water bodies over large longitudinal distances and shallow depths by using a large aspect ratio of a computational cell. Input data requirements for SERATRA are:

- **Common Data Requirements for all the Submodels:**
  - Channel geometry
  - Discharges and flow depths of the rivers during the simulation period
  - Discharges of tributaries, overland runoff and other point/nonpoint sources
  - Vertical dispersion coefficient

- **Additional Requirements for Sediment Transport Submodel**
  - Sediment size fractions
  - Sediment density and fall velocities of sediments (sand, silt, and clay)
  - Critical shear stresses for erosion and deposition of cohesive sediment (silt and clay)
  - Erodibility coefficient of cohesive sediment

**Initial Conditions**
- Sediment concentration for each sediment size fraction
- Bottom sediment size fraction

**Boundary Conditions**
- Sediment concentration at the upstream end of the study reach
- Contributions of sediments from overland, tributaries and other point and nonpoint sources.

Additional Requirements for Dissolved and Particulate Contaminant Transport Submodels:

- Distribution coefficients and transfer rates of contaminant with sediment in each sediment size fraction (i.e., sand, silt, and clay). If values of distribution coefficients are not available, it is necessary to know clay mineral and organic sediment content to estimate these values.

- Degradation, volatilization and decay rates of contaminants

Initial Conditions

- Dissolved contaminant concentration

- Particulate contaminant concentration for each sediment size fraction (i.e., those attached to sand, silt, and clay)

Boundary Conditions

- Dissolved and particulate contaminant concentrations for each sediment size fraction at the upstream end of the study reach

- Contributions of dissolved and particulate contaminant concentrations from tributaries, overland, and other point/nonpoint sources.

With the input data described above, SERATRA simulates the following:

1. Sediment simulation for any given time

   - Longitudinal and vertical distributions of total sediment (sum of suspended and bed load) concentration for each sediment size fraction

   - Longitudinal and vertical distributions of sediment size fractions in the river bed

   - Change in bed elevation (elevation changes due to sediment deposition and/or scour)

2. Contaminant simulation for any given time

   - Longitudinal and vertical distributions of dissolved contaminant concentration

   - Longitudinal and vertical distributions of contaminant concentration adsorbed by sediment for each sediment size fraction
- longitudinal and vertical distributions of contaminant concentrations in the bottom sediment within the bed for each sediment size fraction.
4.0 MODEL TESTING

This chapter describes the testing program which has led to this application of SERATRA to the Cattaraugus and Buttermilk Creeks in New York. Sensitivity analysis results are also discussed here. SERATRA was developed as a site assessment tool for contaminants in surface waters. To build its credibility as a reliable transport model, a rigorous four point testing program was established:

1. analytical solution confirmation
2. mass balance check
3. steady flow field verification
4. unsteady flow field verification.

SERATRA is now in the final phase of model verification.

4.1 ANALYTICAL SOLUTION

First, the model was tested under conditions where analytical solutions were known. These tests examined how accurately the code algorithm portrays the vertical sediment and contaminant distributions. This was accomplished by applying the code to well-posed convection-diffusion boundary value problems having analytical solutions. One of the cases dealt with the following unsteady one-dimensional convection-diffusion equation:

\[
\frac{\partial C}{\partial t} + U \frac{\partial C}{\partial y} = \varepsilon_y \frac{\partial^2 C}{\partial y^2}
\]

with an initial condition of

\[
C(y,0) = \exp \left( \frac{Uy}{\varepsilon_y} \right) \sin \left( \frac{\pi y}{L} \right)
\]

and boundary conditions of

\[
C(0,t) = 0 \text{ and } C(L,t) = 0.
\]

Parameter values employed in the test cases were length \(L = 1\), velocity \(U = -2\), and vertical dispersivity \(\varepsilon_y = 1\). The computed results and the analytical solution compared favorably (Figure 4.1). Such agreement verified that the finite-element computational scheme of the SERATRA code accurately solves the convection-diffusion equation.

4.2 MASS BALANCE

Fundamental to any successful application model is the ability to conserve mass. Errors in mass balance can be due to the model formulation or the truncation error of the computer. Hence, after examining the model against analytical solutions as discussed in Section 4.1, the mass balance of SERATRA
4.2

was tested for 18 runs. These numerical experiments were designed to isolate the various physical and chemical processes in SERATRA for mass balance behavior. Table 4.1 summarizes the processes evaluated in this part of the testing program.

The machine accuracy of the computer used to apply SERATRA is seven significant figures. Each segment in this simulation displays mass conservation with an accuracy of at least five significant figures for each of the tested processes.

4.3 SENSITIVITY ANALYSES

As indicated in Chapter 3, only model parameters and coefficients which can be adjusted to fit to measured sediment and radionuclide data are vertical dispersion coefficient, and three parameters for cohesive sediment erosion and deposition (critical shear stresses for erosion and deposition and erodibility coefficient). Sensitivity analyses revealed that dispersion coefficient was rather important not only to the vertical sediment and contaminant distributions but also to the overall stability of the modeling. Three parameters for cohesive sediment erosion and deposition strongly affect the fine sediment distributions in water column and river bed, thus radionuclide transport, deposition and erosion. For example, sediment concentrations almost linearly increase with the erodibility coefficient once the bed shear stress is above the critical shear stress of erosion. Unfortunately, these parameters are
Scour/Deposition of Sediment
Radiouclide Adsorption/Desorption in Stream
Radionuclide Adsorption/Desorption in Bed
Boundary Conditions
Bed Initial Radionuclide Condition
Radionuclide Decay
Biological Decay
Degradation Due to Photolysis
Degradation Due to Hydrolysis
Degradation Due to Oxidation
Degradation Due to Volatilization

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Table A.1: SERATRA Mass Balance Testing Program

Scour/Deposition of Sediment
some of the least known parameters due to the lack of general understanding of cohesive sediment erosion and deposition. Further field and laboratory studies on the mechanisms of fine sediment transport, deposition and erosion should be conducted to improve the current understanding of the fine sediment transport characteristics to reduce the uncertainty on the fine sediment, thus also radionuclide transport modeling.

Other model parameters and coefficients should be determined by theoretical, experimental and field studies prior to model calibration rather than to adjust these values as a part of the model calibration to fit predicted distributions to measured data.

The study also reveals that the distribution coefficient is a very important parameter and almost linearly affects the particulate radionuclide concentrations, as shown in a series of cases discussed in the next chapter. Profound effects of flow and sediment diameters on the migration of radionuclides are also revealed as indicated in Chapter 5.

4.4 PREVIOUS FIELD TESTING UNDER STEADY FLOW CONDITIONS

The goal of the field testing program was to demonstrate the effectiveness of the model under a wide range of field conditions.

The Columbia River in Washington between Priest Rapids (River Kilometer 640) and McNary Dams (River Kilometer 470) was modeled under previous studies for the transport of sediments, radioactive $^{65}$Zn (Onishi and Wise 1979), and a heavy metal (Onishi et al. 1982). The Columbia is a large river (~1700 m$^3$/s) which contains both free flowing and backwater regions. Flow conditions were assumed to be steady. A comparison of the SERATRA predicted results with measured $^{65}$Zn concentrations appears in Figure 4.2. Correlation is excellent.

The next site chosen for another previous study was the Clinch River in Tennessee (Onishi et al. 1980). The Clinch is of intermediate proportions (~120 m$^3$/s) also exhibiting steady flow conditions. In this case, the modeled reach was 37.2 km of backwater from the river mouth to Melton Hill Dam (river kilometer 37.2). Results from this modeling of $^{90}$Sr are in excellent agreement with measured concentrations (Figure 4.3).

4.5 PREVIOUS FIELD TESTING UNDER UNSTEADY FLOW CONDITIONS

The success of SERATRA in larger rivers under steady flow conditions paved the way for the first field application with unsteady boundary conditions. Generally, the time scale for events on a large stream are much longer than those on a small stream. Thus, without going to longer simulations, the best way to test the dynamics of the code is to apply it to smaller streams. The baseflow of Wolf Creek in Iowa is ~7 m$^3$/s. High runoff events on this stream can raise the flow to 20 m$^3$/s for short periods of time which was the
FIGURE 4.2. Comparison of Predicted Results with Measured Zinc-65 Concentrations in the Columbia River, Washington (Onishi et al. 1979)
FIGURE 4.3. Longitudinal Distributions of Dissolved, Particulate and Total Strontium-90 Concentrations in the Clinch River, Tennessee (Onishi et al. 1980)

case when SERATRA was applied here (Onishi et al. 1979). A 3 year simulation of a pesticide called Alachlor from June 1971 to May 1974 was performed. Since several runoff events introduced significant amounts of water, sediment, and alachlor into Wolf Creek, the transport processes for these constituents were very dynamic. Although the simulation results under these dynamic flow conditions seem reasonable (Figure 4.4), no measured data were available to examine the accuracy of the model prediction for this case.

The quest for a highly dynamic river with adequate verification data on water, sediment, and radionuclides led to a field sampling program performed on Cattaraugus and Buttermilk Creeks in New York. The information gathered in this watershed is the most extensive collection of radionuclide data ever assembled. In the next chapter, testing of SERATRA will be discussed when it was applied to the Buttermilk and Cattaraugus Creeks in which reasonably good data were collected under a separate project (Ecker and Onishi 1978, Walters et al. 1982, Ecker et al. 1982).
FIGURE 4.4. Time Variation of Total Alachlor Concentration at Wolf Creek River Kilometer 5 During the 3-Year Simulation Period (Onishi et al. 1979)
5.0 MODELING APPLICATION

In this chapter, SERATRA, a transient, two-dimensional (laterally-averaged), sediment and radionuclide transport model, is applied to the Cattaraugus/Buttermilk Creeks in New York. Data from an extensive field sampling and analysis program provided the information necessary for the execution of this computer model. Water, sediment, and radionuclides were analyzed for various properties including temperature, concentration and activity levels.

Hydrologic modeling of rainfall, runoff, and instream hydrodynamics were performed to generate data necessary for SERATRA. These data were calibrated against measured streamflow in Cattaraugus Creek. A calibration of the cohesive sediment transport parameters was also done.

Ten simulations were performed on three flow events. The modeled radionuclides were $^{137}\text{Cs}$, $^{90}\text{Sr}$, $^{239,240}\text{Pu}$ and $^3\text{H}$.

5.1 SITE DESCRIPTION

The Western New York Nuclear Service Center, shown in Figure 5.1, is located about 30 miles south of Buffalo, New York. The Center consists of a 3345-acre site in the north central portion of Cattaraugus County. The Center is situated along an elongated rolling plain with glaciated bedrock hills along the eastern, western and southern boundaries, and Buttermilk Valley along the northern boundary. All surface drainage of the Center discharges into Buttermilk Creek. At the northwest end of the property, Buttermilk Creek joins Cattaraugus Creek which flows in a westerly direction into Lake Erie, 39 miles away. Cattaraugus Creek flows in a general westerly direction through Zoar Valley, Gowanda, and Cattaraugus Indian Reservation and empties into Lake Erie, 27 miles southwest of Buffalo. It is 20 stream miles from the confluence of Buttermilk and Cattaraugus Creeks to Gowanda and another 19 miles to the mouth of Cattaraugus Creek at Lake Erie. Franks Creek (Erdmans Brook), a tributary of Buttermilk Creek, serves as a receptor for runoff from the Center's Burial site.

Three water courses, Franks Creek, Buttermilk Creek and Cattaraugus Creek, are the principal water courses of interest in the study of radionuclide transport in surface waters from the Western New York Nuclear Service Center. The following is a brief description of each of these water courses.

Franks Creek, commonly referred to as Erdmans Brook, includes the drainage area for both the low- and high-level nuclear burial sites. The creek flows into Buttermilk Creek about 0.5 miles downstream of the burial sites. The stream flow in the creek is intermittent, varying between 0 and 100 cubic feet per second (cfs). The creek is very narrow, varying in width from 2 to 10 ft. The creek is comprised of chutes and pools, and flows in some places through swampy areas. Stream gradients are moderately steep, and the creek shows active down-cutting through previously undisturbed glacial
FIGURE 5.1. Map of Cattaraugus, Buttermilk and Franks Creeks
till which is comprised of a very stiff clayey material. This clayey material appears to be fairly resistant to erosion. The creek flows through a narrow and steep, V-shaped valley.

Buttermilk Creek has a drainage area of approximately 29.4 mi². For the period of record from October 1961 to September 1968, the average discharge of Buttermilk Creek was 46.5 cfs. The extreme maximum and minimum discharges during the period of record were 3,910 cfs on 28 September 1967 and 2.1 cfs on 10 October 1963, respectively. Buttermilk Creek flows into Cattaraugus Creek about 2.25 miles downstream of the confluence with Franks Creek. The creek width under normal conditions varies from about 20 ft at the upper end to about 75 ft near the confluence with Cattaraugus Creek. The channel bed is comprised of sand, gravel and cobbles with minor amounts of silt and clay size material. Water frequently overflows the channel banks leaving deposits of fine clayey silt along the flood plain. The flood plain varies from 300 to 500 ft wide with sparse to moderate vegetation.

A reservoir upstream of the Buttermilk Creek study reach collects runoff from a small watershed and periodically releases overflow into Buttermilk Creek. Discharge from the reservoir is regulated by a siphon spillway that maintains reservoir levels below a certain elevation. Once the siphon is primed, large quantities of water are discharged in a short period of time, producing extremely fast rising hydrographs in Buttermilk Creek during periods of relatively low flow.

Cattaraugus Creek has an estimated drainage area of 555 mi² at Lake Erie, 432 mi² at Gowanda and 218 mi² at the confluence with Buttermilk Creek. Based on the United States Geological Survey (USGS) flow data records for Cattaraugus Creek at Gowanda, New York, the average discharge for the period of record, 1940-1976, is 731 cfs. The extreme maximum and minimum daily discharges during the period of record were 34,600 cfs on 7 March 1956, and 6 cfs, respectively, on 21 August 1941.

Peak discharges generally occur on Cattaraugus Creek in October and November, prior to the onset of winter snowfall and again in February and March as a result of snowmelt. Low discharges generally occur during the summer months of July through September when rainfall is less and again during the winter months of December and January when persistent freezing conditions exist. Figure 5.2 is a summary of the 1975 and 1976 water year monthly discharge records of Cattaraugus Creek at Gowanda, New York. Cattaraugus Creek, as well as Buttermilk Creek, can be categorized as "flashy" due to their very rapid changes in discharge. Figure 5.3 is an excerpt from the 1976 water year discharge records showing the September daily discharges of Cattaraugus Creek at Gowanda. Discharges can be seen to vary by >5000 cfs in a period of one day.

Cattaraugus Creek is generally free flowing except for a small impoundment (Springville Dam) near the Village of Springville. Water flow in the creek is confined to a fairly well-defined channel under normal discharge conditions and cuts through a series of bedrock gorges which are connected by shallow valley deposits of sand, silt and gravel. Bed deposits in the gorges appear to be
FIGURE 5.2. 1975-76 Monthly Discharges of Cattaraugus Creek at Gowanda

FIGURE 5.3. September Daily Discharges of Cattaraugus Creek at Gowanda
slight and have well defined cross-section profiles. Little bank interaction appears to occur during average- or low-flow conditions.

Springville Dam (Creek Mile 36.5), located about 2.5 miles downstream of the confluence with Buttermilk Creek, is a weir type dam and is 20 ft high. The pool behind the dam is only a few acres in size, is narrow and is surrounded by nearly vertical walls of a deep gorge.

In this study, 41.5 miles of stream length on Buttermilk and Cattaraugus Creeks were modeled. The modeling began on Buttermilk Creek, 2.5 miles above the confluence with Cattaraugus Creek, and continued on Cattaraugus Creek for 39.0 miles to Lake Erie. The only tributary to Buttermilk Creek included in the model was Franks Creek.

Cattaraugus Creek has ten tributaries of varying magnitude, some of which are ephemeral, in addition to numerous transient lateral inflow contributions. The major tributaries on this stretch of Cattaraugus Creek are Spring Brook above Springville Dam, and Spooner, Connoisarauley, South Branch Cattaraugus, and Clear Creeks below the dam. Other than the 0.5 mile long reservoir behind Springville Dam, Cattaraugus Creek is free-flowing. The only permanent stream gaging station on the study reach is operated by the U.S.G.S. at Gowanda Bridge on Cattaraugus Creek 20 miles downstream from the Buttermilk Creek confluence.

5.2 SAMPLING PROGRAM

The Cattaraugus/Buttermilk Creeks sampling program consisted of field surveys of channel geometry and the monitoring of water, sediment, and radionuclides during three time periods: November 30-December 5, 1977; September 20-24, 1978; and April 26-29, 1979. These monitoring periods are referred to as Phase 1, Phase 2, and Phase 3, respectively. Detailed accounts of these monitoring programs can be found in related publications (Ecker and Onishi 1979, Walters et al. 1982, Ecker et al. 1982).

The modeled streams include 2.5 miles of Buttermilk Creek and 39.0 miles of Cattaraugus Creek immediately downstream of the Buttermilk confluence. Although the total modeled streamlength is 41.5 miles, six of the eight data verification stations (Table 5.1) are located in the first 8.8 miles of simulated streamlength.

The data collection effort on the three phases of monitoring are similarly unbalanced. More samples were taken during Phase 3 than in Phases 1 and 2 combined. This is because only in Phase 3 were time-varying data for water, sediment, and radionuclides collected.

Therefore, the problem which is best defined is the Phase 3 simulation of the 8.8 miles of streamlength along Buttermilk and Cattaraugus Creeks. This stretch of channel begins just above the Franks Creeks confluence on Buttermilk Creek, continues as Buttermilk Creek enters Cattaraugus Creek and ends at Frye Bridge, 3.8 miles below Springville Dam (Figure 5.1). In this study, the Phase 3 data will be the most heavily relied upon and the Franks Creek to Frye Bridge area will be under closer scrutiny than the downstream areas.
TABLE 5.1. Sampling Station Location

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<tr>
<th>SERATRA Segment</th>
<th>Sampling Station</th>
<th>River Mile</th>
<th>Description</th>
<th>Phase 1</th>
<th>Phase 2</th>
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<td>BC-2</td>
<td>BCM 2.05</td>
<td>1200 ft downstream of Franks Creek Confluence</td>
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</tbody>
</table>

The modeling strategy was to use the Phase 3 data for calibration, attempting to match, as well as possible, the model results to the information from the data stations in the first 8.8 miles of the simulation reach. Once the input data for SERATRA were prepared, the cohesive sediment parameters and the vertical dispersion coefficient remained to be calibrated. Using the Phase 3 flow event, these parameters were calibrated and then applied without recalibration to the Phase 1 and Phase 2 simulations. All other input parameters were specified from the data collection program.

Channel Geometry

Surveys of the channel cross-sectional geometry were performed during the Phase 1 field investigation and supplemented by additional surveys in the fall of 1980. More than 50 cross-sections were logged, primarily upstream of Frye Bridge. Long stretches of unsurveyed channel exist between Frye Bridge and Lake Erie due to access problems. U.S. Geological Survey Topographic Maps aided in the synthesis of these missing cross-sections.

Sediment Sampling

Grab samples of sediment, both in the channel bed and suspended in the water column, were the source of sediment data input to SERATRA. Samples were taken at each of the collection stations but not in the tributaries. The bulk concentration of the suspended sample was determined before both bed and suspended sediment samples were mechanically separated into sand (>74 μm), silt (74 μm - 4.0 μm), and clay (<4.0 μm) fractions.

Radionuclide Sampling

Radionuclides can exist in both aqueous and particulate forms. On the microscopic level there is a constant exchange of radionuclides between
solution and particle surfaces. In either form, radionuclide measurement requires sophisticated laboratory analysis.

After fractioning and weighing the collected bed and suspended sediment samples from Cattaraugus and Buttermilk Creeks, the samples were sent to the University of Washington for laboratory testing. Thirty radionuclides and their respective activity levels were measured for in this testing. Dissolved radionuclides were collected on reactive resin beds as field-sampled water was pumped through the beds. These beds were then sent to the University of Washington and tested in a manner similar to the sediment samples.

In addition to the activity levels detected in the water and sediment, the University of Washington provided distribution coefficients for five radionuclides: ^{137}\text{Cs}, ^{85}\text{Sr}, ^{237}\text{Pu}, ^{106}\text{Ru}, and ^{241}\text{Am} (Schell et al. 1979).

5.3 HYDROLOGIC MODELING

As part of its input data set, SERATRA requires depths and discharges at each timestep for every computational segment. The hydrodynamic modeling of Cattaraugus and Buttermilk Creeks which provided these data was performed with two models, DWOPER and MUSK. Boundary conditions for these models were based on measured and synthesized flows.

DWOPER, a one-dimensional dynamic wave model developed by the National Weather Service Hydrologic Research Laboratory (Fread 1978), was intended to be the sole model of instream hydrodynamics in this study. However, the application of DWOPER to Buttermilk Creek resulted in depths and velocities which were unreasonable despite the apparently satisfactory resolution of discharges (Figure 5.4a,b,c). Highly dynamic flow on steep, shallow streams seems to cause the model to underestimate the flow depth (Figure 5.5). This results in a prediction of supercritical flow in areas where it was not observed. Generally, problems of this nature can be alleviated by increasing the Manning roughness coefficient and if necessary, averaging cross-sections so that a smoother transition between computational nodes occurs. Although these techniques produce palatable results, they also have the effect of obscuring the description of the physical phenomena. Since errors in the hydrodynamics are passed on and magnified in the subsequent sediment and radionuclide modeling, they must be kept to a minimum. Cattaraugus Creek was modeled satisfactorily by DWOPER and there was no reason to abandon the model due to difficulties in a relatively short stretch of Buttermilk Creek. The depth calculation problems in Buttermilk Creek were avoided by applying MUSK, a one-dimensional diffusion wave model developed at Colorado State University (Ponce 1980), to this section of the hydrodynamic simulation (Figure 5.6a,b,c).

Model Descriptions

DWOPER

DWOPER was developed for application to large dendritic river systems such as the Mississippi-Ohio. However, the model is generally applicable to rivers having irregular geometry, variable roughness parameters, and lateral
inflows. In addition, it has certain features to be discussed below which provide the necessary flexibility for its application to the extreme hydraulic conditions found in the Cattaraugus-Buttermilk Creek system.

As described by Fread (1978), DWOPER uses a finite difference solution to the one-dimensional unsteady flow equations consisting of conservation of mass and momentum equations, i.e.,

$$\frac{aQ}{ax} + \frac{a(A^2A)}{ax} - q = 0$$ (51)

$$\frac{aQ}{at} + \frac{a(Q^2/A)}{ax} + gA\left(\frac{ah}{ax} + S_f + S_e\right) - qv_x + W_fB = 0$$ (52)

in which Q is discharge, A is cross-sectional area, A_0 is off-channel cross-sectional area wherein velocity is considered negligible, q is lateral inflow or outflow, x is distance along the channel, t is time, g is gravitational acceleration, v_x is the velocity of lateral inflow in the x-direction, W_f is the wind term, B is the channel top width and S_f is the friction slope defined as:

$$S_f = \frac{n^2Q/Q}{2.2 A^2 R}$$ (53)

in which n is the Manning roughness coefficient and R is the hydraulic radius. The term S_e is defined as:

$$S_e = \frac{K_e a(Q/A)^2}{2g ax}$$ (54)

in which K_e is the expansion-contraction coefficient.

Equations (51) and (52) are solved using the weighted four-point finite difference scheme originally developed by Preissmann (1961). In the weighted four-point scheme, the continuous x-t region in which solutions of h and Q are sought is represented by a rectangular net of discrete points. The scheme allows the use of equal or unequal intervals of Δx and Δt along the x and t axes, respectively. Each point is identified by a subscript (i) which designates the x position and a superscript (j) for time position. The time derivatives are approximated by:

$$\frac{aK}{at} = (K_i^{j+1} + K_i^{j+1} - K_i^j - K_i^{j+1})/2\Delta t$$ (55)

in which K represents any variable. The spatial derivatives are approximated by a finite difference quotient positioned between two adjacent time lines according to weighting factors t and 1-c, i.e.,

5.8
\[
\frac{\Delta K}{\Delta x} = \theta \left( K_{i+1}^{j+1} - K_i^{j+1} \right) / \Delta x + (1-\theta) \left( K_{i+1}^j - K_i^j \right) / \Delta x
\]

(56)

and variables other than derivatives are approximated in a similar manner, i.e.,

\[
K = \theta \left( K_i^{j+1} + K_{i+1}^{j+1} \right) / 2 + (1-\theta) \left( K_i^j + K_{i+1}^j \right) / 2
\]

(57)

Generally, the ability of a model such as DWOPER to reproduce actual flow events depends on the amount and quality of data available for the stream system under study. These data include: 1) channel geometry, 2) hydraulics, 3) estimate of channel roughness, and 4) initial conditions.

Channel geometry is represented in the model by surface widths as a function of stage at computational points corresponding to actual cross section locations. From the surface widths, wetted area and conveyance are also determined as functions of stage.

Hydraulic data refers to boundary conditions and observed stages and/or discharges. Both upstream and downstream hydrographs are needed on each stream for the operation and calibration of DWOPER. For this study, the upstream boundaries included the inflow hydrographs for each stream as previously discussed. Channel roughness in the model is represented by a single lumped parameter, Manning's "n", which accounts for all the processes that contribute to the loss of energy or momentum, excluding expansion and contraction losses [see Equation (54)]. Initial values for Manning's "n" for the two study streams were computed indirectly from Manning's equation based on velocity measurements at the upstream boundaries. Initial conditions were computed for each computation point using standard step backwater. The use of the computed "n" values resulted in super-critical flow conditions at several locations. This was corrected by increasing the "n" values, within reasonable limits, until the flow became subcritical.

The use of a variable \( \Delta x \) and the ability to change \( \Delta t \) and the weighting factor \( \theta \) are important in the application of DWOPER to Cattaraugus Creek because of the flexibility they provide, when judiciously selected, in controlling the model's numerical stability and convergence. In implicit schemes, such as that used by DWOPER, the finite difference approximations of Equations (51) and (52) converge to the true solutions of the partial differential equations as \( \Delta x \) and \( \Delta t \) approach zero (Abbot and Ionescu 1967, Leendertse 1967). In this sense, convergence is the measure of the error in the numerical scheme due to improper discretization. Stability refers to the ability of a numerical scheme to limit error growth due to round-off. The only necessary condition for stability of implicit schemes is that the weighting factor \( \theta \) be greater than 0.5. Therefore, for a give value of \( \theta \), a decrease in the values of \( \Delta x \) and \( \Delta t \) increases the accuracy of the model. On the other hand, as \( \theta \) approaches 1.0, the model becomes stable and less convergent, increasing numerical distortion.
Certain channel and hydrograph characteristics can also have an effect on the level of numerical distortion present in the model. Fread (1973) demonstrated that numerical distortion increases with increasing channel length, roughness factor and channel slope or with decreasing initial depth of flow. Also, as the time to peak of the upstream boundary hydrograph decreases, the numerical distortion increases. From this it can be seen that the usual problems encountered in building and running mathematical models are magnified considerably in the face of conditions similar to those in the Cattaraugus Creek system.

**MUSK**

MUSK is a simplified flood routing model of the diffusion wave class. In general, it can be applied in steep channels where no downstream controls exist. Unlike DWOPER, MUSK is designed for use on a single primary stream with lateral inflow introduced along the streamlength. Irregular geometries and spatially varying roughness coefficients are normal model input data for MUSK.

The MUSK formulation is based on a manipulated form of the one-dimensional unsteady flow equations. In place of the conservation of momentum equation [Equation (52)], a single-valued resistance equation, i.e., Manning, is substituted. This is known as the kinematic wave approximation. Using this approximation, the one-dimensional convection equation can be derived from the mass conservation equation.

\[
\frac{1}{c} \frac{\partial Q}{\partial t} + \frac{\partial Q}{\partial x} = 0
\]

(58)

where \(c\) = celerity
\(Q\) = discharge

A finite difference representation of this equation with weighting in the time dimension yields the following equation

\[
\frac{1}{\Delta t} \left\{ \theta \left( Q_{i+1}^j - Q_i^j \right) + (1-\theta) \left( Q_{i+1}^j - Q_i^{j+1} \right) \right\} \\
+ \frac{1}{\Delta x} \left\{ \left( Q_{i+1}^{j+1} - Q_i^{j+1} \right) + \left( Q_{i+1}^j - Q_i^j \right) \right\} = 0
\]

(59)

An explicit solution scheme is used in MUSK to solve for \(Q\) across the \(x-t\) domain.

The convection equation is inherently nondiffusive, meaning that a flood wave shape is routed downstream without attenuation. This is precisely the behavior of a kinematic wave, the assumption used in the MUSK formulation. However, an analysis of the higher order error terms of the finite difference analogs discloses that numerical deviations in the flood wave will occur. The actual deviation is a function of \(\Delta x, \Delta t, c,\) and \(\theta\). It can be shown that if
the diffusion wave approximation is used in place of the conservation of momentum equation, i.e., inertia terms are neglected, the one-dimensional convection-diffusion equation can be derived from the unsteady flow equation set

$$\frac{1}{c} \frac{aQ}{a t} + \frac{aQ}{a x} = \frac{Q_0}{2bs} \frac{a^2Q}{a x^2}$$

(60)

By matching the truncation error of the convection equation finite difference scheme to the physical diffusion found in the convection-diffusion equation, the weighting value $a$ can be calculated to produce a physically-based diffusion. Thus, although the MUSK formulation is based on a unique stage-discharge relationship, the flood wave attenuation computed by MUSK does not reflect a single-valued rating curve. The behavior described by MUSK is similar to the less simplified parabolic partial differential equation which describes the diffusion wave. Since this is the case, flow depths are calculated by using continuity rather than the resistance equation.

Nonuniform $\Delta x$ and a constant $\Delta t$ are user supplied in MUSK while the weighting factor, $a$, is computed by the model. Because MUSK solves an initial value problem rather than a boundary value problem, a "marching" solution which propagates downstream is used. This precludes any backwater effects from being resolved by the model.

The data requirements by MUSK are very similar to those of DWOPER. The largest difference occurs in the hydraulic data. MUSK needs discharge hydrographs only at the upstream and lateral inflow boundary conditions. Because it solves an initial value problem, internal and downstream boundary conditions are not necessary. MUSK also uses the Manning roughness coefficient in its formulation; however, in this case energy losses from channel expansion and contraction are lumped into this parameter. The Manning resistance coefficient in MUSK is location dependent.

MUSK has been shown to be unconditionally stable and convergent for the types of problems where it is applicable.

MODEL APPLICATIONS

The MUSK simulation used 13 nodes to represent the 2.5 miles of Buttermilk Creek at the beginning of the study reach (Figure 5.7). The smallest distance between nodes was 0.20 miles while the longest interval was 0.26 miles. The upstream boundary condition was the hydrograph calculated at the beginning of the simulation reach. Lateral inflow from Franks Creek was brought in as a hydrograph at the second node.

The DWOPER simulation of Cattaraugus Creek was divided into two separate simulations: 12 nodes (4.8 miles) above Springville Dam and 21 nodes below. The upstream boundary condition hydrograph for the upper Cattaraugus Creek simulation was located 2.3 miles above the Buttermilk Creek confluence and based on data collected at Bigelow Bridge. The downstream boundary condition was a single-valued rating curve at Springville Dam (Figure 5.7). The longest
interval between nodes on the upper simulation was 0.63 miles while the shortest interval was 0.15 miles. Major tributaries on this simulation reach were Spring Brook and Buttermilk Creek. The discharge hydrograph calculated by MUSK at the end of the Buttermilk Creek was used by DWOPER as the lateral inflow boundary condition to Cattaraugus Creek.

The DWOPER simulation below the dam use a calculated hydrograph as the upstream boundary condition and observed stage hydrographs at Lake Erie as the downstream boundary condition (Figure 5.8). The longest interval between nodes on the lower Cattaraugus Creek simulation was 3.6 miles while the shortest interval was 0.25 miles. Below Springville Dam, four major tributaries enter Cattaraugus Creek: Spooner, Connoisarauley, South Branch Cattaraugus, and Clear Creeks. These tributaries are treated as lateral inflow boundary conditions requiring discharge hydrographs.

In this study, Snyder's method of hydrograph synthesis was used in conjunction with rainfall information and the SCS (Soil Conservation Service) curve number method for runoff calculation (Viessman et al. 1977). Where boundary conditions were not sufficiently monitored in the field, synthetic unit hydrographs based upon watershed characteristics were computed for individual sub-basins. Rainfall data from NOAA were used to reconstruct precipitation events and determine magnitudes for the individual hydrographs. Runoff reaching the boundary condition site was calculated using the SCS curve number method and superposed upon the estimated baseflows.

Hydrodynamic Modeling Results

In the context of the three phases of sampling, the Phase 3 hydrodynamic were moderate in discharge and unsteadiness. Phase 3 was selected for the first modeling effort because boundary conditions and calibration data were available from the field investigation. During Phase 3, all upstream boundary conditions and most major tributaries were gaged for discharge. Hydrograph synthesis was required only at South Branch Cattaraugus Creek which is downstream of the area of primary interest. Calibration of Manning resistance coefficients for the Phase 3 hydrodynamic modeling was available at Frye Bridge (Creek Mile 32.7) and Gowanda Bridge (Creek Mile 16.4). Results of the Phase 3 hydrodynamic modeling are compared with measured values at Gowanda in Figure 5.9. The Phase 3 hydrodynamic modeling began at 8:00 a.m. April 27, 1979 and ended at 8:00 a.m. April 29, 1979. Of the three phases, the Phase 3 hydrodynamics were moderate, as a 48 hr flood wave with a peak discharge of 920 cfs traveled downstream. The modeled discharges are in excellent agreement with the Gowanda stream data.

Phase 2 discharges were the lowest and least dynamic of the three phases. Synthetic inflows were generated for South Branch Cattaraugus, Connisarauley and Clear Creeks in addition to the Cattaraugus Creek upstream boundary condition at Bigelow Bridge. Measured baseflows were used in Franks and Buttermilk Creek while a 0.4 cfs/sq. mi. runoff distribution was used to determine other lateral inflows. The average basin rainfall during the Phase 2 simulation period was 2.28 in. of which 0.14 in. were calculated to become runoff. For
the most part, Manning resistance coefficients calibrated in the Phase 3 hydrodynamic simulation were used in the Phase 2 simulation although coefficients in the steeper sections of lower Cattaraugus Creek were increased in some cases. Figure 5.10 is a comparison of computed and measured discharges at Gowanda.

Phase 2 radionuclide sampling began at 8:00 a.m. September 20, 1978 and ended at 12:00 noon September 24, 1978. Since the radionuclide sampling began on the falling limb of a flood hydrograph, it was necessary to begin the hydrodynamic modeling 74 hr earlier to simulate the entire flood wave. Only the last 30 hr of the flood wave are included in the radionuclide modeling as the stream returned to baseflow for the concluding 70 hr of simulation. The computed flood wave is a few hours out of phase with the measured wave; however, the representation of the hydrodynamics during the period of radionuclide simulation is good.

Phase 1 hydrodynamics were the most unsteady and had the highest discharges of the three phases of data collection. Flow measurements in this phase were not sufficient to provide the necessary boundary conditions for the hydrodynamic modeling. Thus, all boundary conditions were computed. Hydrograph synthesis was performed at the Cattaraugus and Buttermilk Creeks upstream boundary condition sites in addition to four major tributaries: Spring Brook, Spooner, South Branch Cattaraugus, and Clear Creeks. The remaining lateral inflows were determined on a basin square mile basis. Unfortunately, the U.S.G.S. streamgaging station at Gowanda was not operating during the Phase 1 simulation period and accurate calibration information was unavailable. The uncalibrated model results at Gowanda appear in Figure 5.11.

The Phase 1 hydrodynamic modeling began at 1:00 a.m. November 29, 1977 in Buttermilk Creek and at 3:00 a.m. November 30, 1977 in Cattaraugus Creek. The additional modeling period in Buttermilk Creek was needed to resolve a complete flood wave. The Cattaraugus Creek simulation ended at 3:00 a.m. December 5, 1977. The baseflow in Buttermilk Creek was used to fill out the additional simulation time required by the Cattaraugus Creek modeling. The modeling results reveal two distinct flood waves occurring during the simulation period with peak discharges exceeding 3000 cfs.
FIGURE 5.4. DWOPER Modeling at Buttermilk Creek Mile 1.6:
a) Discharge, b) Depth, and c) Velocity
FIGURE 5.5. Channel Bottom and Water Surface Profiles of Cattaraugus-Buttermilk Creeks
FIGURE 5.6. MUSK Modeling at Buttermilk Creek Mile 1.6:
  a) Discharge, b) Depth, and c) Velocity
FIGURE 5.7. Map of Cattaraugus-Buttermilk Creeks System, New York
FIGURE 5.8. Cattaraugus Creek, New York
FIGURE 5.9. Phase 3 Discharge Hydrograph at Gowanda
Radionuclide simulation begins @ 74 hours

FIGURE 5.10. Phase 2 Discharge Hydrograph at Gowanda
FIGURE 5.11. Phase 1 Discharge Hydrograph at Gowanda
5.4 SEDIMENT AND RADIONUCLIDE SIMULATION

This section describes data input to SERATRA and the SERATRA simulation results. Essentially, the Cattaraugus Creek watershed sampling program provided the data set which enabled SERATRA to be applied to four radionuclides (\(\text{Cs}^{137}\), \(\text{Sr}^{90}\), \(\text{Pu}^{239,240}\) and \(\text{H}^{3}\)) in the course of three flow events.

The three flow events which are the basis for this study are very different with respect to hydrodynamic characteristics. Of the three phases, Phase 1 hydrodynamics are the most unsteady with the highest discharges occurring during this study period. Unfortunately, time-dependent sediment and radionuclide concentrations were not measured during the Phase 1 field program. Thus, the boundary conditions of a very unsteady flow event are characterized by constant sediment and radionuclide concentrations. The Phase 2 flows were the lowest and steadiest of the three phases. However, as in Phase 1, a single field sampling at each data collection site was relied upon to represent the entire simulation period. Phase 3 hydrodynamics were relatively moderate in discharge magnitude and dynamics. The most extensive data collection effort took place during the Phase 3 field sampling program. In Phase 3, time-dependent sampling was instituted at various data collection sites. The additional data generated provided SERATRA with time-varying sediment and radionuclide boundary conditions.

5.4.1 Input Data Description

The SERATRA input data stream is comprised of information which fall into six categories:

1. Numerical Model Parameters
2. Channel Geometry
3. Flow and Fluid Characteristics
4. Sediment Characteristics
5. Radiochemical Parameters
6. Initial Conditions
7. Boundary Conditions

In the Cattaraugus/Buttermilk Creek modeling study, the radionuclide initial and boundary conditions are unique for each of ten applications of SERATRA. However, the remainder of the input parameters are, for the most part, not specific to any of the three flow events being studied.

**Numerical Model Parameters**

The numerical model parameters required by SERATRA are the:

1. number of segments
2. number of timesteps
3. segment length
4. timestep size
5. water column standard element thickness
6. standard channel bed layer thickness
7. number of initial layers in the channel bed.

Basically, the segments and timesteps used in the hydrodynamic modeling of Cattaraugus and Buttermilk Creeks were preserved in the sediment-radionuclide transport simulations. Although segment lengths vary along the study reach, the same channel representation is used for each of the three flow events. Channel bed parameters, i.e., the number of initial bed layers and the bed layer thickness were assigned to be initially constant in this study, regardless of location or flow event.

Channel Geometry

At each computational segment, SERATRA requires:
1. segment elevation, and
2. depth-surface area data pairs.

The modeling effort divided the 41.5 mile simulation reach into 34 computational segments. Some of the cross-sections used in the modeling effort were modified/averaged from the original surveys. This is because of model requirements and the existence of more field-surveyed cross-sections than model cross-sections. SERATRA represents channel geometry as depth-width data pairs, i.e., at a given elevation a certain width is associated. This precludes the accurate description of complex or braided channels. For such geometry, an optimized representation of the channel must be developed. Where field information is plentiful, the geometry for a particular cross-section might be the result of averaging two or more field-surveyed cross-sections. In this study, each cross-section at a given location is uniquely characterized but unchanged for all three phases. The channel geometry is taken from the hydrodynamic modeling study performed prior to the execution of the SERATRA code.

Flow and Fluid Characteristic

1. the number of water columns based on the flow depth obtained by hydrodynamic models
2. flow discharges obtained by hydrodynamic models
3. water temperature.

Sediment Characteristics

The sediment characteristics input to SERATRA are:
1. particle diameter
2. particle density
3. settling velocity
4. critical shear stress for deposition of cohesive sediment
5. critical shear stress for resuspension of cohesive sediment
6. erodability of cohesive sediment, and
7. vertical diffusion coefficient.

In the present application of SERATRA, three particle sizes representing the sand, silt and clay sediment fractions are routed. The selection of the specific size range for each of the three classifications was based on the field measurements in Cattaraugus and Buttermilk Creeks.

The sand fraction can be routed by either the Tofaletti or Colby sediment transport method. The Tofaletti method was used in this study. Silt and clay are treated as cohesive soils whose erosion and deposition rates were estimated by Partheniades (1962) and Krone's Formulas (1962). In the Buttermilk and Cattaraugus Creeks field sampling program, it was not possible to determine the three cohesive sediment parameters (resuspension critical shear stress, deposition critical shear stress, and erodability) required by the SERATRA input stream for the silt and clay size fractions. Therefore, a set of calibration runs were performed prior to the application of the model. The Phase 3 event was chosen for the calibration runs because of the extensive data that was available. To avoid "curve-fitting" the simulation results to the field values, the cohesive sediment transport parameters calibrated with the Phase 3 data were used without recalibration in the Phase 1 and Phase 2 simulations. This is possible because these parameters are theoretically event-independent. The sediment transport parameters are summarized in Table 5.2.

<table>
<thead>
<tr>
<th>TABLE 5.2. Sediment Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter, m</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Density, kg/m³</td>
</tr>
<tr>
<td>Porosity</td>
</tr>
<tr>
<td>Vertical Diffusion Coefficient, m²/s</td>
</tr>
<tr>
<td>Erodability kg/m²/s</td>
</tr>
<tr>
<td>Critical Scour Shear Stress kg/m²</td>
</tr>
<tr>
<td>Critical Deposition Shear Stress kg/m²</td>
</tr>
</tbody>
</table>

n.a. = not applicable
A reasonable radionuclide modeling requires boundary conditions, distribution coefficients, and verification data to be adequately defined. Of the 30 radionuclides which were detected in the field samples, only four radionuclides generated sufficient information for a reasonable modeling study: 137Cs, 90Sr, 239,240Pu, and 3H. Except for the Phase 1 simulation where only 137Cs and 3H were modeled, these four radionuclides were simulated in the Phase 2 and Phase 3 events. Fortunately, these four radionuclides display a wide range of behavior with which SERATRA can be tested. Half lives vary from 12 to 7000 yr while distribution coefficients, i.e., Kds, range over two orders of magnitude.

SERATRA is unique in its treatment of the adsorption/desorption phenomenon. Not only does the model simulate the time-dependent exchange of radionuclide between the dissolved and sorbed forms, but the adsorption and desorption processes are treated as distinctly different mechanisms requiring separate $K_d$ values. The adsorption $K_d$ values used in this study are from laboratory measurements of samples taken from the Cattaraugus and Buttermilk Creeks. However, the desorption $K_d$s were not measured in the field.

**Radiochemical Parameters**

The radiochemical parameters used in this modeling study are the:

1. adsorption distribution coefficient
2. desorption distribution coefficient
3. adsorption transfer rate
4. desorption transfer rate, and
5. radionuclide decay rate.

The adsorption/desorption parameters were determined through laboratory radionuclide analyses of bulk water-sediment samples in Cattaraugus Creek. Where data were insufficient, desorption parameters were calculated using adsorption/desorption ratios from other studies (Schell et al. 1980). Specific distribution coefficients for each sediment size fraction were created by apportioning the bulk values such that a weighted average of the distribution coefficients would equal the laboratory value. Radionuclide decay rates were based on published physical data. The radiochemical parameters used in this study were unique to the radionuclide being modeled but were kept independent of the flow event being simulated.

Distribution coefficients for adsorption and desorption measured at other freshwater sites (Table 5.3) were used to estimate the desorption $K_d$s in this study. For each radionuclide modeled by SERATRA, an average ratio of desorption $K_d$ was determined from data published in previous studies. This ratio was then applied to the adsorption distribution coefficient measured in Cattaraugus Creek to create the necessary model input (Schell et al. 1980).
The adsorption–desorption process is also a function of sediment size with finer sediment exhibiting a stronger affinity for dissolved radionuclides. SERATRA accounts for this variation by allowing each sediment size fraction to be treated with a separate K_d value. Since the distribution coefficients measured by the University of Washington were not differentiated by sediment size, an approximate partitioning was employed. It was assumed that a 1:5:10 ratio for sand, silt, and clay distribution coefficients was appropriate. The actual value of each K_d value was computed such that a weighted average based on sediment fractions yielded the bulk value measured in the laboratory, i.e.,

\[
(K_d)_{sand} \times (\% \text{ sand}) + (K_d)_{silt} \times (\% \text{ silt}) + (K_d)_{clay} \times (\% \text{ clay}) = (K_d)_{measured}
\]

where

\[
(K_d)_{silt} = 5 \times (K_d)_{sand}
\]

\[
(K_d)_{clay} = 10 \times (K_d)_{sand}
\]

Radionuclide input data provided to SERATRA are shown in Table 5.4.
### TABLE 5.4. Radionuclide Data Input to SERATRA

<table>
<thead>
<tr>
<th>Radionuclide</th>
<th>Adsorption</th>
<th>Desorption</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\lambda_s^{-1}$</td>
<td>$K_d_{sand}$</td>
</tr>
<tr>
<td>$^{137}Cs$</td>
<td>$7.27 \times 10^{-10}$</td>
<td>0.1</td>
</tr>
<tr>
<td>$^{90}Sr$</td>
<td>$7.82 \times 10^{-10}$</td>
<td>0.01</td>
</tr>
<tr>
<td>$^{239,240}Pu$</td>
<td>$3.34 \times 10^{-12}$</td>
<td>3.5</td>
</tr>
<tr>
<td>$^3H$</td>
<td>$1.79 \times 10^{-9}$</td>
<td>0.0</td>
</tr>
</tbody>
</table>

#### Initial Conditions
SERATRA requires the following initial conditions to be specified at each segment:

1. bed sediment size fractions
2. bed radionuclide activity
3. suspended sediment size fractions and concentrations
4. suspended radionuclide activity, and
5. dissolved radionuclide activity.

Except for the dissolved radionuclide activity, the initial conditions are defined for each of the three sediment size fractions being modeled. The initial bed conditions for sediment and radionuclide are based on the field sampled values while the water column initial conditions are specified to match boundary conditions at the beginning of the SERATRA simulation.

#### Boundary Conditions
The boundary conditions in SERATRA represent time-varying loadings external to the study reach and include:

1. suspended sediments concentrations
2. particulate radionuclides, and
3. dissolved radionuclides.
Other than the dissolved radionuclides, boundary conditions are specified for each sediment size fraction. Two types of boundary conditions are possible in SERATRA: upstream and lateral inflow. The time-varying boundary conditions in this modeling study were generated by fitting a curve through field-sampled values which were taken over a period of time. If time varying data was sparse, an average value was used.

5.4.2 Sediment Transport Simulation Results

In general, the sediment transport modeling describes a silt-dominated suspended sediment load washing through the creek system. The three flow events modeled are accompanied by relatively high suspended sediment concentrations due in part to the erosion of the channel bed in the study reach. Very little of the fine-grained sediments (silt and clay) are deposited on the channel bottom as the flow carries these particles into Lake Erie. On the other hand, sand displays a net deposition as it passes through the Cattaraugus Creek system. The deposited sediments occur almost exclusively in the Lake Erie and Springville Dam backwaters. Except for these backwater areas, the general tendency is for bed scouring. This scouring of the smaller bed sediment particles leaves a protective surface layer of larger particles which prevents further erosion of the finer sediment. This phenomenon is called bed armoring and was predicted to occur especially during the Phase 1 flow event. The comparison of computed and measured sediment concentrations are shown in this section as well as in Appendix A.

Phase 3

From a modeling standpoint, the Phase 3 simulation by SERATRA was well-defined. Time-dependent sampling of water, sediment, and radionuclides at the boundary conditions and verification sites provided a data set which required minimal data generation. Calibration was necessary only for the cohesive sediment transport submodel. All other parameters, including those used in the radionuclide transport submodel were fully specified, thus, no calibration was performed in these cases.

Throughout the simulation silt is a dominant size fraction in the water column accounting for about 85% of the total suspended sediments. Clay accounted for the bulk of the remaining 15% as sand occurred in relatively small concentrations.

The Phase 3 sediment and radionuclide simulation period begins at 8:00 a.m. April 26, 1979 and ends at 8:00 a.m. on April 29, 1979. A summary of the observed and predicted Phase 3 sediment concentrations is found in Table 5.5.

Results from the Phase 3 sediment transport modeling showed a sediment cloud propagating downstream with the 40 hour flood wave. The 'spike' of high discharge in Buttermilk Creek was not reflected in the predicted suspended sediment concentrations, in fact there was a slight decrease in clay concentrations as the spike passed through Buttermilk Creek (Figure 5.12). Although
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<td>BC-4/1</td>
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<td>11.1</td>
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<td>12.0</td>
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<td>Silt</td>
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<tr>
<td>Clay</td>
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<td>5.6</td>
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The total mass of suspended sediment increased as the spike passed through, dilution by the sudden increase of water volume offset any increases in sediment concentration.

The results of the Phase 3 sediment calibration efforts with SERATRA are in general agreement with measured data. At BC-3, computed silt concentrations are the highest of the three sediment constituents, with clay and sand concentrations considerably below the silt levels. Unlike the sudden high discharges found in Phase 1, a sediment wave gradually changing over 40 hours of simulation characterizes the plots of sediment concentrations. A comparison with the field sampled concentrations at hour 27.5, show predicted concentrations to be 50% lower.

Three field samplings were taken at BC-4 at 3.4, and 36, and 64.5 hr. The gross phenomenon indicated by the field data is a sediment concentration peak occurring near the time of the 37-hour sample. Computed concentrations are in agreement with this trend and compare favorably with the field values (Figure 5.12), especially at the 3.5 and 64.5 hr marks. The predicted sediment concentrations, except for sand, are below the sampled concentrations. As the sediment from Buttermilk Creek enters Cattaraugus Creek, suspended sediment concentrations are reduced by a factor of two (Figure 5.13). A more diffuse sediment wave of a 55 hr duration occurs in this section of Cattaraugus.
FIGURE 5.12. Phase 3 Sediment Concentrations at BC-4
FIGURE 5.13. Phase 3 Sediment Concentrations at CC-3
Creek than in Buttermilk Creek. In this case however, the effect of the Buttermilk Creek discharge is visible. This is due to the sudden increase of sediment mass entering Cattaraugus Creek with the discharge spike.

At CC-3 (Figure 5.13), downstream of the Buttermilk confluence, the predicted sediment wave is broader at the base than that seen on Buttermilk Creek. The "spike" of the Phase 3 hydrodynamics is visible on the sediment wave at CC-3 because the concentrations in Buttermilk Creek are higher than those found in Cattaraugus Creek. Predicted concentrations closely approximate the measured values at 25 hr and are consistently lower.

The field data at CC-5 are samplings at 9, 33, and 59 hr. These data indicate a sediment peak around the 33-hr mark of the event. The modeled peak occurs at 37 hr (Figure 5.14). At 9 and 33 hr, predicted concentrations are consistently 35% below the field concentrations. At 59 hr, predicted silt and clay concentrations are higher than the measured values while the predicted sand is lower than the field concentration.

Downstream of Springville Dam, the wave of predicted sediment becomes more diffuse, taking up the entire simulation period. Although peak sediment concentrations follow the trend of the flood wave, the transported sediment displays the effects of bed scouring and subsequent armoring. Elevated levels of silt concentrations in the first 20 hr of the simulation are the result of bed material suspended by scour. After 50 hr of simulation, the drop in the silt concentration is attributable to the armoring of the silt in the bed by the heavier sand fraction. Clay and sand suspended fractions are not strongly affected by the scouring mechanism and remain in low concentrations with less dynamic effects.

At CC-6 (Figure 5.15) and subsequent segments, the computed silt fraction of the suspended sediment is increasing due to scour. The trend exhibited by the three field samples is in general preserved quite well by the simulation. Clay and sand concentrations computed by SERATRA are within 0.002 kg/m³ of the measured concentrations. Predicted silt concentrations are consistently about 0.015 kg/m³ higher than the field silt values.

Data Stations CC-9 and CC-11 have very similar results. The sharp wave outline has dissipated, leaving a gentle increase in concentration at hour-50 of the simulation. While the sand and clay concentrations predicted by SERATRA match quite well with sampled data, the silt concentration is about four times higher than the field value. The elevated silt concentrations produced by the model is a result of silt scoured off the channel bottom.

Figure 5.16 is the predicted longitudinal distribution of the total suspended sediment concentration at the end of the 72 hour simulation period. The first four data points represent the modeled concentrations at sites BC-3, BC-4, CC-3, and CC-5. The temporal concentration distributions at these locations indicate these concentrations are at levels near those which existed prior to the flood event. The steady increase in concentration from CC-3 through CC-11 is the spatial description of the falling limb of the sediment wave.
FIGURE 5.14. Phase 3 Sediment Concentrations at CC-5
FIGURE 5.15. Phase 3 Sediment Concentrations at CC-6
FIGURE 5.16. Longitudinal Distribution of Suspended Sediment Total Concentration at Hour 72, Phase 3
In Phase 3, deposition was predicted to occur only at Springville Dam (segment 14) and at the mouth of Cattaraugus Creek at Lake Erie (segment 34). These are the two backwater areas on this creek system. Scour was predicted in almost all the other modeled segments. Figure 5.17 is a bar graph of the predicted deposition and scour occurring as a function of distance. The areas of the bars reflect the total mass of sediment scoured or deposited. Large depositions of sand at the Springville Dam and Lake Erie backwaters offset the sand scoured in the other segments. In Phase 3 the net sand deposited amounted to 3400 kg. As Figure 5.17 indicates, the largest volumes of scoured bed material occurred below Springville Dam. Ninety-eight percent of the scoured material was silt amounting to 410,000 kg while scoured clay amounted to 7500 kg. The most intensive erosion took place just below Springville Dam.

A summary of the observed and predicted suspended sediment concentrations is found in Table 5.5. Additional plots of sediment concentration at the data collection stations are in Appendix A. Comparison of these values revealed that SERATRA reproduced reasonably well a dynamic pattern of sediment transport and that most predictions were within 50% of the measured data. Considering the complexity of the stream system and the accuracy of the field data, SERATRA was judged reasonably capable of simulating a dynamic sediment transport process.

Phase 2

Other than the calibration of the cohesive sediment parameters in Phase 3, no other calibration was performed in this study. In Phase 2 and Phase 1, only a single sample was taken at each data station along the study reach. Thus, no time-dependent sediment or radionuclide information was available. The assumption of constant influence concentrations throughout the flow event was made with the full knowledge that some inaccuracy might result.

The Phase 2 sediment and radionuclide simulation period began at 8:00 a.m. on September 20, 1978 and ended at 12:00 noon on September 24, 1978. A summary of the observed and predicted suspended sediment concentrations is found in Table 5.6.

The modeled flow event begins on the falling limb of a flood wave after which a steady discharge occurs. The effect of the flood wave is significant downstream of the dam. Upstream of the dam, suspended sediment concentrations are virtually constant with silt comprising about 75% of the suspended material while clay accounts for the bulk of the remaining 25%.
### TABLE 5.6. Phase 2 Observed and Computed Sediment Concentrations

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<tr>
<td>Sand</td>
<td>0.42</td>
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<tr>
<td>Silt</td>
<td>45.65</td>
<td>45.7</td>
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<td>Clay</td>
<td>13.55</td>
<td>14.7</td>
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<tr>
<td><strong>CC-3</strong></td>
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<tr>
<td>Sand</td>
<td>0.105/0.15/0.21</td>
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<td>Silt</td>
<td>7.15/8.37/15.90</td>
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<td>Clay</td>
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<td><strong>CC-5</strong></td>
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<tr>
<td>Sand</td>
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<tr>
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<tr>
<td>Sand</td>
<td>0.57</td>
<td>0.1</td>
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<tr>
<td>Silt</td>
<td>20.16</td>
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<td>Clay</td>
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<tr>
<td>Clay</td>
<td>0.83</td>
<td>2.5</td>
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</table>

At BC-4 (Figure 5.18), the steady Buttermilk Creek discharge is reflected in unchanging sediment concentrations. Silt is the largest constituent with clay and sand sediment accounting for one-fourth of the total suspended sediment. In comparison with field samples, the predicted concentrations are in excellent agreement.

As sediment enters Cattaraugus Creek from Buttermilk Creek, sediment concentrations are reduced by a factor of three. In Cattaraugus Creek Station CC-3, the predicted concentrations are in general 100% higher than the measured values. At CC-5, good correlation for sand and silt fractions with field data is seen in Figure 5.19. Through CC-5, the concentrations computed by SERATRA were steady. Downstream of Springville Dam, the high discharges from the flood wave are accompanied by high sediment concentrations. The increased suspended sediment load is due to the scour of the channel bed primarily below the dam.
Figure 5.17: Predicted Sediment Deposition and Erosion, Phase 3
FIGURE 18. Phase 2 Sediment Concentrations at BC-4
FIGURE 5.19. Phase 2 Sediment Concentrations at CC-5
Figure 5.20 is the plot of sediment concentrations at CC-9. Obviously, the dynamics displayed in CC-9 are due to scouring and eventual armoring of the stream bed downstream of Springville Dam. In this case, predicted concentrations for all constituents are about 50% of the field data. Station CC-11 has a very smooth silt sediment wave that is quite different in character from CC-9. The difference between the CC-9 and CC-11 sediment plots is due primarily to the fact that segments beyond CC-9 are influenced by the recession limb of the hydrograph. These higher discharges are sufficient to resuspend sand and silt from the channel bed. However, on approach to the mouth of Cattaragus Creek at Lake Erie the sand deposits out.

The longitudinal distribution of suspended sediment concentrations in Phase 2 (Figure 5.21) is a good assessment of the equilibrium conditions that one might find on Cattaragus and Buttermilk Creeks during normal flow. This spatial distribution is at the end of the 100 hour simulation. Only CC-11 at the mouth of Lake Erie has not reverted completely to the base concentration levels. The highest concentration occurs in Buttermilk Creek and is diluted 2.5 times when it mixes with Cattaraugus Creek. Sediment concentrations decrease slightly as Lake Erie is approached.

Bed armoring of silt was predicted just downstream of Springville Dam (Creek Mile 35.5) and 15 miles upstream from Lake Erie. The scoured bed material is practically all silt, the bulk of which comes from an 18 mile stretch of creek above the Lake Erie backwater (Figure 5.22). The net amount of silt scoured from the channel bed under study was 70,000 kg. The scoured clay amounted to 280 kg. These values are roughly one order of magnitude below the Phase 3 scoured sediment. The largest amount of material scoured in one segment occurred at segment 33, 2.8 miles from Lake Erie.

Deposition is predicted in three locations: 0.5 miles upstream of Springville Dam, at Springville Dam, and at Lake Erie. By far, the greatest deposition of sediment occurs at the Lake Erie backwater. As the suspended sand fraction passes through the study reach, a net deposition of 1000 kg occur.

Phase 1

The Phase 1 sediment and radionuclide simulation period begins at 3:00 a.m. on November 30, 1977 and ends at 3:00 a.m. on December 5, 1977. A summary of the observed and predicted suspended sediment concentration is found in Table 5.7.

The Phase 1 hydrodynamics were the most unsteady of the three phases. In Buttermilk Creek there were three discharge peaks predicted in the 120 hr SERATRA simulation period. The suspended sediment concentrations tend to follow the trend of the discharge, i.e., increased concentrations at high flows. Two trains of double peaked sediment waves occur in Phase 1. Buttermilk suspended silt accounts for 90% of the sediment in the water column while clay makes up the bulk of the remaining 10%.
FIGURE 5.20. Phase 2 Sediment Concentrations at CC-9
FIGURE 5.21. Longitudinal Distribution of Suspended Sediment Total Concentration at Hour 100, Phase 2
FIGURE 5.22. Predicted Sediment Deposition and Erosion, Phase 2
### TABLE 5.7. Phase 1 Observed and Computed Sediment Concentrations

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At BC-2 (Figure 23), the comparison of the field sample taken at 31.5 hr with SERATRA predicted values indicates excellent agreement. The silt field value is perfectly correlated with the predicted silt concentration. The predicted sand and clay concentrations both lie below the field values. The character of the various sediment graphs is one of small perturbations about a base value.

At BC-3, the sediment transport behavior is almost identical to that seen at Station BC-2. However, in this case only the predicted sand value is close
FIGURE 5.23. Phase 1 Sediment Concentrations at BC-2
to the field sand concentration as the field-sampled concentrations exhibit a large deviation from the BC-2 values. Computed silt and clay are four to five times larger than the measured counterparts.

The discrepancy between computed and sampled results is even larger at BC-4 where the silt concentration measured in the field is even below the clay concentration predicted by the model.

As the Buttermilk Creek sediment is transported into Cattaraugus Creek above Springville Dam, all sediment concentration peaks are preserved with the 65 hr peak exhibiting amplification due to a matchup with sediment coming from Upper Cattaraugus Creek. Dilution of sediment concentrations from Buttermilk Creek to Cattaraugus Creek are by a factor of 5.

At CC-3 (Figure 5.24), the peak concentration occurs at 66 hr according to the model. Other peaks are comparatively insignificant and gently dispersing into the base concentrations. At 80 hr, the computed concentrations match quite closely to the sampled data.

At CC-5, very little of the character of the sediment curves has changed from CC-3. Agreement with field data is excellent.

Below Springville Dam, the sediment concentration peaks diffuse and join together so that no sharp or outstanding peaks are visible.

At CC-9, the sediment curves predicted by SERATRA have changed. Highest concentrations now occur between 7 and 23 hr of simulation. Verification at 108 hr is very good with predicted values being slightly low.

At CC-11 (Figure 5.25), the highest concentration occurs at 40 hr with no evidence of the previously visible concentration peaks. Sand and clay computed by the simulation are close to measured values despite the higher sand values indicated in the field data. Predicted silt is running considerably below the field value at 105 hr.

The longitudinal distribution of sediment concentrations at the end of the 120 hr simulation (Figure 26) demonstrates the large dilution which occurs between the three Buttermilk Creek sites and the four Cattaraugus Creek sites. In general, the highest suspended sediment concentrations are found in Phase 1 even at base flow. And as on the Phase 1 and Phase 2 simulations, suspended silt displays the highest concentrations and the most dynamic behavior of the three routed sediment fractions. This is due to the large amounts of silt removed from the bed prior to armoring.

Armoring in Phase 1 is predicted to occur in 30 out of the 34 computational segments. In most of these 30 segments, both silt and clay display armoring. Phase 1 is the only event where clay armoring was predicted. A net erosion of 200,000 kg of silt and 17,000 kg of clay was predicted by SERATRA for the channel bed in the study reach. Sand exhibited a net deposition of 19,000 kg. The deposition of sand occurred strictly in the backwaters of Springville Dam and Lake Erie. Figure 5.27 is a bar graph of scour and
FIGURE 24. Phase 1 Sediment Concentrations at CC-3
FIGURE 5.25. Phase 1 Sediment Concentrations at CC-11
FIGURE 5.26. Longitudinal Distribution of Suspended Sediment Total Concentration at Hour 120, Phase 1
FIGURE 5.27. Predicted Sediment Deposition and Erosion, Phase 1
deposition predicted in each segment during Phase 1. Deposition occurs only in the two backwater areas while scour occurs everywhere else. The most intensive deposition occurs at Springville Dam (Segment 14) whereas the most intensive bed scour is found above the Lake Erie backwater, where slope and depth are quite large. However, the segments immediately below Springville Dam collectively exhibit the area where bed scouring is most active.

5.4.3 Radionuclide Transport Simulation Results

Ten applications of the SERATRA code were performed in the course of this modeling study. Four radionuclides, $^{137}$Cs, $^{90}$Sr, $^{239,240}$Pu and $^3$H were modeled using the Phase 2 and Phase 3 flow events while $^{137}$Cs and $^3$H were modeled with the Phase 1 data.

Although 30 radionuclides were tested for in the laboratory, only these four radionuclides had sufficient information to properly pose the problem for a modeling study. The radionuclides available for modeling were limited largely by the number of distribution coefficients ($K_d$s) measured in Cattaraugus Creek. Of the five radionuclides with measured $K_d$ values, $^{137}$Cs, $^{90}$Sr, and $^{239,240}$Pu had adequate data at boundary conditions and verification points. Tritium, which does not sorb to sediment, was sampled separately and thus had the necessary information for a modeling effort. Phase 1 was modeled with $^{137}$Cs and $^3$H because $^{90}$Sr and $^{239,240}$Pu did not have data suitable for modeling.

The purpose of simulating the transport and fate of four radionuclides during three flow events was to test SERATRA under a wide range of hydraulic and radiochemical conditions. Two radionuclides, $^{137}$Cs and $^3$H, were tested under highly dynamic, moderate, and near-steady flows to demonstrate the effect of varying the field conditions while keeping the radionuclide parameters constant. The use of four radionuclides allows the radiochemical effects to be tested, i.e., varying the radionuclide parameters while field conditions are kept constant. This latter analysis pertains to the Phase 2 and Phase 3 SERATRA simulations where all four radionuclides were modeled. The characteristics of the modeled radionuclides are very diverse. $^{239,240}$Pu has a half-life of 6,600 years and a measured adsorption $K_d$ of 21 m$^3$/kg. $^3$H, on the other hand, has a half-life of 12 years and no measurable distribution coefficient. The other two radionuclides fall between these extremes.

Radionuclides levels in Franks Creek are the highest in the area with dissolved and sorbed forms exhibiting activity many times greater than that found upstream of the study reach. As Franks Creek enters Buttermilk Creek, activity is reduced by dilution and by the mixing of the relatively 'clean' Buttermilk Creek sediments with the contaminated Franks Creek sediments. Subsequent reductions in radionuclide levels occur as Buttermilk Creek joins Cattaraugus Creek and wherever lateral inflow (such as a tributary) is found. The general trend is for lower activity levels to be found at greater distances from Franks Creek.

For the most part, Springville Dam contains the downstream transport of coarse sediment. This limits the activity levels in the downstream channel beds to values lower than those upstream of Springville Dam.
In general, bed activity levels do not change much unless large amounts of sediment with radionuclide concentrations very different from the bed are deposited. Since significant deposition occurs only at the Springville Dam and Lake Erie backwater areas (near the mouth of Cattaraugus Creek), sorbed levels in the bed in most areas during the simulation periods are largely unchanged even under the most unsteady flow conditions.

Of the four modeled radionuclides, $^{239,240}\text{Pu}$ consistently has the lowest dissolved and particulate activity levels. Highest dissolved concentrations are found with $^3\text{H}$ while, the highest sorbed activities are found with $^{137}\text{Cs}$.

Partitioning among the three sediment size fractions usually reflects the $K_d$ values associated with each size fraction, i.e., highest sorbed levels with the clay sediment and lowest with the sand fraction. However, in some instances sand with organic matter or silt exhibit the highest concentrations due to upstream boundary conditions which have such partitioning. For the relatively short reach modeled, these radionuclides do not have enough time to equilibrate. Thus, these uncommon distributions will persist.

The SERATRA radionuclide results presented here are from the same simulations which produced the previously discussed sediment transport results. Thus, the beginning and ending times for the three phases of simulation are the same as those reported earlier and can be directly compared. As in the sediment transport results, time is referenced from the beginning of the SERATRA simulations.

The comparison of computed and measured radionuclides will be shown in this section as well as in Appendix A.

Phase 3

The general description of the radionuclide concentrations in Phase 3 is a dilution and dispersion of initially dynamic activity levels. The spike of high discharge which occurs on Buttermilk Creek at 35 hours has the effect of causing low radionuclide concentrations in Buttermilk Creek due to dilution and high concentrations in Cattaraugus Creek because of the suddenly large fraction of contaminated water entering from Buttermilk Creek. The dilution of the lateral inflow and the dispersion caused by the vertical velocity shear smooths the upstream changes in radionuclide levels to gentle curves as the radionuclides are transported downstream.

$^{137}\text{Cs}$

The total sorbed concentration of $^{137}\text{Cs}$ was always higher than the dissolved concentration in this simulation. This was merely a reflection of the boundary conditions at Buttermilk and Franks Creeks. Considering the suspended sediment concentrations in this phase and the distribution coefficients used for $^{137}\text{Cs}$, the system was not in equilibrium, with desorption from particulate to dissolved forms occurring. For the short reach of creek being simulated, the system did not have sufficient time to equilibrate to the sampled $K_d$ value.

5.54
The partitioning of $^{137}\text{Cs}$ among the three modeled sediment size fractions was usually highest for clay and lowest for sand. This was to be expected as the finer sediments normally have more capacity to adsorb radionuclides than the coarser sediments.

In Buttermilk Creek, $^{137}\text{Cs}$ sorbed to the suspended sediment (pCi/kg) has two peaks during the 72 hr simulation, spaced 50 hr apart. The peaks occurred before and after the suspended sediment concentration peak. This was due to the relatively uncontaminated sediment in the wave which originated upstream of the Franks Creek confluence. As greater amounts of the 'clean' sediment mixed with the influent activity from Franks Creek, a strong dilution occurred. Dissolved $^{137}\text{Cs}$ entered Buttermilk Creek as a wave of higher concentration in the first 30 hr of simulation. Sorbed concentrations per unit volume of water (pCi/m$^3$) tend to increase with the suspended sediment concentration.

Predicted sorbed activities associated with the three types of sediment at BC-3 are very close to the field data values as shown in Appendix A. The predicted clay activity is slightly higher and the sand and silt activities are slightly lower than the sampled values.

Although clay has the highest sorbed activity (activity per unit weight of sediment), the relatively low concentrations of clay sediment prevent the radionuclides associated with clay from being greater than the amount of radionuclides sorbed to silt. "Dips" in the concentration at the 35-hour mark coincide with the passing of the spike of water. The predicted dissolved concentration is below the BC-3 concentration data.

In Segment 6, BC-4, predicted sorbed activities are 2 to 3 times higher than those found in the field (Appendix A). The three field samplings appear to be very consistent while the predicted results are somewhat unsteady. Only the field data taken at 37 hours matches closely with the predicted values. The two dissolved radionuclide field data points agree well with the predicted concentrations.

In Cattaraugus Creek above Springville Dam both sorbed and dissolved $^{137}\text{Cs}$ have been diluted by a factor of three from the Buttermilk Creek levels. At CC-3, Segment 8, predicted and measured data are highly correlated in both sorbed activity and concentration. This is borne out by Figures 5.28 and 5.29. Interestingly, the plot of silt concentration in Figure 5.29 bears a resemblance to the Buttermilk hydrograph. This would seem to imply that the activity in Buttermilk Creek has a very strong imprint on the subsequent results in Cattaraugus Creek despite the relatively small discharge found in Buttermilk Creek.

At Springville Dam, the field values for sorbed activity are fairly consistent with the predicted concentrations at the 9- and 59-hour data points. At 33 hours predicted silt and clay sorbed activities are 800 pCi/kg higher.
Phase 3 Particulate Radionuclide Concentrations: 137Cs at CC-3
FIGURE 5.29. Phase 3 Particulate and Dissolved Radionuclide Concentrations: $^{137}$Cs at CC-3
higher than the measured values. The predicted dissolved radionuclide concentra-
tion is below the actual value but very reasonable in an absolute sense. Below Springville Dam, radionuclide peaks are more diffuse and generally follow the pattern of the sediment concentration waves.

At Segment 21 which represents CC-6, Frye Bridge, there was no field value for dissolved radionuclide concentration. Predicted sorbed activity for silt is in excellent agreement with the three data points taken in the field. The clay activity field points at 5 and 31 hr are not very consistent in magnitude with respect to the silt activity found in the field. Predicted clay activity lies both above and below the two field-sampled clay values.

At CC-9 and CC-11, Segments 28 and 34, respectively, no dissolved radionuclide concentrations from sampling are available. The results from the field sampling are taken at the end of the simulation. The predicted activity for each sediment type is consistently below the sampled data. The field values are indicating activities which are as high or higher than previous sampled data.

The longitudinal distribution of $^{137}$Cs in the water column shows high values in Buttermilk Creek and much lower values in Cattaraugus Creek. At the end of the 72 hr simulation (Figure 5.30), Buttermilk Creek and Cattaraugus Creek upstream of Springville Dam had radionuclide levels near base values. The increase in activity from BC-3 to BC-4 is due to the scouring of $^{137}$Cs-laden sediment from the bed into the water column. Lower total (sum of dissolved and particulate) radionuclide concentrations per unit volume of water at Springville Dam are the result of the deposition of $^{137}$Cs carrying sediment. Downstream of Springville Dam, a steady increase in water column activity is the descending limb of a wave of high $^{137}$Cs concentration which was present in these downstream segments.

Bed sediment activity is practically unchanged throughout all simulations. The $^{137}$Cs distribution is presented as an example (Figure 5.31) as all longitudinal distributions are quite similar. Initial bed radionuclide concentra-
tions are highest in Buttermilk Creek and lowest in lower Cattaraugus Creek. The only noticeable change in the bed activity was at the final segment in the Lake Erie backwater near the mouth of the creek. At this point suspended sediment with higher levels of $^{137}$Cs than in the bed deposited out of the water column. During the simulation bed activity increased to 760 pCi/kg; quite small when compared with the 10,000 pCi/kg found in the Buttermilk Creek bed.

The vertical distribution of radionuclides is uniform in most cases because of the dominance of silt- and clay-sorbed activity in addition to the dissolved activity. In this creek system, most of silt, clay, and dissolved radionuclides simply wash through to Lake Erie without settling. At CC-3, on Cattaraugus Creek above Springville Dam, this uniform vertical distribution is almost perfect (Figures 5.32 and 5.33). Other simulations in this study produce similar results indicating that a possible simplification in future modeling of this creek could be one dimensional.
FIGURE 5.30. Phase 3. Longitudinal Distribution of $^{137}$Cs Total Concentration at Hour 72
FIGURE 31. Phase 3. Longitudinal Distribution of Bed Activity
The phase 3 vertical distribution of total sediment at CC-3 shows a significant decrease in concentration with depth. The highest values are observed near the surface, indicating higher sedimentation rates in shallower areas. The concentration decreases sharply with depth, reaching lower levels at deeper depths. This distribution pattern is consistent with the expected behavior of sediments in a dynamic system, where deposition rates are influenced by factors such as flow velocity and turbulence.
The \(^{90}\text{Sr}\) simulation consistently has much more dissolved radionuclide than sorbed radionuclide. This reflects the low affinity that \(^{90}\text{Sr}\) has for the sediment. The value of K\(_d\) of \(^{90}\text{Sr}\) is 10 times smaller than the value of K\(_d\) of \(^{137}\text{Cs}\). The partitioning of \(^{90}\text{Sr}\) among the different sediment fractions is unusual in that the sand particles or more precisely, sediment in a sand size fraction, have higher activity levels than the silt particles. This is corroborated by the field data. This may be due to the fact that sand size fraction contains suspended organic matter.

In Buttermilk Creek, the \(^{90}\text{Sr}\) sorbed to clay peaked highest after 35 hr of simulation, dropped to background levels, and peaked at a lower activity at 60 hr. The first peak corresponds with the maximum sediment concentration while the second peak corresponds with the minimum sediment concentration. The high peak is a result of high sorbed activity sediment being scoured from the bed and suspended in the water column. When the bed armors against further clay scour, the sorbed levels in the suspended sediment drop sharply. As the sediment wave from upstream Buttermilk Creek diminishes in concentration the sorbed levels begin to increase, since a larger fraction of the suspended sediments are due to the more contaminated sediments from Franks Creek. Sand- and silt-sorbed \(^{137}\text{Cs}\) display lowest concentration levels during the peak sediment concentrations which indicate that the corresponding upstream clear sediments dilute the sorbed activity.

Dissolved \(^{90}\text{Sr}\) behavior in Buttermilk Creek is basically controlled by the Franks Creek influent. The small wave of high dissolved concentrations is from the Franks Creek boundary condition. The low concentration at 35 hr is due to the passing of the discharge spike from upstream Buttermilk Creek.

At BC-3, predicted silt activity agrees well with the sampled value while the sand activity predicted is 50% below the sampled activity. No clay activity is available for comparison. Strontium-90 differs from the previous \(^{137}\text{Cs}\) result by exhibiting a very high dissolved radionuclide concentration. In comparison with the dissolved activity, the sorbed fractions appear to be insignificantly small. Predicted dissolved concentration is below the measured concentration.

Figure 5.34 is the sorbed activity plot at BC-4. The predicted sand value at 37 hr is one-third of the sampled activity for sand. Field and predicted silt values are fairly consistent with the predicted values being 250 pCi/kg higher. The clay activity from the 4-hr sample is approximated closely by the predicted graph. However, at 37 hr the sampled clay value is almost identical to the low silt value while the predicted clay activity is many times higher. Agreement with field-sampled dissolved concentrations is good for the 37- and 65-hr samples (Figure 5.35). The predicted dissolved concentration at 4 hr is considerably below the measured value.

As Buttermilk Creek enters Cattaraugus Creek sorbed concentrations decrease by a factor of three while dissolved concentrations decrease by a
FIGURE 5.34. Phase 3 Particulate Radionuclide Concentrations: 90Sr at BC-4
FIGURE 5.35. Phase 3 Particulate and Dissolved Radionuclide Concentrations: $^{90}$Sr at BC-4
The sorbed $^{90}\text{Sr}$ behaves as it did in Buttermilk Creek. The dissolved $^{90}\text{Sr}$ in Cattaraugus Creek has a peak at 35 hr where there was a trough in Buttermilk Creek. This is because of the large volume of high activity water accompanying the discharge spike from Buttermilk Creek.

At CC-3, fairly good correlation is achieved with the sorbed activity. Predicted sand is slightly lower and predicted silt slightly higher. The computed dissolved concentration at CC-3 is fairly smooth with a sharp increase and decrease at the time the hydrograph peak passes through the segment. The field concentration of dissolved strontium is about 25% the predicted concentration at 25 hr.

At CC-5, extremely high sand activities found in the field are not duplicated. However, clay and silt activities are matched reasonably. The dissolved concentrations predicted by SERATRA are about the same as in CC-3. However, in this case the field-sampled concentrations are both higher than the predicted.

Downstream of Springville Dam, sorbed and dissolved $^{90}\text{Sr}$ exhibit no sharp peaks as dispersion and dilution create rather steady effects. At Fryge Bridge, CC-6, sand and clay activities are underestimated by the model. Predicted dissolved concentrations at 6, 32 and 58 hr are 10 to 60% lower than field data.

At CC-9, Segment 28, no dissolved field value is available for comparison. The only sorbed activity collected in the field is for silt. The predicted activity is many times smaller than that field value.

At CC-11, the trend of large field values for sorbed activity downstream of Springville Dam continues. Only the silt activity predicted by SERATRA is fairly close to a field data point; clay and sand field activities simply dwarf those predictions. The predicted dissolved concentration is 60% below the field data. This is fairly consistent with Segments 14 onward.

Figure 5.36 is the longitudinal distribution of $^{90}\text{Sr}$. This illustrates the strong dilution of radionuclides from Buttermilk Creek to Cattaraugus Creek.

$^{239,\,240}\text{Pu}$

$^{239,\,240}\text{Pu}$ has a Kd value 350 times that of $^{90}\text{Sr}$. Given the sediment concentrations predicted in the Phase 3 study reach and the Kd value $^{239,\,240}\text{Pu}$ in sorbed form per unit volume of water should be on the same order of magnitude as the dissolved $^{239,\,240}\text{Pu}$ if equilibrium exists. As it happens this is the predicted result.

Partitioning of $^{239,\,240}\text{Pu}$ is quite dynamic. In Buttermilk Creek silt has the highest sorbed levels; strictly a result of the Franks Creek boundary condition. In Cattaraugus Creek above Springville Dam clay sediment has the highest sorbed levels while below Springville Dam silt retains the most activity. The background condition is for clay to be the most efficient at
FIGURE 5.36. Phase 3, Longitudinal Distribution of $^{90}$Sr Total Concentration of Hour 72
radionuclide uptake which explains the upstream Cattaraugus Creek results. In
downstream Cattaraugus Creek, large amounts of high activity silt were sus-
pended from the bed which increased the silt sorbed activity to be above the
clay level in the water column.

In Buttermilk Creek, sorbed $^{239,240}$Pu in sand and clay react inversely
to the sediment wave from upstream Buttermilk Creek. Silt-sorbed radionuclides
are fairly constant. Dissolved $^{239,240}$Pu is virtually constant except for
the passing of the discharge spike.

Unlike other radionuclides, predicted silt-sorbed plutonium concentrations
are higher than those with clay. The computed silt activity is fairly steady
while the computed sand and clay activity display a wider range of values. The
relatively sharp peak of computed activity with sand and a valley in the clay
activity at 35 hr coincides with the hydrograph spike. A single silt activity
data point is available from the field study. The predicted silt activity at
that point (28 hr) is about 0.7 pCi/kg greater than the field value. The trend
of the $^{239,240}$Pu radionuclide concentration is very similar to the sediment
graphs in BC-3 (Segment 3); the dissolved concentration is very steady except
for hour 35 in which the hydrograph spike passes through this segment. No
field dissolved data points are available for comparison.

At BC-4, Figure 5.37 is the sorbed activity plot. Field data at 37 hr
has clay activity higher than silt activity. This is the opposite of the
computed results. The predicted clay activity fairly approximates the field
data point while the predicted silt activity is two times the sampled data.
The radionuclide concentrations in Figure 5.38 are again very similar to the
sediment discharges. The predicted dissolved concentration is steady and well
above the field-sampled concentration at 65 hr.

In Cattaraugus Creek above Springville Dam clay sorbed $^{239,240}$Pu increase
gradually to a peak at 60 hr while sand- and silt-sorbed radionuclides remain
steady. At CC-3, the predicted sorbed activity for clay is many times higher
than sand and silt activities. The field point for silt activity lies very
closely to the predicted silt activity. Radionuclide concentrations are
reversed from Buttermilk Creek; radionuclides adsorbed to clay now provide the
largest concentrations. No data are available to confirm this with the field.

At CC-5, measured sorbed activities include two silt activity points at 9
and 33 hr. Computed results are similar with one field data point above and
one below predicted results. Radionuclide concentrations appear to be very
similar to those shown previously at Segment CC-3. No dissolved data from the
field is available for comparison. Downstream of Springville Dam, silt-sorbed
$^{239,240}$Pu scoured from the bed creates high activity on the water column.
Other size fractions exhibit gently changing levels of radionuclide at much
lower total concentrations.
SEGMENT 6 FIELD DATA
- SAND
- SILT
+ CLAY

FIGURE 5.37. Phase 3 Particulate Radionuclide Concentrations:
239,240pu at BC-4
FIGURE 5.38. Phase 3 Particulate and Dissolved Radionuclide Concentrations: 239,240Pu at BC-4
At CC-6, Fryge Bridge, silt- and clay-sorbed activity, as predicted by SERATRA, alternate having the highest activity. One measured concentration attached to sand is available for verification at 59 hr. The sand activity predicted at that time is about 15 pCi/kg below that data point. Another reversal occurs in the total radionuclide concentration with silt now being the dominant carrier of radionuclides. Predicted dissolved concentrations are almost constant and very near the single field value at 31 hr.

At CC-9, silt is the highest activity carrier of sorbed radionuclide. The predicted clay activity is 50% below the field value. The radionuclide concentrations are relatively low with the exception of silt. This is a direct reflection of the high silt sediment concentration. No field data are available for comparison.

CC-11, the mouth of Cattaraugus Creek, is almost identical to Segment 28 (CC-9) in both concentration and sorbed activity. No field data are available for comparison.

Because of the $^{239,240}$Pu-laden silt scoured from the bed downstream of Springville Dam, total radionuclide concentrations are much higher at downstream locations. This is shown in the longitudinal distribution of $^{239,249}$Pu at the end of the simulation (Figure 5.39).

$^3$H

Tritium on Phase 3 displays very steady concentration levels, changing minutely for the most unsteady field conditions. The reason for this is that the background levels tend to dominate any transport effects. Since tritium exists in dissolved form alone, it is affected greatly by dilution. While high sediment concentrations from Franks Creek tend to preserve the elevated values of sorbed radionuclide in Buttermilk Creek as discussed above, dissolved radionuclides are diluted by a factor of 10.

At BC-3, tritium concentrations are very steady except for hour 35 when the hydrograph spike disrupts the consistency. Predicted concentrations are 40% below the reported value.

At BC-4, there are field values at hour 37 and hour 65. At hour 37 the computed dissolved concentration is about 20% below the field value while at hour-65 the computed concentration is about 50% of the measured value.

At CC-3, the dissolved concentration graph in Figure 5.40 has slightly more dynamics due to the Cattaraugus Creek inflow. At 25 hours the predicted dissolved concentration is about 20% below the field value.

Figure 5.41 is a plot of the dissolved concentrations at CC-5. There is good agreement between the predicted and field values.

At CC-6, the predicted concentrations are below the measured data by 5 to 25% and very consistent. This is the last segment with field data.
FIGURE 5.39. Phase 3 Longitudinal Distribution of $^{239-240}$Pu Total Concentration at Hour 72
FIGURE 5.40. Phase 3 Dissolved Radionuclide Concentrations: $^3$H at CC-3
FIGURE 5.41. Phase 3 Dissolved Radionuclide Concentration: $^3$H at CC-5
As it happens, the dilution in Buttermilk Creek reduces the tritium levels to below the Cattaraugus Creek background levels. This is borne out by the longitudinal distribution of tritium in Figure 5.42.

A summary of the observed and predicted Phase 3 radionuclides is in Table 5.8. Additional radionuclide plots with field comparison data are in the Appendix A.

**Phase 2**

The Phase 2 flow event was mostly steady. Much of the hydrodynamics were synthesized in this phase and single samples of sediment and radionuclides collected at a given sampling location were assumed to be valid to the entire simulation period there. Throughout Phase 2, the radionuclides are partitioned highest to the clay sediment fraction and lowest to the sand fraction.

The results of the Phase 2 radionuclide simulation are very much the same for all four radionuclides. The only area where major change occurs is at the confluence of Buttermilk and Cattaraugus Creeks where all radionuclides are diluted by a factor of four. This can be seen in the four longitudinal distribution plots of $^{137}$Cs, $^{90}$Sr, $^{239,240}$Pu and $^{3}$H in Figures 5.43 through 5.46, respectively.

$^{137}$Cs

In general, the predicted $^{137}$Cs radionuclide concentrations in Phase 2 are much higher than the values measured in the field. This discrepancy between predicted and measured data for Phase 2 was mostly due to lack of accurate time varying data as both input data and validation data. At BC-4, the constant boundary condition at FC-1 produces a dissolved concentration three times the field concentration. At CC-3 (Figures 5.47 and 5.48) and CC-5 very steady computed results occur which exceed the field data. At downstream locations CC-9 and CC-11, some dynamics appear in the first 60 hr of simulation before a steady state is approached. Although predicted silt activity appears to be nearing field levels, the particulate $^{137}$Cs is desorbing to the dissolved phase as evidenced by the increasing dissolved concentration of $^{137}$Cs at CC-11.

$^{90}$Sr

The Franks Creek boundary condition for dissolved $^{90}$Sr measured in the field was over 100 times larger than any field value found in Cattaraugus Creek. Such a large dilution factor in a steady flow event for these flow conditions seemed impossible. Therefore, a dissolved $^{90}$Sr boundary condition was estimated to produce the BC-4 dissolved field concentration. The steady particulate radionuclide activities are very similar to those found in the $^{137}$Cs modeling. Once again, field particulate levels of radionuclide activity are many times smaller than those predicted. As expected, the BC-4 dissolved concentration predicted is perfectly calibrated to the field concentration.
TABLE 5.42. Phase 3 Longitudinal Distribution of $^3$H Concentration at Hour 72
### Table 5.8: Phase 3 Observed and Computed Radionuclide Concentrations

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**Phase 3**

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# TABLE 5.8. (contd)

## Phase 3 $^{90}\text{Sr}$ Comparison (pC/g)

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## Phase 3 $^{239,240}\text{Pu}$ Comparison (pC/g)

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Phase 3 ³H Comparison (pC/m³)

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5.81
FIGURE 5.43. Phase 2 Longitudinal Distribution of $^{137}$Cs Total Concentration at Hour 100
FIGURE 5.44. Phase 2 Longitudinal Distribution of $^{90}\text{Sr}$ Total Concentration at Hour 100
FIGURE 5.45. Phase 2 Longitudinal Distribution of $^{239,240}$Pu Total Concentration at Hour 100
FIGURE 5.46. Phase 2 Longitudinal Distribution of $^3$H Total Concentration at Hour 100
FIGURE 5.47. Phase 2 Particulate Radionuclide Concentrations: $^{137}$Cs at CC-3
FIGURE 5.48. Phase 2 Particulate and Dissolved Radionuclide Concentrations:
$^{137}$Cs at CC-3
At CC-3 and CC-5 (Figures 5.49 and 5.50), both dissolved and particulate \(^{90}\text{Sr}\) predicted by SERATRA are somewhat higher than measured values. At CC-11 (Figure 4.51), the field verification dissolved concentration at 100 hours of simulation is closely approximated by the predicted value.

\(^{239,240}\text{Pu}\)

At BC-4, predicted silt and clay specific activities are two and eight times the respective field values (Figure 5.52). Predicted dissolved \(^{239,240}\text{Pu}\), however, is in excellent agreement with the field concentration (Figure 5.53).

Plots at CC-3 and CC-5 are very similar in character and concentration levels. Field values for specific silt activity are in excellent agreement with predicted values (Figures 5.54 and 5.55). Predicted dissolved \(^{239,240}\text{Pu}\) at CC-3, however, is 20% of the field concentration.

At CC-11 predicted activities for both silt and dissolved concentration are a fair approximation of the field activity levels but consistently low, as shown in Figures 5.56 and 5.57.

\(^{3}\text{H}\)

The comparison of predicted tritium concentrations with field values is not so much a test of the SERATRA code but a gauge of the accuracy of the posed problem. Since tritium exists in dissolved form only, the concentrations found downstream are merely the result of the hydrodynamics, i.e., migration, dilution and dispersion, and radionuclide decay. For the relatively short simulation period considered in Phase 2, radionuclide decay is insignificant. Therefore, the sediment and radionuclide transport interaction mechanisms on which SERATRA is based are not being exercised. Discrepancies between predicted and observed tritium concentrations are then the results of an error in the field values or an error in the hydrodynamics.

At BC-4, excellent agreement between predicted and observed tritium is displayed in Figure 5.58. However, subsequent comparisons at CC-3, CC-5 and CC-11 show predicted values to be consistently about 60% of the field concentrations.

A summary of the observed and predicted Phase 2 radionuclide concentrations is found in Table 5.9. Additional plots comparing field data with the predicted radionuclide concentrations are found in Appendix A.

Phase 1

The Phase 1 hydrodynamics were the most unsteady of the three phases; consequently the radionuclide concentration fluctuate most accordingly. As mentioned earlier, the Phase 1 hydrodynamics were completely synthesized without calibration due mostly to the lack of continuous flow measurement at Gowand (CC-9). Sediment and radionuclide sampling was performed once at each boundary condition which forced a steady concentration to be input for the very unsteady case.
FIGURE 5.49. Phase 2 Particulate and Dissolved Radionuclide Concentrations: $^{90}\text{Sr}$ at CC-3
FIGURE 5.50. Phase 2 Particulate and Dissolved Radionuclide Concentrations: 90Sr at CC-5
FIGURE 5.51. Phase 2 Particulate and Dissolved Radionuclide Concentration: $^{90}\text{Sr}$ at CC-11
FIGURE 5.52. Phase 2 Particulate Radionuclide Concentrations: 239,240Pu at BC-4
FIGURE 5.53. Phase 2 Particulate and Dissolved Radionuclide Concentrations: 239, 240Pu at BC-4
FIGURE 5.54. Phase 2 Particulate Radionuclide Concentrations: 239,240Pu at CC-3
FIGURE 5.55. Phase 2 Particulate Radionuclide Concentrations: \( {\text{239,240}}_{\text{Pu}} \) at CC-5
FIGURE 5.56. Phase 2 Particulate Radionuclide Concentrations: 239,240Pu at CC-11
FIGURE 5.57. Phase 2 Particulate and Dissolved Radionuclide Concentrations:

\( ^{239,240} \text{Pu} \) at CC-11
FIGURE 5.58. Phase 2 Dissolved Radionuclide Concentrations: $^3$H at BC-4
### Phase 2 Observed and Computed Radionuclide Concentrations

#### Phase 2 Cs\(^{137}\) Comparison (pC/g)

<table>
<thead>
<tr>
<th>Location</th>
<th>Observed</th>
<th>Computed</th>
</tr>
</thead>
<tbody>
<tr>
<td>BC-4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sand</td>
<td>0.6</td>
<td></td>
</tr>
<tr>
<td>Silt</td>
<td>9.5</td>
<td></td>
</tr>
<tr>
<td>Clay</td>
<td>27.8</td>
<td></td>
</tr>
<tr>
<td>Dissolved</td>
<td>28 pC/m(^3)</td>
<td>94 pC/m(^3)</td>
</tr>
<tr>
<td>CC-3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sand</td>
<td>0.4</td>
<td></td>
</tr>
<tr>
<td>Silt</td>
<td>1.46/1.17/1.72</td>
<td>4.9</td>
</tr>
<tr>
<td>Clay</td>
<td>2.84/4.29/5.0</td>
<td>14.3</td>
</tr>
<tr>
<td>Dissolved</td>
<td>1.0/2.0/4.0 pC/m(^3)</td>
<td>21 pC/m(^3)</td>
</tr>
<tr>
<td>CC-5</td>
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<td></td>
</tr>
<tr>
<td>Sand</td>
<td>0.4</td>
<td></td>
</tr>
<tr>
<td>Silt</td>
<td>1.17/1.09/1.20</td>
<td>4.8</td>
</tr>
<tr>
<td>Clay</td>
<td>1.90/2.10/2.36</td>
<td>14.1</td>
</tr>
<tr>
<td>Dissolved</td>
<td>3.0 pC/m(^3)</td>
<td>24 pC/m(^3)</td>
</tr>
<tr>
<td>CC-9</td>
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</tr>
<tr>
<td>Silt</td>
<td>1.85</td>
<td></td>
</tr>
<tr>
<td>Clay</td>
<td>2.74</td>
<td></td>
</tr>
<tr>
<td>Dissolved</td>
<td>---</td>
<td>26 pC/m(^3)</td>
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<tr>
<td>CC-11</td>
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<td></td>
</tr>
<tr>
<td>Silt</td>
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<td></td>
</tr>
<tr>
<td>Clay</td>
<td>2.51</td>
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</tr>
<tr>
<td>Dissolved</td>
<td>---</td>
<td>32 pC/m(^3)</td>
</tr>
</tbody>
</table>

#### Phase 2 \(^{90}\)Sr Comparison (pC/g)

<table>
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<th>Computed</th>
</tr>
</thead>
<tbody>
<tr>
<td>BC-4</td>
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<td></td>
</tr>
<tr>
<td>Sand</td>
<td>0.0</td>
<td></td>
</tr>
<tr>
<td>Silt</td>
<td>3.3</td>
<td></td>
</tr>
<tr>
<td>Clay</td>
<td>0.327</td>
<td>5.1</td>
</tr>
<tr>
<td>Dissolved</td>
<td>868 pC/m(^3)</td>
<td>880 pC/m(^3)</td>
</tr>
<tr>
<td>CC-3</td>
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<td></td>
</tr>
<tr>
<td>Sand</td>
<td>0.0</td>
<td></td>
</tr>
<tr>
<td>Silt</td>
<td>1.6</td>
<td></td>
</tr>
<tr>
<td>Clay</td>
<td>0.359</td>
<td>2.8</td>
</tr>
<tr>
<td>Dissolved</td>
<td>62 pC/m(^3)</td>
<td>250 pC/m(^3)</td>
</tr>
</tbody>
</table>

5.99
### TABLE 5.9. (contd)

<table>
<thead>
<tr>
<th>Location</th>
<th>Phase 2 (^{90})Sr Comparison (pC/g) (contd)</th>
<th>Location</th>
<th>Phase 2 (^{239,240})Pu Comparison (pC/g)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Observed</td>
<td>Computed</td>
<td>Observed</td>
</tr>
<tr>
<td>CC-5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sand</td>
<td>0.192</td>
<td>1.5</td>
<td>0.0026</td>
</tr>
<tr>
<td>Silt</td>
<td>-</td>
<td>2.8</td>
<td>-</td>
</tr>
<tr>
<td>Clay</td>
<td>-</td>
<td>240 pC/m³</td>
<td>-</td>
</tr>
<tr>
<td>Dissolved</td>
<td>177 pC/m³</td>
<td>180 pC/m³</td>
<td></td>
</tr>
<tr>
<td>C-11</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sand</td>
<td>0.185</td>
<td>0.4</td>
<td>0.0027</td>
</tr>
<tr>
<td>Silt</td>
<td>-</td>
<td>2.1</td>
<td>-</td>
</tr>
<tr>
<td>Clay</td>
<td>-</td>
<td>180 pC/m³</td>
<td>-</td>
</tr>
<tr>
<td>Dissolved</td>
<td>201 pC/m³</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>
### TABLE 5.9. (contd)

<table>
<thead>
<tr>
<th>Location</th>
<th>Observed</th>
<th>Computed</th>
</tr>
</thead>
<tbody>
<tr>
<td>BC-4</td>
<td>830 x 10³</td>
<td>810 x 10³</td>
</tr>
<tr>
<td>CC-3</td>
<td>356 x 10³/383 x 10³/1056 x 10³</td>
<td>200 x 10³</td>
</tr>
<tr>
<td>CC-5</td>
<td>312 x 10³/365 x 10³</td>
<td>200 x 10³</td>
</tr>
<tr>
<td>CC-11</td>
<td>298 x 10³</td>
<td>190 x 10³</td>
</tr>
</tbody>
</table>

Because of the high flows in this phase, large amounts of sediment were removed from the bed into the water column accompanying the sorbed radionuclides. As most of the channel bed became armored against further silt and clay erosion, the contribution of the suspended radionuclides from the contaminated bed was stopped resulting in falling sediment and radionuclide levels.

137\(^{Cs}\)

Because of the constant sediment and radionuclide concentrations used at the Franks Creek boundary condition, the radionuclide levels in Buttermilk Creek are generally proportional to the discharges from Franks Creek. Therefore, as in the hydrodynamic case, two trains of peak concentrations in both sorbed and dissolved forms are visible in Buttermilk Creek. 137\(^{Cs}\) sorbed clay exhibits the highest radionuclide concentrations while sorbed sand has the lowest radionuclide concentrations.

The predicted specific activity levels of particulate 137\(^{Cs}\) at BC-2 are highly dynamic with the clay-sorbed activity being consistently twice as large as those adsorbed by sand and silt. Correlation with measured particulate 137\(^{Cs}\) with silt and clay is good while the field activity with sand is five times the predicted value.

At BC-3 and BC-4, the time-dependent profiles of specific activity levels have changed little from those appearing at BC-2. However, the field values at these locations, despite being taken at times less than three hours apart, are widely divergent. At BC-3, measured 137\(^{Cs}\) adsorbed by suspended sand is the highest particulate activity. Predicted silt and clay activities are 60% of the corresponding field values. At BC-4, the sand field activity lies well below the lowest predicted values. The predicted sand and silt activity levels compare favorably with the field values, activities appearing to be 5 hr out of phase with field data.

The two sets of peaks diffuse and coalesce into two general peaks at the radionuclides are transported to Lake Erie. Dilution from Buttermilk Creek to
Cattaraugus Creek reduces total concentrations of $^{137}$Cs by a factor of four while sorbed activity levels are reduced very slightly. High silt-sorbed $^{137}$Cs concentrations in the water column near the mouth of Cattaraugus Creek are a result of silt-sorbed sediment being scoured from the bed between the mouth of the creek at Gowanda and Lake Erie.

The character of the predicted particulate activity in Buttermilk Creek is preserved in the plots at CC-3 and CC-5 (Figure 5.59). At CC-3, the sand activity field value is much higher than the magnitude of the sampled silt and clay activities. The entire range of predicted results at 80 hours of simulation is between the activity values measured at CC-3. At CC-5, the silt activity correlation between predicted and sampled values is good while the predicted value associated with clay is 40% below the field clay activity. Predicted dissolved $^{137}$Cs levels at the end of the simulation are four times the value in the field (Figure 5.60).

The predicted particulate activity levels at CC-9 display more gradual dynamics than the upstream sites. The silt activity predicted at 108 hours of simulation is twice as high as the field value.

At CC-11, the sudden increase and decrease of the predicted clay specific activity appears due to high activity-bearing clay being scoured from the bed followed by the onset of bed armoring. At 105 hours of simulation, predicted silt activity is fairly close to the field-sampled value while predicted clay activity is 40% of the field value.

The longitudinal distribution of $^{137}$Cs in the water column (Figure 5.61) shows a large dilution effect from Buttermilk Creek to Cattaraugus Creek. Radionuclides in the water column decrease steadily in concentrations as flow moves toward Lake Erie.

$^{3}$H

Tritium does not interact with the sediment and is therefore influenced only by the hydrodynamics with some dispersion and radioactive decay. Since $^{3}$H concentrations at FC-1, BC-1 and CC-1 were not sampled during the Phase 1 data collection effort, a boundary condition at FC-1 was estimated to match the measured $^{3}$H concentration at BC-4. Background concentrations were taken from the Phase 3 $^{3}$H field collection data.

The dynamic behavior found in Buttermilk Creek is preserved in form in Cattaraugus Creek above Springville Dam. However, concentrations are reduced by a factor of two. Downstream of Springville Dam, the tritium concentrations tend to slowly oscillate about an average value as the sharply peaked $^{3}$H concentrations are diffused into two gently curved waves. Predicted values of tritium at BC-4, CC-3 (Figures 5.62 and 5.63) and CC-11 are in excellent agreement with the field values. The longitudinal distribution of $^{3}$H at hour 120 is shown in Figure 5.64.
FIGURE 5.59. Phase 1 Particulate Radionuclide Concentrations: $^{137}$Cs at CC-5
FIGURE 5.60. Phase 1 Particulate and Dissolved Radionuclide Concentrations: $^{137}\text{Cs}$ at CC-5
FIGURE 5.61. Phase 1 Longitudinal Distribution of $^{137}$Cs Total Concentration at Hour 120.
A summary of the observed and predicted Phase 1 radionuclide concentrations is found in Table 5.10. Additional plots of predicted radionuclide concentrations with field verification points appears in Appendix A.

The study revealed that SERATRA simulated general patterns of radionuclide transport mechanisms fairly well and that most of predicted values with good measured data are within 100% of the observed value. Again, considering that SERATRA does not have adjustable parameters for radionuclide transport calibration, that the Cattaraugus/Buttermilk Creek system is very complex, and that some of the field data were not adequate for its accuracy or quantity, SERATRA performed well for its radionuclide transport simulation.

**TABLE 5.10. Phase 1 Observed and Computed Radionuclide Concentrations**

<table>
<thead>
<tr>
<th>Location</th>
<th>Observed</th>
<th>Computed</th>
</tr>
</thead>
<tbody>
<tr>
<td>BC-2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sand</td>
<td>7.64/14.50</td>
<td>1.7</td>
</tr>
<tr>
<td>Silt</td>
<td>0.841/1.50</td>
<td>1.5</td>
</tr>
<tr>
<td>Clay</td>
<td>3.10/1.65</td>
<td>3.9</td>
</tr>
<tr>
<td>Dissolved</td>
<td>---</td>
<td>14 pC/m³</td>
</tr>
<tr>
<td>BC-3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sand</td>
<td>13.6</td>
<td>1.8</td>
</tr>
<tr>
<td>Silt</td>
<td>2.55/3.26</td>
<td>1.6</td>
</tr>
<tr>
<td>Clay</td>
<td>7.80/7.37</td>
<td>4.1</td>
</tr>
<tr>
<td>Dissolved</td>
<td>---</td>
<td>15 pC/m³</td>
</tr>
<tr>
<td>BC-4</td>
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</tr>
<tr>
<td>Sand</td>
<td>0.316</td>
<td>1.9</td>
</tr>
<tr>
<td>Silt</td>
<td>2.67/2.41</td>
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</tr>
<tr>
<td>Clay</td>
<td>6.55/4.48</td>
<td>4.1</td>
</tr>
<tr>
<td>Dissolved</td>
<td>---</td>
<td>21 pC/m³</td>
</tr>
<tr>
<td>CC-3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sand</td>
<td>9.02</td>
<td>0.8</td>
</tr>
<tr>
<td>Silt</td>
<td>0.422/0.385/0.326</td>
<td>1.4</td>
</tr>
<tr>
<td>Clay</td>
<td>0.198/0.253</td>
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<tr>
<td>Dissolved</td>
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<td>116 pC/m³</td>
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<tr>
<td>CC-5</td>
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<tr>
<td>Sand</td>
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<td>0.5</td>
</tr>
<tr>
<td>Silt</td>
<td>0.887/0.740</td>
<td>0.9</td>
</tr>
<tr>
<td>Clay</td>
<td>5.46/3.53</td>
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<tr>
<td>Dissolved</td>
<td>26.0 pC/m³</td>
<td>106 pC/m³</td>
</tr>
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</table>

--- = below detection.
TABLE 5.10. (contd)

### Phase 1 $^{137}$Cs Comparison (pC/g)

<table>
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<tr>
<th>Location</th>
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<tbody>
<tr>
<td>CC-9</td>
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</tr>
<tr>
<td>Sand</td>
<td>---</td>
<td>0.2</td>
</tr>
<tr>
<td>Silt</td>
<td>0.290</td>
<td>0.6</td>
</tr>
<tr>
<td>Clay</td>
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<td>1.5</td>
</tr>
<tr>
<td>Dissolved</td>
<td>---</td>
<td>80 pC/m$^3$</td>
</tr>
<tr>
<td>CC-11</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sand</td>
<td>---</td>
<td>0.4</td>
</tr>
<tr>
<td>Silt</td>
<td>0.454/0.571</td>
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</tr>
<tr>
<td>Clay</td>
<td>5.50</td>
<td>2.2</td>
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<tr>
<td>Dissolved</td>
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<td>63 pC/m$^3$</td>
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</table>

### Phase 1 $^3$H Comparison (pC/g)

<table>
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<th>Location</th>
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</thead>
<tbody>
<tr>
<td>BC-4</td>
<td>$461 \times 10^3$</td>
<td>$460 \times 10^{10}$</td>
</tr>
<tr>
<td>CC-3</td>
<td>$305 \times 10^3$</td>
<td>$290 \times 10^3$</td>
</tr>
<tr>
<td>CC-11</td>
<td>$206 \times 10^3$</td>
<td>$210 \times 10^3$</td>
</tr>
</tbody>
</table>
FIGURE 5.62 Phase 1 Dissolved Radionuclide Concentration: $^3$H at CC-3
FIGURE 5.63. Phase 1 Dissolved Radionuclide Concentration: $^3$H at CC-11
FIGURE 5.64. Phase 1 Longitudinal Distribution of $^3$H Total Concentration at Hour 120
6.0 HYPOTHETICAL TEST CASES

After SERATRA was tested in the Cattaraugus Creek system as discussed in Chapter 5, SERATRA was then applied to the same site for two hypothetical cases. These cases of instantaneous radionuclide releases were conducted to illustrate how SERATRA can be used as a site assessment tool.

Case 1. Instantaneous Release of X Dissolved Radionuclide

An instantaneous release of X (highly sorptive but short-lived) radionuclide to Buttermilk Creek at the confluence of Franks Creek was simulated as an example. The assumed conditions for this case are shown in Table 6.1.

<table>
<thead>
<tr>
<th>Table 6.1. Assumed Conditions for Case 1</th>
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<tbody>
<tr>
<td>Half Life</td>
</tr>
<tr>
<td>Release Amount</td>
</tr>
<tr>
<td>$K_d$ for Sand</td>
</tr>
<tr>
<td>$K_d$ for Silt</td>
</tr>
<tr>
<td>$K_d$ for Clay</td>
</tr>
</tbody>
</table>

Computed results at BC-2 and the mouth of Buttermilk (BC-4) Creek for this case are presented in Figures 6.1 through 6.4. The instantaneous release dispersed longitudinally to form a bell-shaped wave with a 10-hour duration. The three particulate radionuclide waves are each slightly out of phase, with the smaller diameter particles arriving before the heavier sediment. Clay is the most efficient in concentrating radionuclide on particle surfaces while the sand particles are the least efficient.

Case 2. Instantaneous Release of Y Dissolved Radionuclide

The second hypothetical case was instantaneous release of Y (less sorptive but long-lived) dissolved radionuclide at FC-1. The conditions used for this case are shown in Table 6.2.

At BC-2 and BC-4 in Buttermilk Creek, predicted results are shown in Figures 6.5 through 6.8. Comparison of Cases 1 and 2 reveals that sorbed Y radionuclide concentrations are 100 times higher than those of Case 1 and that the total Y radionuclides (sum of dissolved and sorbed radionuclide concentrations) after 10 hr are approximately twice as much as those of Case 1. These are reflections of half-lives and distribution coefficients selected for Cases 1 and 2. These two hypothetical cases demonstrate the usefulness of SERATRA as a site assessment tool.

6.1
TABLE 6.2. Assumed Conditions for $^{129}$I (Case 2)

<table>
<thead>
<tr>
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<th>Value</th>
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<tr>
<td>Half Life</td>
<td>$1.7 \times 10^7$ years</td>
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<tr>
<td>Release Amount</td>
<td>333 pCi</td>
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<tr>
<td>$K_d$ for Sand</td>
<td>20 ml/g</td>
</tr>
<tr>
<td>$K_d$ for Silt</td>
<td>100 ml/g</td>
</tr>
<tr>
<td>$K_d$ for Clay</td>
<td>200 ml/g</td>
</tr>
</tbody>
</table>

An important consideration is the interaction of the contaminants with the environment. The conditions for this case are shown in Table 6.2. For Case 1, refer to the Appendix A for a detailed description of the case conditions.
FIGURE 6.1. Computed Sorbed X Radionuclide Concentrations at Buttermilk Creek RM 2.26 for Case 1
FIGURE 6.2. Computed Sorbed and Dissolved X Radionuclide Concentrations at Buttermilk Creek RM 2.26 for Case 1
FIGURE 6.3. Computed Sorbed X Radionuclide Concentrations at the Mouth of Buttermilk Creek (BC-4) for Case 1
FIGURE 6.4. Computed Sorbed and Dissolved X Radionuclide Concentrations at the Mouth of Buttermilk Creek (BC-4) for Case 1
FIGURE 6.5. Computed Sorbed Y Radionuclide Concentrations at Buttermilk Creek RM 2.26 for Case 2
FIGURE 6.6. Computed Sorbed and Dissolved Y Radionuclide Concentrations at Buttermilk Creek RM 2.26 for Case 2
FIGURE 6.7. Computed Sorbed Y Radionuclide Concentrations at the Mouth of Buttermilk Creek (BC-4) for Case 2
FIGURE 6.8. Computed Sorbed and Dissolved Y Radionuclide Concentration at the Mouth of Buttermilk Creek (BC-4) for Case 2
REFERENCES


Ref.2
APPENDIX A

COMPARISONS OF COMPUTED AND MEASURED CONCENTRATIONS OF SEDIMENT AND RADIONUCLIDES
A.1.1. SEDIMENT CONCENTRATIONS FOR PHASE 3
A.1.2. SEDIMENT CONCENTRATIONS FOR PHASE 2
A.1.3. SEDIMENT CONCENTRATIONS FOR PHASE 1
SEGMENT 14
- SAND
△ SILT
+ CLAY

FIELD DATA
◊ SAND
★ SILT
□ CLAY
A.2.1 RADIONUCLIDE CONCENTRATIONS FOR PHASE 3
SEGMENT 14
- SAND
- SILT
- CLAY

FIELD DATA
* SILT
□ CLAY
SEGMENT 14
- SAND
- SILT
- CLAY
- DISSOLVED

FIELD DATA

× DISSOLVED

CECIUM CONCENTRATION (PC/M^3) * 10^-1

0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
10.0  10.0  10.0  10.0  10.0  10.0  10.0  10.0  10.0
20.0  20.0  20.0  20.0  20.0  20.0  20.0  20.0  20.0
30.0  30.0  30.0  30.0  30.0  30.0  30.0  30.0  30.0
40.0  40.0  40.0  40.0  40.0  40.0  40.0  40.0  40.0
50.0  50.0  50.0  50.0  50.0  50.0  50.0  50.0  50.0
60.0  60.0  60.0  60.0  60.0  60.0  60.0  60.0  60.0
70.0  70.0  70.0  70.0  70.0  70.0  70.0  70.0  70.0
80.0  80.0  80.0  80.0  80.0  80.0  80.0  80.0  80.0

TIME (HRS)
SEGMENT 28
- SAND
- SILT
+ CLAY

FIELD DATA
- SAND
- SILT
+ CLAY

CESIUM CONCENTRATION (PC/KG) = 10^{-2}

TIME (HRS)
SEGMENT 34
- SAND
- SILT
- CLAY
- DISSOLVED

CECIUM CONCENTRATION [PC/CM^3] = 10^-1

TIME (HRS)

0.00 10.00 20.00 30.00 40.00 50.00 60.00 70.00 80.00
SEGMENT 8
- SANO
- SILT
- CLAY
- DISSOLVED

FIELD DATA

Strontium Concentration (mg/L) vs. Time (hours)
SEGMENT 14
- SAND
- SILT
+ CLAY
* DISSOLVED
X

FIELD DATA

X DISSOLVED

STRONTIUM CONCENTRATION [PC/MM^2] = 10^-2
3.21
4.29
5.36

TIME (HRS)
0.00 10.00 20.00 30.00 40.00 50.00 60.00 70.00 80.00
0.00 1.07 2.14 3.21
SEGMENT 20
- SAND
- SILT
- CLAY
- DISSOLVED

FIELD DATA

× DISSOLVED

STRONTIUM CONCENTRATION [PC/M^3] * 10^3

10.00 15.00 20.00 25.00 30.00 35.00 40.00 45.00 50.00 55.00 60.00 65.00 70.00 75.00 80.00

TIME (HRS)

<table>
<thead>
<tr>
<th>TIME (HRS)</th>
<th>STRONTIUM CONCENTRATION [PC/M^3]</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>10.00</td>
<td>5.95</td>
</tr>
<tr>
<td>20.00</td>
<td>11.90</td>
</tr>
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<td>30.00</td>
<td>17.85</td>
</tr>
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<td>40.00</td>
<td>23.81</td>
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<td>70.00</td>
<td>41.76</td>
</tr>
<tr>
<td>80.00</td>
<td>47.81</td>
</tr>
</tbody>
</table>
PLUTONIUM CONCENTRATION (PC/KG)

- SAND
- SILT
- CLAY

SEGMENT 3

FIELD DATA

* SILT

TIME (HRS)
SEGMENT 8
- SAND
- SILT
- CLAY

FIELD DATA
* SILT

PLUTONIUM CONCENTRATION (PC/ KG) *10^-1

TIME (HRS)
SEGMENT 8
- SAND
- SILT
- CLAY
- DISSOLVED

PLUTONIUM CONCENTRATION (PC/M^3) × 10^2

TIME (HRS)
SEGMENT 28
- SAND
- SILT
- CLAY

FIELD DATA

PLUTONIUM CONCENTRATION (PC/KG) * 10^-1

TIME (HRS)
SEGMENT 28

- SAND
- SILT
- CLAY
- DISSOLVED

PLUTONIUM CONCENTRATION (PC/M^3)

TIME (HRS)
SEGMENT 6

- DISSOLVED

FIELD DATA

× DISSOLVED
SEGMENT 8

FIELD DATA

- DISSOLVED

X DISSOLVED

TRITIUM CONCENTRATION [g/l]
SEGMENT 21

FIELD DATA

- DISSOLVED

X DISSOLVED

TRITIUM CONCENTRATION (PC/M = 10^-4)

TIME (HRS)
SEGMENT 28

Dissolved
A.2.2. RADIONUCLIDE CONCENTRATIONS FOR PHASE 2
SEGMENT 6
- SAND
- SILT
- CLAY
SEGMENT 14
- SAND
+ SILT
+ CLAY

FIELD DATA

CECIUM CONCENTRATION (PC/Kg3) = 10^{-3}

TIME (HRS)
SEGMENT 14

- SAND
- SILT
- CLAY
- DISSOLVED

X DISSOLVED

FIELD DATA

CESIUM CONCENTRATION (PC/M^3) = 10^{-1}

A.53
SEGMENT 34
- SAND
- SILT
- CLAY
- DISSOLVED

FIELD DATA

X DISSOLVED
SEGMENT 6
- SAND
- SILT
- CLAY
- DISSOLVED

FIELD DATA

X DISSOLVED

STRIONTIUM CONCENTRATION (PC/M^3) x 10^-2

6.68
4.45
2.22

TIME (HRS)

0.00 15.00 30.00 45.00 60.00 75.00 90.00 105.00 120.00
SEGMENT 34
- SAND
+ SILT
+ CLAY

STRIONTIUM CONCENTRATION (PC/KG) • 10^-2

TIME (HRS)
SEGMENT 8
- SAND
- SILT
- CLAY
- DISSOLVED

FIELD DATA

× DISSOLVED

PLUTONIUM CONCENTRATION (P/M² * 3) • 10²

TIME (HRS)

0.00 15.00 30.00 45.00 60.00 75.00 90.00 105.00 120.00
SEGMENT 14

- DISSOLVED

FIELD DATA

X DISSOLVED
SEGMENT 34

FIELD DATA

- DISSOLVED

- DISSOLVED

TRITIUM CONCENTRATION (pCi/L) vs. TIME (Hrs)

TIME (HRS)

0.00  15.00  30.00  45.00  60.00  75.00  90.00  105.00  120.00
A.2.3. RADIONUCLIDE CONCENTRATIONS FOR PHASE 1
SEGMENT 3
- SAND
* SILT
+ CLAY

FIELD DATA
◊ SAND
* SILT
□ CLAY

CECIUM CONCENTRATION (PC/KG) x 10^3
17.00
13.50
10.20
0.00

TIME (HRS)
0.00 20.00 40.00 60.00 80.00 100.00 120.00 140.00 160.00
SEGMENT 8

- SAND
- SILT
- CLAY
- DISSOLVED

CESIUM CONCENTRATION (PC/M^3) • 10^-2

TIME (HRS)
SEGMENT 34
- SAND
- SILT
- CLAY
- DISSOLVED
APPENDIX B

LISTING OF SERATRA ROUTINES
SUBROUTINE READIC(LAY,LEM,LRED,AREA,BUIV,DEPS,PON,XYBU,IBED)
C  THIS ROUTINE IS RESPONSIBLE FOR READING THE INITIAL BED CONDITIONS.
C
C  FORMAL PARAMETERS:
C  U = INITIAL BED CONDITIONS
C  ECHU = TRUE IF ECHO OPTION CONTROL VARIABLE (L*1)
C  NRED = NUMBER OF RED LAYERS
C  AREA = VERTICAL PROJECTION AREA
C  TIV = THICKNESS OF BED ELEMENT
C  DEPS = DENSITY
C  PON = POROSITY
C  XYBU = THICKNESS OF TOP BED ELEMENT
C  THEB = HEIGHT OF MATERIAL, TOTAL OF CONTAMINANT IN BED
C  C
C  CALLED BY UGRATHA
C
C INCLUDE 'ELMS1.PRN'
C INCLUDE 'SYELMS1.PRM'
C
C LOGICAL ECHU
C INTEGER IJNCH
C
C DIMENSION BMAX(2),MALE,JMAX,DEPS(3),PBED(MAXCUM),
C        CEBL(MAXLEY,MAXCHN)
C
C CARD 1,..., INITIAL BED CONDITIONS
C
C IF THERE IS NO VERTICAL VARIATION, COLUMNS 1=5 CONTAIN A NEGATIVE
C VALUE AND COLUMNS 6-15 CONTAIN THE CONSTANT VALUE, WHEN THE DATA
C DOESN'T VARY WITH DEPTH, A VALUE IS READ FOR EACH ELEMENT, THE UNITS
C OF THE CONTAMINANT CONCENTRATIONS DEPEND UPON THE TYPE OF CONTAMINANT
C (FACONICLIDE, FEED OR PESTICIDE, AGRA)
C
C PARAMETERS ARE READ IN THE FOLLOWING ORDER
C
C   PARAMETER 1, WEIGHT FRACTION OF SAND IN THE BED
C   2, WEIGHT FRACTION OF SILT IN THE BED
C   3, WEIGHT FRACTION OF CLAY IN THE BED
C   4, CONTAMINANT CONCENTRATION IN SAND
C   5, CONTAMINANT CONCENTRATION IN SILT
C   6, CONTAMINANT CONCENTRATION IN CLAY
C   7, PREDICATE FOR VERTICAL VARIATION
C   ... (MAX3, MAXCUM-1)
C
C   *PARAMETER 8, SWITCH VALUE
C   **VARIABLE (SWITCH AT 0)
C
C   ***PARAMETER DOES NOT VARY VERTICALLY ***
C   ****SWITCH 0 (INITIAL 0,0,0) ***
C   ****SWITCH 1 (INITIAL 0,0,0) ***

B.1
ELSE
*** PARAMETER VARIES VERTICALLY ***
READ(I,J) (H(I,J),J=1,MAXJ)
***FIN
WRITE(6,*)
DO (J=1,MAXJ)
DO (I=1,MAXI)
WRITE(6,*) (H(I,J),J=1,MAXJ)
***FIN
***FIN
C
DO (J=1,MAXJ) TEND(J)=0.
DO (J=1,MAXJ)
DO (I=1,MAXI)
WRITE(6,*) (H(I,J),J=1,MAXJ)
***FIN
***FIN
C
DO (J=1,MAXJ) H(J,1)=0.
C
DO (J=1,MAXJ)
DO (I=1,MAXI)
WRITE(6,*) (H(I,J),J=1,MAXJ)
***FIN
***FIN
C
DO (J=1,MAXJ) TEND(J)=0.
DO (J=1,MAXJ)
DO (I=1,MAXI)
WRITE(6,*) (H(I,J),J=1,MAXJ)
***FIN
***FIN
C
DO (J=1,MAXJ) VOLUME(J)=0.
DO (J=1,MAXJ)
DO (I=1,MAXI)
WRITE(6,*) (H(I,J),J=1,MAXJ)
***FIN
***FIN
C
DO (J=1,MAXJ) THE(J)=0.
DO (J=1,MAXJ)
DO (I=1,MAXI)
WRITE(6,*) (H(I,J),J=1,MAXJ)
***FIN
***FIN
C
RETURN
C
FORMAT(AF10,6)
FORMAT(15,F10.0)
FORMAT(5X,'INITIAL BED CONDITIONS'/10X,'LAYER'/
3*8X,'SAND',13X,'SILT',13X,'CLAY')
FORMAT(2*8X,'SAND',13X,'SILT',13X,'CLAY')
FORMAT(2*8X,'SAND',13X,'SILT',13X,'CLAY')
FORMAT(12X,13)*7X,'PE12.5',2(8X,'PE12.5'))
FORMAT(2*8X,'SAND',13X,'SILT',13X,'CLAY')
FORMAT(2*8X,'SAND',13X,'SILT',13X,'CLAY')
FORMAT(2*8X,'SAND',13X,'SILT',13X,'CLAY')
FORMAT(12X,13)*7X,'PE12.5',2(8X,'PE12.5'))
SUBROUTINE RINO(ETA, DECAY, DELT, NR)  

C THIS ROUTINE CALCULATES THE DECAY OF THE CONTAMINANTS IN THE 
C GIVEN GEO.

C FORMAL PARAMETERS
C
C ETA = FFCONCENTRATIONS
C DECAY = DECAY VALUES
C DELT = TIME STEP IN DAYS
C NR = NUMBER OF FEED LAYERS

C CALLED BY TRANSF, SERATRA

C INCLUDE 'SYELMSIZ,PRM'

DIMENSION B(MAXLEV,MAANG+1), DECAY(B)

IF (DECAY(1) .LE. 0.0) THEN
  UD (JJK,0)
C *** RADIOACTIVE DECAY ***
  UD (JJK,MR)
  B(JJK,JJ) = B(JJK,JJ)*EXP(-DECAY(1)*DELT)
C ***FIN
C ***FIN
RETURN
END
SUBROUTINE REDIHIST, HDIV, RED, COLO, DEL7, DELZ, DENS,
1 FEMOR, ILAYR, NRED, NELEM, PON, XNT, XY8O,
2 DEPO, SCOU, REDSS)
00004 C
00005 C THIS SUBROUTINE HELPS A RECORD OF RED HISTORY, INCLUDING RED
00006 C SURFACE ELEVATION, RATIO OF RED SEDIMENT WEIGHT FRACTIONS, AND
00007 C ASSOCIATED CONCENTRATIONS IN THE RED
00008 C
00009 C FORMAL PARAMETERS:
00010 C R = RED CONDITIONS (WEIGHT FRACTION, PC/ KG)
00011 C ADIV = STANDARD RED LAYER THICKNESS (M)
00012 C RED = RED THICKNESS (M)
00013 C REUD = TRANSFER OF DISSOLVED TO ABSORBED (PC/ KG/DAY)
00014 C COLD = CELL-CENTERED CONCENTRATION (KG/MM^3, KG/MM^2)
00015 C DELT = TIME STEP (DAYS)
00016 C DELZ = DIAMOND ELEMENT THICKNESS (M)
00017 C DENS = DENSITY (KG/MM^3)
00018 C DEPO = DEPOSITION RATE (KG/PC)/ MM/DAY)
00019 C FEMOR = FATAL ERRORS FLAG (LA)
00020 C ILAYR = NUMBER OF LAYERS COMPLETELY COVERED BY EACH RESPECTIVE
00021 C SEDIMENT, ILAYR(J) = 1 FOR DEPOSITION
00022 C NRED = NUMBER OF RED LAYERS
00023 C NELE = NUMBER OF ELEMENTS
00024 C PIR = POROSITY
00025 C SCOUH = SOUR RATE (KG/PC)/ MM/DAY)
00026 C XHY8O = HEIGHT OF THE RED SEDIMENT LAYER (KG/MM)
00027 C XY8O = THICKNESS OF TOP RED LAYER (M)
00028 C ZERO = NORMALIZED INCREASE ERROR = SIGNIFICANT DIGITS
00029 C
00030 C CALLED MW1 TRANSP
00031 C
00032 C INCLUDE SYSCALE,PRM
00033 C
00034 C LOGICAL FEMOR
00035 C
00036 C DIMENSION ALEF1(3), AKAD(3), R(MAXLEY,MAXCON+1), M2FD(1)
00037 C RED(3), COLO(MAXLEY,MAXCON), DENS(3), DEPO(3),
00038 C ILAYR(3), SCOUR(6), SUMS(3), SUMSOC(3), XNT(3)
00039 C DATA ZERD1, DENS
00040 C
00041 C FEMOR = .FALSE.
00042 C
00043 C ALEF1 = A,N,layr(1)
00044 C IP=ILAYR(2)
00045 C IP=ILAYR(3)
00046 C
00047 C DO (IJ=1,3)
00048 C SUMS(IJ)=DEPO(IJ)
00049 C SUMSOC(IJ)=SUMSOC(IJ)
00050 C IF(REDD(IJ),LlO,Q) SUMSOC(IJ)+=DENS(IJ)+SUMSOC(IJ)
00051 C
00052 C SCOUH = AMOUNT OF CHEMICALS LEFT IN TOP RED LAYER.
00053 C ALEF1 = AMOUNT OF SEDIMENT LEFT IN TOP RED LAYER.

B.4
Cład (l1=1,3)  
* ARAD(I1)=0.0  
* ALEFT(I1)=0.0  
...FIN

C IF (SCOUR(1)+SCOUR(2)+SCOUR(3),GT,0.0) GO TO 110  
TM=FNT(I)/DEN(1),*N(2)/DEN(2),*N(3)/DEN(3)/  
I = (1.0-POR)  
DEP0=DEP0(1)+DEP0(2)+DEP0(3)  
D=TEMP - BC1)/HOT  
IF (DEP0,GT,0.0,AND,ABS (DEL),.LE.,ZERO)  
C******************************************************  
C IF ONLY DEPOSITION OCCURS AND THE TOP LAYER HAS A  *  
C THICKNESS IF BC1,..,TU AVOID HOMOGENIZING THE OLD  *  
C AND NEW MATERIAL HE CREATE A NEW ELEMENT WITH  *  
C XNT(I)=0, AND ALEFT(I) AND ARAD(I) EQUAL TO  *  
C DEPOSITED MATERIAL AND CONTAMINATION RESPECTIVELY.  *  
C**********************************************************  
C COMPUTES SEDIMENT (KG/2) AND CONTAMINANT (PC/H2)  
C READING IN THE TOP LAYER  
C**********************************************************  
110 IF (IN,LT,0) IMHO  
ALEFT(I)*XNT(I)*SUMSD(I)*DELT  
ARAD(I)*XNT(I)*SUMSD(1)*DELT  
IF (REUS(I),GT,0.0) ARAD(I)*ARAD(I)*BESD(1)*DELT  
IMILAY(1)  
IF (IP,LT,0) IP=0  
ALEFT(2)*XNT(2)*SUMSD(2)*DELT  
ANADO(2)*XNT(2)*SUMSD(2)*DELT  
IF (REUS(2),GT,0.0) APAD(2)*APAD(2)*BESD(2)*DELT  
IP = ILAY2(2)  
IF (IW,LT,0) IW=0  
ALEFT(3)*XNT(3)*SUMSD(3)*DELT  
ANADO(3)*XNT(3)*SUMSD(3)*DELT  
IF (REUS(3),GT,0.0) APAD(3)*APAD(3)*BESD(3)*DELT  
ILAY3(3)  
C**********************************************************  
C IF SAND HAS NOT SCOURER A COMPLETE LAYER ALEFT(I)  
C AND ARAD(I) ARE COMPLETELY DETERMINED  
C**********************************************************  
110 IF (IN,LT,1) GO TO 270  
C**********************************************************  
C IF SAND AND SAND PROFILES (DIFFERENT) ARE WITHIN  
B.5
C THE SAME LAYER ..., LEFT(2), AND RAD(2) ARE
C COMPLETELY DETERMINED
C OTHERWISE INCLUDE ADDITIONAL LAYERS
*
C**********************************************************
IF(IN GT IP)
  * IP = IP + 1
  IF (IP GT IOO) IP = 1
  DO (IT = IP, IN)
   * NB = NRED = IT
   RX = (1.0 - POR)/(B(NB,1)/DENB(1) + B(NB,2)/DENB(2) +
   1.0 - 0(NB,3)/DENB(3))
   DELNT = RX*NB*DIVB(NB,2)
   LEFT(2) = LEFT(2) + DELNT
   RAD(2) = RAD(2) + DELNT*NB(NB,5)
  END
C**********************************************************
C IF CLAY AND SAND EXHIBIT DEPOSITION (DEPOSITION) ARE WITHIN
C THE SAME LAYER ..., LEFT(3) AND RAD(3) ARE
C COMPLETELY DETERMINED
C OTHERWISE INCLUDE ADDITIONAL LAYERS
C**********************************************************
IF(IN GT IQ)
  * IQ = IQ + 1
  IF (IQ GT IOO) IQ = 1
  DO (IT = IQQ, IQ)
   * XND = (1.0 - POR)/(B(NH,1)/DENV(NH,1) + B(NH,2)/DENV(NH,2) +
   1.0 - 0(NH,3)/DENV(NH,3))
   DELNTXND = XND*NB*DIVB(NH,3)
   LEFT(3) = LEFT(3) + DELNTXND + NB(NH,5)
   RAD(3) = RAD(3) + DELNTXND*NB(NH,5)
  END
C**********************************************************
C ESTABLISH THE B MATRIX VALUES FOR THE NEWLY CREATED
C NEW ELEMENTS
C**********************************************************
CONTINUE
M1 = LEFT(1) + LEFT(2) + LEFT(3)
XM = [LEFT(1)/DENB(1) + LEFT(2)/DENB(2) + LEFT(3)/
   1.0 - 0(NB,3)/DENB(3)](1.0 - POR)
IN = XM*NB*DIVB(NB,2)
REM = XM*NRED = 1
NIN = IN + 1
M1 = XM*NB*DIVB(NB,2)
NRE2 = NRED - 1
NIN = IN + 1
D11(I, N1, 5)
D10 = 0
D12 = 0
D11 = 0
D12 = 0
D11 = 0
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00166  *  K(IY,IX),  =  RZ(IX)
00167  *   *FIN
00168  *FIN
00169  WHEN  WHEN  =  I
00170  XYSO  =  REMAIN
00171  IF  (REMAIN./ZERO)  XYSU  =  RDIV
00172  BED  =  (NUMBER-1)  =  RDIV  +  XYSN
00173  IF  (NUMBER  =  0)  MAXFY)
00174  *  WRITE(6,290)  NHED
00175  290  FORMAT(2X,'DEFINITION EXCEEDS PERMISSIBLE BED DEPTH IN BEDST'),/
00176  *  NX,/'(HEBD'.15)
00177  *  FERMOR  =  .TRUE.
00178  **FIN
00179  C
00180  **FIN
00181  END

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--------------------------------------------
SUBROUTINE COLBY(ALEN, CT, DELZ, D50, MPAD, NELEM, DTOT,
1       TEMP, VOL, G51, FERROR)

THIS SUBROUTINE USES COLBY'S METHOD TO CALCULATE THE CAPACITY OF
THE FLOW TO TRANSPORT SAND.

INPUT PARAMETERS:
CT     = SEGMENT LENGTH
D50   = NODAL VALUES OF CONCENTRATION
DELZ  = STANDARD ELEMENT THICKNESS
MPAD  = MEDIAN BED SEDIMENT DIAMETER (M)
NELEM = HYDRAULIC RADIUS
DTOT  = TOTAL FLOW WITHIN THE SEGMENT
TEMP  = WATER TEMPERATURE
V     = AVERAGE VELOCITY
VOL   = VOLUME

OUTPUT PARAMETERS:
G51   = TOTAL SAND TRANSPORT
FERROR = FATAL ERROR FLAG (L=1)

CALLED BYI SAND
THE COLBY METHOD HAS THE FOLLOWING UNITS AND APPLICABLE RANGES OF
VARIABLES,
AVERAGE VELOCITY..................V..................1-10 FPS
HYDRAULIC RADIUS...................MPAD..................1-100 FT
WATER SURFACE WIDTH................K..................1-100 FT
MEDIAN BED MATERIAL SIZE..............D50..................0.1-0.8 MM
TEMPERATURE.........................TEMP..................32-100 DEG
FINE SEDIMENT CONCENTRATION........FSL..................0-20000 ppm
TOTAL SEDIMENT LOAD..................TSL..................1-1000 TON

INCLUDE 'BYLEMUZ,PAM'

LOGICAL* FERROR

DIMENSION C(MXLEM,MAXCUN),CF(5),DF(10),DP(4),DPI(11),DQG(6),
1       P(5,10), Q(4,8,6), II(2), JJ(2), KX(2), PI(11), I(7,9),
00016  2       TEMP(7), VQ(9), X(2,2), XX(2), XCI(2), XF(2,2),
00017  3       XG(2), X(T,2), XV(2), Y(2), ZZ(2)
00018  1

DATA G(1,1,1),G(1,2,1),G(1,3,1),G(1,4,1)/1.0, 0.30, 0.20, 0.10/
00021  2       DATA G(2,1,1),G(2,2,1),G(2,3,1),G(2,4,1)/0.30, 1.30, 2.50, 2.00/
00024  3       DATA G(3,1,1),G(3,2,1),G(3,3,1),G(3,4,1)/1.30, 2.50, 4.00, 6.00/
00027  4       DATA G(4,1,1),G(4,2,1),G(4,3,1),G(4,4,1)/2.00, 4.00, 6.00, 10.00/
00030  5       DATA G(5,1,1),G(5,2,1),G(5,3,1),G(5,4,1)/10.00, 20.00, 30.00, 40.00/
00033  6       DATA G(6,1,1),G(6,2,1),G(6,3,1),G(6,4,1)/10.00, 20.00, 30.00, 40.00/
00036  7       DATA G(7,1,1),G(7,2,1),G(7,3,1),G(7,4,1)/10.00, 20.00, 30.00, 40.00/
00039  8       DATA G(8,1,1),G(8,2,1),G(8,3,1),G(8,4,1)/10.00, 20.00, 30.00, 40.00/
00042  9       DATA G(9,1,1),G(9,2,1),G(9,3,1),G(9,4,1)/10.00, 20.00, 30.00, 40.00/
00045  0       DATA G(10,1,1),G(10,2,1),G(10,3,1),G(10,4,1)/10.00, 20.00, 30.00, 40.00/
00048  1       DATA G(11,1,1),G(11,2,1),G(11,3,1),G(11,4,1)/11.00, 22.00, 33.00, 44.00/
00051  2       DATA G(12,1,1),G(12,2,1),G(12,3,1),G(12,4,1)/22.00, 33.00, 44.00, 55.00/
00054  3       DATA G(13,1,1),G(13,2,1),G(13,3,1),G(13,4,1)/33.00, 44.00, 55.00, 66.00/
00057  4       DATA G(14,1,1),G(14,2,1),G(14,3,1),G(14,4,1)/44.00, 55.00, 66.00, 77.00/
00060  5       DATA G(15,1,1),G(15,2,1),G(15,3,1),G(15,4,1)/55.00, 66.00, 77.00, 88.00/
00063  6       DATA G(16,1,1),G(16,2,1),G(16,3,1),G(16,4,1)/66.00, 77.00, 88.00, 99.00/
00066  7       DATA G(17,1,1),G(17,2,1),G(17,3,1),G(17,4,1)/77.00, 88.00, 99.00, 100.00/
00069  8       DATA G(18,1,1),G(18,2,1),G(18,3,1),G(18,4,1)/88.00, 99.00, 100.00, 110.00/
00072  9       DATA G(19,1,1),G(19,2,1),G(19,3,1),G(19,4,1)/99.00, 100.00, 110.00, 120.00/
IF((DS50 LT, D50G(1)) OR, (DS50 GT, D50G(6)))

WRITE(6,1)

IF((ORMAD LT, ORG(1)) OR, (ORMAD GT, ORG(4)))

WRITE(6,2)

WRITE(m,3)

WRITE(6,4)

WRITE(m,5)

WRITE(6,6)

WRITE(m,7)

WRITE(6,8)

WRITE(m,9)

WRITE(6,10)

WRITE(m,11)

WRITE(6,12)

WRITE(m,13)

WRITE(6,14)

WRITE(m,15)

WRITE(6,16)

WRITE(m,17)

WRITE(6,18)

WRITE(m,19)

WRITE(6,20)

WRITE(m,21)

WRITE(m,22)

WRITE(6,23)

WRITE(m,24)

WRITE(6,25)

WRITE(m,26)

WRITE(m,27)

WRITE(6,28)

WRITE(m,29)

WRITE(6,30)

WRITE(m,31)

WRITE(6,32)

WRITE(m,33)

WRITE(6,34)

WRITE(m,35)

WRITE(6,36)

WRITE(m,37)

WRITE(6,38)

WRITE(m,39)

WRITE(6,40)

WRITE(m,41)

WRITE(6,42)

WRITE(m,43)

WRITE(6,44)

WRITE(m,45)

WRITE(6,46)

WRITE(m,47)

WRITE(6,48)

WRITE(m,49)

WRITE(6,50)

WRITE(m,51)

WRITE(6,52)

WRITE(m,53)

WRITE(6,54)

WRITE(m,55)

WRITE(6,56)

WRITE(m,57)

WRITE(6,58)

WRITE(m,59)

WRITE(6,60)

WRITE(m,61)

WRITE(6,62)

WRITE(m,63)

WRITE(6,64)

WRITE(m,65)

WRITE(6,66)

WRITE(m,67)

WRITE(6,68)

WRITE(m,69)

WRITE(6,70)

WRITE(m,71)

WRITE(6,72)

WRITE(m,73)

WRITE(6,74)

WRITE(m,75)

WRITE(6,76)

WRITE(m,77)

WRITE(6,78)

WRITE(m,79)

WRITE(6,80)

WRITE(m,81)

WRITE(6,82)

WRITE(m,83)

WRITE(6,84)

WRITE(m,85)

WRITE(6,86)

WRITE(m,87)

WRITE(6,88)

WRITE(m,89)

WRITE(6,90)

WRITE(m,91)

WRITE(6,92)

WRITE(m,93)

WRITE(6,94)

WRITE(m,95)

WRITE(6,96)

WRITE(m,97)

WRITE(6,98)

WRITE(m,99)
00106  IF ((FMX11 .GE. VGI(1)) .AND. (FMRAO .LE. VGI(I+1)))
00107   IU1 = I
00108   DD2 = IU1
00109   GO TO 116
00110   CONTINUE
00111   CONTINUE
00112   CONTINUE
00113   CONTINUE
00114   CONTINUE
00115   CONTINUE
00116   CONTINUE
00117   CONTINUE
00118   CONTINUE
00119   CONTINUE
00120   CONTINUE
00121   CONTINUE
00122   CONTINUE
00123   CONTINUE
00124   CONTINUE
00125   CONTINUE
00126   CONTINUE
00127   CONTINUE
00128   CONTINUE
00129   CONTINUE
00130   CONTINUE
00131   CONTINUE
00132   CONTINUE
00133   CONTINUE
00134   CONTINUE
00135   CONTINUE
00136   CONTINUE
00137   CONTINUE
00138   CONTINUE
00139   CONTINUE
00140   CONTINUE
00141   CONTINUE
00142   CONTINUE
00143   CONTINUE
00144   CONTINUE
00145   CONTINUE
00146   CONTINUE
00147   CONTINUE
00148   CONTINUE
00149   CONTINUE
00150   CONTINUE
00151   CONTINUE
00152   CONTINUE
00153   CONTINUE
00154   CONTINUE
00155   CONTINUE
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00157   CONTINUE
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00167   CONTINUE
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00170   CONTINUE
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00206   CONTINUE
00207   CONTINUE
00208   CONTINUE
00209   CONTINUE
00210   CONTINUE
00211   CONTINUE
00212   CONTINUE
00213   CONTINUE
00214   CONTINUE
00215   CONTINUE
00216   CONTINUE
00217   CONTINUE
00218   CONTINUE
00219   CONTINUE
00220   CONTINUE
00221   CONTINUE

B.11
00222 - FIN
00223 - FIN
00224 - X\(2\) = ALOG10(UH/50) - ZZ(1)
00225 - X(1) = X(1,2) - X(1,1)
00226 - X(2,2) = X(2,2) - X(2,1)
00227 - XDEN = ZZ(2) - ZZ(1)
00228 - XA(1) = X(1,1) + XM1*XD/XDEN
00229 - XA(2) = X(2,1) + XM2*XD/XDEN
00230 - XOH = XA(2) - XA(1)
00231 - XDY = YY(2) - YY(1)
00232 - XG(1) = XA(1) + XM*XY/XDY
00233 - FIN
00234 - XH = XG(2) - XG(1)
00235 - X\(2\) = ALOG10(FH/AD) - X(1)
00236 - XDEN = XX(2) - XX(1)
00237 - GTUC = XG(1) - XM1*XD/XDEN
00238 - GTUE = 10**XG
00239 - C
00420 - C
00421 - C
00422 - C
00423 - C
00424 - WHEN (IMPR, LE, 60.0), CFT = 1.0
00425 - ELSE
00426 - IT1 = 0
00427 - IT2 = 0
00428 - DO 150 IMP
00429 - IF (IMPR - LE, TEMP(I)) AND (IMPR - LE, TEMP(I+1))
00430 - IT1 = 1
00431 - IT2 = IT2 + 1
00432 - GO TO 136
00433 - C
00434 - FIN
00435 - C
00436 - CONTINUE
00437 - 150 IF (TEMP(I), LE, TEMP(I)) AND (TEMP(I) - LE, TEMP(I+1))
00438 - XT(1,1) = ALOG10((IT1, IT1))
00439 - XT(1,2) = ALOG10((IT1, IT1))
00440 - XT(2,2) = ALOG10((IT1, IT1))
00441 - XT(2,2) = ALOG10((IT1, IT1))
00442 - XNT = ALOG10(TEMP(I))/ALOG10(TEMP(I))/ALOG10(TEMP(I))/ALOG10(TEMP(I))
00443 - CF = XT(1,1) + XNT*XT(2,2) - XT(1,1)
00444 - CF = XT(1,1) + XNT*XT(2,2) - XT(1,1)
00445 - CFT = CF + (XT(2,2) = XT(1,1))/XNT
00446 - CFT = CF + (XT(2,2) = XT(1,1))/XNT
00447 - CFT = CF + (XT(2,2) = XT(1,1))/XNT
00448 - CFT = CF + (XT(2,2) = XT(1,1))/XNT
00449 - 136 C
00450 - C
00451 - C
00452 - C
00453 - C
00454 - WHEN (FSL, LE, 1.0), CFF = 1.0
00455 - ELSE
00456 - IT1 = 0
00457 - IT2 = 0
00458 - DO (I = 1, 9)
00459 - IF (FH/AD, LE, DF(I)) AND (FH/AD, LE, DF(I+1))
00460 - IT1 = 1
00461 - ITF = ITF + 1
00462 - GO TO 136
00278  *  *  ***FIN
00279  ***FIN
00280  142  *  CONTINUE
00281  WHEN (FSL, GT, 1, EPS)
00282  *  WRITE(6, S)
00283  5  *  FORMAT(I0A, 16, ** SUBROUTINE COLBY == FSL MENT > 1, EPS)"
00284  IF  =  4
00285  IF2  =  5
00286  ***FIN
00287  ELSE
00288  IF1  =  0
00289  IF2  =  0
00290  UO (I=1, 4)
00291  IF (FSL, GE, CF(I))  AND, (FSL, LE, CF(I+1))
00292  IF1  =  1
00293  IF2  =  I+1
00294  GO TO 148
00295  ***FIN
00296  ***FIN
00297  148  *  CONTINUE
00298  ***FIN
00299  I/O((1, 1)  =  ALOGIO(F(IF1, I(I))
00300  X(F(1, 2))  =  ALOGIO(F(IF2, I(2))
00301  X(F(1, 2))  =  ALOGIO(F(IF1, I(2))
00302  X(F(2, 2))  =  ALOGIO(F(IF2, I(2))
00303  XNT  =  (FSL, CF(IF1)) / (CF(IF2) = CF(IF1))
00304  KCT(I)  =  X(F(1, 1)) / XNT * (X(F(2, 2))  =  X(F(1, 1))
00305  XCT(2)  =  X(F(1, 2)) / XNT * (X(F(2, 2))  =  X(F(1, 2))
00306  XNT  =  ALLOG1O(FHAGA/DF(ID)) / ALLOG1O(CDF(ID2)/DF(ID))
00307  CFF  =  KCT(1)  +  XN1A*KCT(2)  =  KCT(1)
00308  CFF  =  10, ** CFF
00309  ***FIN
00310  TCF = CFT + CFF  =  1, 0
00311  CFD  =  1
00312  UMLES6 ((D50, GE, 0, 20)  AND, (D50, LE, 0, 30))
00313  IP1  =  0
00314  IP2  =  0
00315  UO (I=1, 10)
00316  IF (D50, GE, DP(I))  AND, (D50, LE, DP(I+1))
00317  IF1  =  1
00318  IP1  =  I+1
00319  IP2  =  I+1
00320  GO TO 153
00321  ***FIN
00322  153  *  CONTINUE
00323  P2  =  ALLOGIO(P(IP2))
00324  PI  =  ALLOGIO(P(IP1))
00325  XNT  =  ALLOG1O((D50/DP(IP1)) / ALLOG1O(P(IP2)/DP(IP1))
00326  CDP  =  P1  +  XNT * (P2-P1)
00327  CDF  =  10, ** CFD
00328  ***FIN
00329  CFF  =  CFD  +  CNT
00330  XFF  =  FFF + 1, 0
00331  GSI  =  FFF  *  GTUC
00332  C
00333  C  *  *** CONVERTING GSI FROM (YEU/DA/FFT) TO (KG/DA/AM) ***
00334  G81 = G81 * 2.976328E+3
00335  ***FIN
00336  RETURN
00337  END

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00110 C  
00111 C  
00112 C  
00113 C  
00114 C  
00115 C  
00116 C  
00117 C  
00118 C  
00119 C  
00120 C  
00121 C  
00122 C  
00123 C  
00124 C  
00125 C  
00126 C  
00127 C  
00128 C  
00129 C  
00130 C  
00131 C  
00132 C  
00133 C  
00134 C  
00135 C  
00136 C  
00137 C  
00138 C  
00139 C  
00140 C  
00141 C  
00142 C  
00143 C  

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==================================================================

B.17
SUBROUTINE COM(M, S, Z, R)

THIS SUBROUTINE MULTIPLIES THE UNSYMMETRIC BAND MATRIX (S)
BY THE KNOWN LOAD VECTOR (Z) AND ADDS THE RESULT TO (R).

CALLED BY TRASP,

INCLUDE 'ELPSIZ.PRN'

REAL*8 A, B, Y

DIMENSION S(MXLELEM,1), R(MXLELEM), Y(MXLELEM), Z(MXLELEM)

K(1) = R(1) + S(1,2) * Z(1) + S(1,3) * Z(2)

K(M) = R(M) + S(M,1) * Z(M-1) + S(M,2) * Z(M)

Y(1) = S(1,1) * Z(1-1) + S(1,2) * Z(1) + S(1,3) * Z(1+1)

RETURN

END
SUBROUTINE DIAG(ECH02, ECH03, ECH04, ECH05, ECH06, ECH07, ECH08, ECH09, ECH10, ECH11, ISEG, JSEG, SAVECH)

LOGICAL ECH02, ECH03, ECH04, ECH05, ECH06, ECH07, ECH08, ECH09, ECH10, SAVECH

INTEGER JSEG(5), SAVECH(10)

ECHO2, FALSE
ECHO3, FALSE
ECHO4, FALSE
ECHO5, FALSE
ECHO6, FALSE
ECHO7, FALSE
ECHO8, FALSE
ECHO9, FALSE
ECHO10, FALSE
ECHO11, FALSE
ECHO12, SAVECH(6)
ECHO13, FALSE
ECHO14, FALSE
ECHO15, FALSE
ECHO16, FALSE
ECHO17, FALSE
ECHO18, FALSE
ECHO19, FALSE
ECHO20, FALSE
ECHO21, FALSE
ECHO22, FALSE
ECHO23, FALSE
ECHO24, FALSE
ECHO25, FALSE
ECHO26, FALSE
ECHO27, FALSE
ECHO28, FALSE
ECHO29, FALSE
ECHO30, FALSE
ECHO31, FALSE
ECHO32, FALSE
ECHO33, FALSE

END
THIS ROUTINE IS RESPONSIBLE FOR READING AND PROCESSING THE DATA

FORMAL PARAMETERS:
- ALEN = SEGMENT LENGTH
- AREA = SEGMENT AREA
- BDIV = STANDARD BED THICKNESS
- BEO = INITIAL BED THICKNESS
- DLZSAW = STANDARD ELEMENT THICKNESS
- ECHO = LINE PRINTER ECHO OPTION CONTROL VARIABLE (LAI)
- EL = ELEVATIONS ABOVE THE BED CORRESPONDING TO THE SEGMENT AREA
- ELEY = ELEVATION OF THE SEGMENT
- HLDERR = HOLDING ARRAY FOR ERROR NUMBERS (BYTE)
- ISEG = CURRENT SEGMENT NUMBER
- IRED = NUMBER OF RED LAYERS
- NELEM = NUMBER OF VERTICAL ELEMENTS
- NNUMERR = NUMBER OF INPUT ERRORS DETECTED
- PELEV = UPSTREAM ELEVATION OF SEGMENT NUMBER 1
- POR = PROXIMITY
- RIVER = SHEAR STRESS COMPUTATION CONTROL VARIABLE
- XYD = THICKNESS OF THE TOP BED LAYER

CALLED BY: SEGATKA

CALLS: PUTERR

INCLUDE 'ELMB2Z.PHY'

BYTE HLDERR(100)

LOGICAL ECHO,RIVER

DIMENSION AREA(XELEM), EL(XELEM)

CAND 1, SEGMENT DIMENSIONS

COL = 5, XELEM,, NUMBER OF VERTICAL ELEMENTS

XED = XED,, NUMBER OF BED LAYERS

DLZSAW,, STANDARD ELEMENT THICKNESS (METERS)

BDIV,, STANDARD BED LAYER THICKNESS

BEO,, INITIAL BED THICKNESS (METERS)

LAI,, LENGTH OF THE SEGMENT (METERS)

EL,, ELEVATION OF THE SEGMENT (METERS)

POR,, PROXIMITY

PELEY,, UPSIDE ELEVATION OF SEGMENT 1 ONLY

NO SHEAR STRESS COMPUTED USING VELOCITY

NO, SHEAR STRESS COMPUTED USING MOTION

SLOP, HYDRAULIC RAUSIM AND SPECIFIC
HEIGTH OF WATER (FREE FLOWING)

00054 C
00055 C
00056 C
00057 C
00058 C WHEN (IGE EQ .EQ. 1)
00059 C READ(1,1) NELEM,HEXED,DLZBAY,HDIV,RED,ALN,ELEV,POR,PELEY
00060 C WHEN (PELEY .EQ. 0.0) RIVER = .FALSE.
00061 C ELSE RIVER = .TRUE.
00062 C ***FIN
00063 C ELSE
00064 C ***FIN
00065 C ***XYBO = THICKNESS OF THE POP RED LAYER
00066 C
00067 C XYBO = MED = (MED+1) * HBUY
00068 C IF (ECHU)
00069 C WRITE(6,5) ISEG
00070 C WRITE(6,2) NELEM,HEXED,DLZBAY,HDIV,RED,ALN,ELEV,POR,XYBO
00072 C IF (ISEG .EQ. 1)
00073 C WRITE(6,5) PELEY
00074 C WHEN (PELEY .EQ. 0.0) WRITE(6,7)
00075 C ELSE WRITE(4,8)
00076 C ***FIN
00077 C ***FIN
00078 C
00079 C IF (NELEM .LT. 0 OR NELEM .GT. AXELAN)
00080 C WRITE(6,100)NELEM,AXELAN
00081 C 100 FORMAT(5X,'ERROR IN THE NELEM',13, 'AXELAN',13)
00082 C
00083 C CALL PUTERR(13,NUMERA,MLDERA)
00084 C ***FIN
00085 C IF (MED .LE. 0) CALL PUTERRA(NUMERA,MLDERA)
00086 C IF (MED .GT. MAXELY) CALL PUTERRB(NUMERA,MLDERA)
00087 C IF (DLZBAY .LE. 0.0) CALL PUTERRA9(NUMERA,MLDERA)
00088 C IF (HDIV .LE. 0.0) CALL PUTERRA9(NUMERA,MLDERA)
00089 C IF (RED .GT. (MED+1)*HDIV OR BED .LE. (MED+1)*DLZBAY)
00090 C CALL PUTERRA9(NUMERA,MLDERA)
00091 C ***FIN
00092 C IF (ALEN .LE. 0.0) CALL PUTERRA10(NUMERA,MLDERA)
00093 C IF (ELEV .LE. 0.0) CALL PUTERRA11(NUMERA,MLDERA)
00094 C IF (POR .AT. 0.0) CALL PUTERRA12(NUMERA,MLDERA)
00095 C
00096 C CERO 2,...........AREA OF EACH ELEMENT
00097 C
00098 C*******************************************************************************
00099 C
00100 C 6/4/81
00101 C
00102 C WARNING
00103 C A NONZERO SURFACE AREA IS REQUIRED FOR THE
00104 C CHANNEL BOTTOM.
00105 C*******************************************************************************
00106 C UN (1,IMAXELAN)
00107 C AREA(I)=0
00108 C ELSE
00109 C ***FIN

B.21
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00110     READ(1,9) NAREA, VPAREA, DELEV
00111     XEN= (NAREA * W, 0)
00112     * ELEM0
00113     * NO(1=1, MXELEM)
00114     * . AREA(I) = VPAREA
00115     . EL(I) = ELEM0
00116     . ELE=M0+DELEV
00117     **FIN
00118     **FIN
00119     ELSE
00120     * READ (1,3) (AREA(I), I=1,NAREA)
00121     * READ (1,3) (EL(I), I=1,NAREA)
00122     * IF (NAREA = LT. MXELEM)
00123     * . DU (1 = AREA(I), MXELEM)
00124     * . AREA(I) = VPAREA
00125     * . EL(I) = EL(I-1) + DELEV
00126     * . **FIN
00127     * **FIN
00128     IF (ECH=0)
00130     WRITE (9, 10) (1, AREA(I), I=1, MXELEM)
00131     WRITE (9, 10) (1, EL(I), I=1, MXELEM)
00132     **FIN
00133     C
00134     RETURN
00135     C
00136     1 FORMAT(2I5,7F10.0)
00137     2 FORMAT(1H0,13X,15,'***NUMBER OF VERTICAL ELEMENTS***/
00138     3 109,15,'***NUMBER OF GEO LAYERS***/
00139     4 7X,1PE12.5,'***STANDARD ELEMENT THICKNESS (METERS)***/
00140     5 7X,1PE12.5,'***STANDARD BED LAYERS THICKNESS (METERS)***/
00141     6 7X,1PE12.5,'***INITIAL BED THICKNESS (METERS)***/
00142     7 7X,1PE12.5,'***LENGTH OF THE SEGMENT (METERS)***/
00143     8 7X,1PE12.5,'***SEGMENT ELEVATION (METERS)***/
00144     9 7X,1PE12.5,'***PHYSIC***/
00145     10 7X,1PE12.5,'***THICKNESS OF THE TOP BED LAYER (CALCULATED)***/
00146     11 FORMAT(10.0)
00147     12 FORMAT(1H0,5X,'ELEMENT AREAS'/G(2X,5(I3,1PE12.5)))
00148     13 FORMAT(1H0,5X,'INPUT DATA FOR SEGMENT I,13)
00149     14 FORMAT(7X,1PE12.5,'***UPSTREAM ELEVATION (METERS)***/
00150     15 FORMAT(1H0,5X,'SHEAR STRESS VALUES COMPUTED USING METHOD***/
00151     16 FORMAT(1H0,5X,'FOR REVERIES***/
00152     17 FORMAT(1H0,5X,'SHEAR STRESS VALUES COMPUTED USING METHOD***/
00153     18 FORMAT(1H0,5X,'FOR FREE FLOWING RIVERS***/
00154     19 FORMAT(15,7F20.0)
00155     20 FORMAT(1H0,5X,'MODAL ELEVATIONS'/G(2X,5(I3,1PE12.5)))
00156     21 FORMAT(215,6F10.0,15)
00157     C
00158     END

(FLECS VERSION 22.46)

-------------------------------
The text appears to be a listing of a FORTRAN program for calculating environmental parameters such as deposition rates, sediment thickness, and light extinction coefficients. The code is structured in a series of comments and declarations, indicating that the program is designed to model environmental processes, possibly related to water pollution or sedimentation. The comments are in English, and the code is formatted in a way typical of early FORTRAN programming practices, with many hyphens and underscores for emphasis and alignment.
CBAR(I,JP3) + CBAR(IP1,JP3))

0011 3,  *  ADB82 = (SDBAR(J) * SDBAR(K) * SDBAR(J) * SDBAR(K) / 12.0 * (CBAR(I,J) * CBAR(I,J) + CBAR(I,J) * CBAR(I,J) + CBAR(I,J) * CBAR(I,J) + CBAR(I,J) * CBAR(I,J)) / 6.0;
0012 3,  *  CBAR(I,J) * CBAR(IP1,JP1) = CBAR(I,J) * CBAR(IP1,JP1) = SDBAR(J) * SDBAR(K) / 6.0;
0013 3,  *  (CBAR(I,JP3) + 2.0 * CBAR(I+1,JP3))
0014 3,  *  (CBAR(I,JP3) + 2.0 * CBAR(I+1,JP3))
0015 3,  *  (CBAR(I,JP3) + 2.0 * CBAR(I+1,JP3))
0016 3,  *  IF(ADB82, GT, 0.0, OH, AVDB1, EDB1, DB1) * BETAV * BETAV = ADB82
0017 3,  *  IF(ADB82, GT, 0.0, OH, AVDB2, EDB2, DB2) * BETAV = BETAV = ADB82
0018 3,  *  IF(ADB82, GT, 0.0, OH, AVDB2, EDB2, DB2) * BETAV = BETAV = ADB82
0019 3,  *  IF(ADB82, GT, 0.0, OH, AVDB2, EDB2, DB2) * BETAV = BETAV = ADB82
0020 3,  *  IF(ADB82, GT, 0.0, OH, AVDB2, EDB2, DB2) * BETAV = BETAV = ADB82
0021 3,  *  IF(ADB82, GT, 0.0, OH, AVDB2, EDB2, DB2) * BETAV = BETAV = ADB82
0022 3,  *  IF(ADB82, GT, 0.0, OH, AVDB2, EDB2, DB2) * BETAV = BETAV = ADB82
0023 3,  *  FIN
0024 C
0025 *** FIN
0026 C******************************************************************************
0027 C TRANSFER BETWEEN DISSOLVED STREAM CONTAMINANT AND ABSORBED A
0028 C BET CONTAMINANT IS INCLUDED WHENEVER NO SCOURING OCCURS FOR A
0029 C A PARTICULAR SEDIMENT SIZE (SB BAND, BILT, OR CLAY) A
0030 C******************************************************************************
0031 C
0032 C
0033 C
0034 C
0035 C
0036 C
0037 C
0038 C
0039 C
0040 C
0041 C
0042 C
0043 C
0044 C
0045 C
0046 C
0047 C
0048 C
0049 C
0050 C
0051 C
0052 C
0053 C
0054 C
0055 C
0056 C
0057 C
0058 C
0059 C
0060 C
0061 C
0062 C

B.25
00163  
      KAY = KAY1 + KAY2 = AVGKD
00164  
      WHEN (I .EQ. NLEN) TERM1 = 1.0
00165  
      ELSE TERM1 = EXP(-KAY*(NLEN-I)*DELZ)
00166  
      TERM2 = (1.0 + EXP(-KAY*DELZ)) / (KAY*DELZ)
00167  
      PHOTO = PCDEF * TERM1 * TERM2
00168  
      END

-----------------------------------------------

PROCEDURE CROSS-REFERENCE TABLE

00192  COMPUTE=PHOTOLYSIS RATE FOR ELEMENT-I
00193

(FLECS VERSION 22.96)
SUBROUTINE EQPCEXP(XSAR, XMID, VEL, XAREA, NELEM, MELEM, RATIO, IELP, HEWX, FERROR, DELTA)

C THIS SUBROUTINE FINDS CROSS-SECTIONAL AREAS AND HEIGHTS WITHIN THE
C UPSTREAM CROSS-SECTION WHICH CORRESPONDS TO THE SEGMENT IMMEDIATELY
C DOWNSTREAM.

C INARISE O--FERROR

C DIMENSION PXSAR(MALEMENT), XMID(MALEMENT), VEL(MALEMENT),
C XAREA(MALEMENT), IELP(MALEMENT), HEWX(MALEMENT)

C FERROR = FALSE.

IP=1
PXSPXSA(I)
XTRIMUX(I)
ELTRMUVEL(I)
TEMPXSM=0

C

XAREA(I,NELEM)

XAREA(I,NELEM)

XTRIMUX(I)
HEWX(I)HEL(I+1)
IF (VEL(I+1)XAR(I)HEL(I+1))
ELTRMUVEL(I)
XTRIMUX(I+1)
PXSA0

C TEMPXSM=0

C

ELSE

A=(XMID(IP+1)-XMID)/2.0*(VEL(IP+1)+ELBtm)

B=0

C=PSX-TEMPX

WHEN (A>0.5) HEWX(I)AC/RELBTM
ELSE

IF (PSX>AC *EL(I, 0.5) CU TO 200

WHEN (I) = 0.49) 1/2, AFKELBTM

C

ELSE

WHEN (AC-PSX) ELB?M+M

ELSE

ELTRMUVEL(I)

PXSA0

-TEMPXSM0

C

------------------------------------------------------------------------
00054        ***FIN
00055        RETURN
00056        200 CONTINUE
00057        IF (FORD==TRUE) THEN
00058            WRITE(6,1)
00059        1 FORMAT(10X,'FATAL ERROR - BAD NCI IN EQUPG SUBROUTINE IN 4 0')
00060        RETURN
00061        END

(FLECS VERSION 22.46)

-----------------------------------------------
SUBROUTINE EQUIPS(PXBAR, PHID, PDELZ, XBAREA, MELEM, MELEM,
  RATIO, IELP, HEXAB)
  INCLUDE 'SYSMBMIZ, FMN*'
  DIMENSION PXBAR(MXelem), PHID(MXelem), XBAREA(MXelem),
  IELP(MXelem), HEXAB(MXelem)

1P=1
PXBAR=PXBAR(1)

DO[1=1, MELEM]

XX=XRATIO*XBANE(1)
UNTIL[XX.GE. PXS , UX, IP .EQ. MELEM]

IP=IP+1

TEMPX=PXBAR

WHEN[XX.EQ. PXB]
HEXBA=IP+1
PDELZ=IP

WHEN[XX.GE. PHID(IP)]
HEXBA=IP+1

WHEN[XX.LE. PHID(IP)]
HEXBA=IP+1

TEMPX=PXBAR(IP+1)

FIN

WHEN[XX.EQ. PXB]
HEXBA=IP+1

WHEN[XX.LE. PHID(IP)]
HEXBA=IP+1

WHEN[XX.GE. PHID(IP)]
HEXBA=IP+1

FIN

ELSE
HEXBA=IP+1

WHEN[XX.LE. PHID(IP)]
HEXBA=IP+1

WHEN[XX.EQ. PXB]
HEXBA=IP+1

FIN

RETURN
END
SUBROUTINE FCUE(FNAME,BASE,HPRT,STYPE,DEV1,UC1,UC2)

THIS ROUTINE BUILDS A FILE SPECIFICATION INTO THE OUTPUT

PARAMETER PHNAME

BASE = FIRST FIVE CHARACTERS OF THE FILE NAME (BYTE ARRAY)
HPRT = FILE PLINE NUMBER. THIS BECOMES THE LAST 4 CHAR.
STYPE = THE 9 CHARACTER FILE NAME (INTEGER)
CTYPE = THESE 3 CHARACTERS BECOME THE EXTENSION (BYTE ARRAY)
DEV = DEVICE (BYTE ARRAY)
UC1 = 1ST UIC (BYTE ARRAY)
UC2 = 2ND UIC (BYTE ARRAY)

CALLED BY J SERA

BYTE FNAME(27),STYPE(3),DEV(3),UC1(3),UC2(3),COLON,LBRAK,

DATA COLON'/1'/
DATA LBRAK'/1'/
DATA HNRAK'/1'/
DATA PERIOD'/1'/
DATA COMMA'/1'/
DATA BLANK'/1'/

ICAR

*** DETERMINE IF A DEVICE HAS BEEN SPECIFIED AND IF SA THE NUMBER

CHARACTERS IN THE SPECIFICATION ***

***

DO (IM, 5)

* IF(DEV(I) .NE. BLANK) IFN

*** FIN

IF (N .LT. 0) *** TRANSFER DEVICE SPECIFICATION ***

* IF (IM .LT. N) *** INSERT "I" ***

FNAME(ICAR)#COLON

***

*** INSERT LEFT BRACKET ***
```plaintext
**FLECS Version 22.46**

00054  * FNAM(ICALI)=MARK
00055  * ICARNICAN+1
00056  C  * *** TRANSFER 1ST UIC ***
00057  C  * DO (I=1,4)
00058  C  * FNAM(ICALI)=UIC(I)
00059  C  * ICARNICAN+1
00060  C  * ***FIN
00061  C
00062  C  * *** INSERT COMMA ***
00063  C  * FNAM(ICALI)=COMMA
00064  C  * ICARNICAN+1
00065  C  * *** TRANSFER 2ND UIC ***
00066  C  * DO (I=1,3)
00067  C  * IF (UIC2(I) .NE. BLANK)
00068  C  * , FNAM(ICALI)=UIC2(I)
00069  C  * ICARNICAN+1
00070  C  * ***FIN
00071  C
00072  C  * *** TRANSFER 3TH UIC ***
00073  C  * DO (I=1,2)
00074  C  * IF (UIC3(I) .NE. BLANK)
00075  C  * FNAM(ICALI)=UIC3(I)
00076  C  * ICARNICAN+1
00077  C  * ***FIN
00078  C
00079  C  * *** TRANSFER 5 CHARACTER NAME FILE NAME, ASSUME ALL 5 CHARACTER ARE BEING USED ***
00080  C  * DO (I=1,5)
00081  C  * FNAM(ICALI)=NAME(I)
00082  C  * ICARNICAN+1
00083  C  * ***FIN
00084  C
00085  C  * *** CONVERT TIME PLANE NUMBER TO ASCII AND INSERT IT INTO FNAM ***
00086  C
00087  C
00088  C
00089  C
00090  C  * NAMEPUP
00091  C  * 
00092  C  * NAME[ICALI]=NAME[ICALI]+48
00093  C  * ICARNICAN+1
00094  C  * ICARNICAN+4
00095  C  * *** INSERT NEWLINE ***
00096  C
00097  C
00098  C
00099  C
00100  C  * *** TRANSFER THE 3 CHARACTER EXTENSION ***
00101  C  * 
00102  C
00103  C  * ICARNICAN+1
00104  C  * ***FIN
00105  C
00106  C
00107  C
00108  C
00109  C
```

B.31
C
C   FNAME(INCHAR)
C   RETURN
C   EQU

(FLECO VERSION 22.06)
SUBROUTINE FDCOU(E(FNAME, BASE, MBRTP, FTYPE, DEV, UIC1, UIC2)
C THIS ROUTINE OPERATES FNAME INTO 6 COMPONENTS
C
C BASE = 9 CHARACTER BASE FILE NAME (BYTE ARRAY)
C MBRTP = FILE PLANEx NUMBER THAT IS THE LAST 6 CHARACTERS OF THE
C FTYPE = 9 CHARACTER FILE NAME (INTEGER)
C UIC1 = PHYSICAL DEVICE SPECIFICATION (BYTE ARRAY)
C UIC1 = 1ST UIC
C
C THE OPTIONAL PARAMETERS DEV, UIC1, AND UIC2 WILL BE SET
C TO BLANKS IF NOT PRESENT IN THE ORIGINAL FILE SPECIFICATION.
C
C CALLED BY: STATUS
C
C BYTE FNAME(27), BASE(3), FTYPE(3), DEV(3), UIC1(3), UIC2(3),
C 1 LBRACK,MBRACK,COMMA,PERIOD,COLON,BLANK
C DATA LBRACK,'(1)/
C DATA MBRACK,'(/1/
C DATA COMMA,'(1/
C DATA PERIOD,'(1/
C DATA COLON,'(1/
C DATA BLANK,'(1/
C
C *** FILE SPECIFICATION HAVE FOUR POSSIBLE FORMS ***
C 00309 (1) FILENAME_EXT
C 00310 (2) DEV+FILENAME_EXT
C 00311 (3) UIC1+UIC2+FILENAME_EXT
C 00312 (4) DEV+UIC1+UIC2+FILENAME_EXT
C 00313 THE FORM CAN BE DETERMINED BY COUNTING THE FOUR SPECIAL
C 00314 CHARACTERS ( ) / 8
C 00315 A FILE CAN HAVE ONLY ONE OF THE FOUR FORMS.
C 00316
C 00317 NEQ
C 00318 UO (1=1,27)
C 00319 * SELECT (FNAME(I))
C 00320 * (COLUMN) NNN+1
C 00321 * (LBRACK) NNN+1
C 00322 * (PERIOD) NNN+1
C 00323 * FIN
C 00324 ***FIN
C 00325 ICNHI
C 00326 CO (1=1,3)
C 00327 * DEV(I)=BLANK
C 00328 * UIC1(I)=BLANK
C 00329 * UIC2(I)=BLANK
C 00330 ***FIN
C 00331 SELECT (N)
C 00332 * (1) DECODE FORM1
C
C
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00050   . (2) DECODE-FORM1
00055   . (3) DECODE-FORM2
00056   . (4) DECODE-FORM3
00057   ***FIN
00058   RETURN
00059   C

-----------------------------------------------

00060   TO DECODE-FORM1
00061   DECODE-FIENNAME-EXTENSION
00062   ***FIN
00063   C

-----------------------------------------------

00064   TO DECODE-FORM2
00065   DECODE-DEVICE
00066   DECODE-FIENNAME-EXTENSION
00067   ***FIN
00068   C

-----------------------------------------------

00069   TO DECODE-FORM3
00070   DECODE-UIC
00071   DECODE-FIENNAME-EXTENSION
00072   ***FIN
00073   C

-----------------------------------------------

00074   TO DECODE-FORM4
00075   DECODE-DEVICE
00076   DECODE-UIC
00077   DECODE-FIENNAME-EXTENSION
00078   ***FIN
00079   C

-----------------------------------------------

00080   TO DECODE-FIENNAME-EXTENSION
00081   DU (1,#5)
00082   * BASE(I)#NAME(I(AR)
00083   IC#ICAR+1
00084   ***FIN
00085   WHEN (NAME(I(AR) = PERIOD)
00086   * IC#NAME(I(AR)
00087   IC#NAME(I(AR+1)
00088   IC#NAME(I(AR+2)
00089   IC#NAME(I(AR+3)
00090   * NAME(I(CHAR=4#)10#+(IC#NAME=8#)*10#+(IC#NAME=8#)10#+(IC#NAME=8)
00091   C   *** SKIP (OVER PERIOD) ***
00092   * IC#ICAR+5
00093   ***FIN
00094   ELSE

B.34
```plaintext
00095  ICAN[ICAR+1
00096  WHIPD9
00097  **FIN
00098  OU [IM1,3]
00099  TYPE[ICAR]FNAME[ICAR]
00100  ICAN[ICAR+1
00101  **FIN
00102  **FIN

C

----------------------------------------

00103  TO DECODE=DEVICE
00104   IM1
00105  REPEAT WHILE (FNAME[ICAR] NE, COLON)
00106  DEV[ICAR]FNAME[ICAR]
00107  ICAN[ICAR+1
00108   IM1
00109  **FIN
00110  **FIN
00111  C ** SKIP OVER COLON **
00112  ICAN[ICAR+1
00113  **FIN
00114  C

----------------------------------------

00115  TO DECODE=VIC
00116  C ** SKIP OVER LEFT BRACKET **
00117  ICAN[ICAR+1
00118   IM1
00119  REPEAT WHILE (FNAME[ICAN] NE, COMMA)
00120  VIC[ICAR]FNAME[ICAN]
00121  ICAN[ICAR+1
00122   IM1
00123  **FIN
00124  C ** SKIP OVER COMMA **
00125  ICAN[ICAR+1
00126   IM1
00127  REPEAT WHILE (FNAME[ICAN] NE, #BRK)
00128  VIC[ICAR]FNAME[ICAN]
00129  ICAN[ICAR+1
00130   IM1
00131  **FIN
00132  C ** SKIP OVER RIGHT BRACKET **
00133  ICAN[ICAR+1
00134  **FIN
00135  END

----------------------------------------

PROCEDURE CROSS=REFERENCE TABLE
00064  DECODE=FORM1
00063
00064  DECODE=FORM2
```

B.35
00115 DECODE=UIC
00070 00076

00069 DECODE=FMM3
00055

00074 DECODE=FMM4
00056

00080 DECODE=FILENAME-EXTENSION
00061 00066 00071 00077

00104 DECODE=DEVICE
00065 00075

(PLECS VERSION 22.46)
SUBROUTINE GETNPC(HBASE, HSEG, BSEG, CHAIN, EXT, DEV, FILNAME, GUIC, 
    INTSEG, INITIM, LSEG, LTIM, TSEG, TIMX, UNITS, GUIC)
  
  THIS ROUTINE IS RESPONSIBLE FOR INTERROGATING THE USER TO LEARN 
  THE SPECIFICATION NEEDED FOR POST PROCESSING.

  FORMAL PARAMETERS:
  
  HBASE = 9 CHARACTER BASE FILE NAME FOR CHAINED OPERATIONS
  HSEG = BEGINNING SEGMENT NUMBER FOR CHAINED OPERATIONS
  BSEG = BEGINNING TIME PLANE NUMBER
  CHAIN = LOGICAL FLAG FOR CHAINED OPERATIONS
  EXT = BASE FILE NAME EXTENSION FOR CHAINED OPERATIONS
  DEV = BASE FILE NAME DEVICE FOR CHAINED OPERATIONS
  FILNAME = FILE SPECIFICATION FOR UNCHAINED PROCESSING
  GUIC = GROUP GUIC FOR CHAINED PROCESSING
  LSEG = SEGMENT INTERVAL FOR CHAINED PROCESSING
  LTIM = TIME PLANE INTERVAL
  INTSEG = ENDING SEGMENT NUMBER FOR CHAINED PROCESSING
  TIMX = TIME STEP SIZE

  UNITS = MEMOIRCS FOR CONCENTRATION OF CONTAMINANT ATTACHED TO 
  SEDIMENTS (PC OR KG)
  
  CALLS FOCODE
  
  DATA YES/111/

  WRITE(1,11) 
  READ(1,11) ANSWER
  
  WHEN (ANSWER.EQ.YES)
  
  * CHAIN = TRUE,
  * WRITE(1,3)
  READ(1,19) FILNAME
  CALL FOCODE(FILNAME, BSEG, JSEG, EXT, DEV, GUIC, GUIC)
  WRITE(1,4)
  READ(1,5) HSEG
  WRITE(1,4)
  READ(1,5) LSEG
  WRITE(1,4)
  READ(1,5) INTSEG
  HSEG = (LSEG - HSEG) / INTSEG + 1

  **FIN
  
  ELIF
  
  GUIC = 1
  CHAIN = FALSE.

  END
0054  * WRITE(1,9)
0055  * READ(12,CHR,FILHAM(1),I=1,NCHR)
0056  * FILM4(NCHR+1) = 0
0057  * INTSEG1
0058  ***FIN
0059  C
0060  WRITE(1,10)
0061  READ(11)REGIM
0062  WRITE(1,12)
0063  READ(11)NTRIM
0064  WRITE(1,13)
0065  READ(11)INTIM
0066  NTIM = (L$TTNI$-REGIM)/INTIM + 1
0067  C
0068  WRITE(1,17)
0069  READ(1,18)STEP
0070  WRITE(1,19)
0071  READ(1,16)UNITS
0072  C
0073  WRITE(1,18)NSEG
0074  WRITE(1,14)NTIM
0075  C
0076  RETURN
0077  C
0078  1 FORMAT(/10x,'********* SERATHA POST PROCESSING *********/)
0079  ( THIS IS TO BE A CHAINED OPERATION (Y OR N)?)
0080  2 FORMAT(Q30A1)
0081  3 FORMAT('ENTER NAME FILE NAME*)
0082  4 FORMAT('ENTER BEGINNING SEGMENT NUMBER (I4)*)
0083  5 FORMAT(')
0084  6 FORMAT('ENTER ENDING SEGMENT NUMBER (I4)*)
0085  7 FORMAT('ENTER INTERVAL BETWEEN SEGMENTS (I4)*)
0086  8 FORMAT(/10x,16,SEGMENTS (FILES) WILL BE PROCESSED*)
0087  9 FORMAT('ENTER THE NAME OF THE FILE TO BE PROCESSED (28A1)*)
0088  10 FORMAT('ENTER BEGINNING TIME PLANE NUMBER (I10)*)
0089  11 FORMAT(')
0090  12 FORMAT('ENTER ENDING TIME PLANE NUMBER (I10)*)
0091  13 FORMAT('ENTER INTERVAL BETWEEN TIME PLANES (I10)*)
0092  14 FORMAT(/10x,'TIME PLANES FOR EACH SEGMENT WILL BE PROCESSED*)
0093  15 FORMAT('ENTER THE CONCENTRATION UNITS (PC OR KG)*)
0094  16 FORMAT(')
0095  17 FORMAT('ENTER THE TIME STEP SIZE (10,0)*)
0096  18 FORMAT('V04,0)
0097  19 FORMAT('30A1)
0098  END

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B.38
SUBROUTINE HYDAT (ALEN, AREA, DELT, DEZ, DSD, ECHO, HLDERR, NSETS, NUMERR, SIMLEN, DEPMIN, DLZ8AV, EL)

C DEPMIN HAS BEEN ADDED TO THE SUBROUTINE CALL

C THIS ROUTINE IS RESPONSIBLE FOR READING AND PROCESSING THE
C HYDROLOGY DATA. THE DATA IS READ FROM THE INPUT STREAM (LUN 1)
C AND WRITTEN TO "HYDROLOGY.INP" (LUN 4) FOR USE DURING THE
C SIMULATION.

C FORMAL PARAMETERS:
C ALEN = SEGMENT LENGTH
C AREA = CROSS SECTIOAL AREA OF EACH ELEMENT
C DELT = TIME STEP IN SECONDS
C DEZ = STANDARD ELEMENT THICKNESS
C DSD = MEDIAN BED SEDIMENT DIAMETER
C ECHO = LINE PRINTER OPTION CONTROL VARIABLE (L=1)
C HLDERR = HOLDING ARRAY FOR ERROR NUMBERS (BYTE)
C NSETS = NUMBER OF TIMES INITIAL CONDITIONS MUST BE WRITTEN
C TO OUTFLO. (NSETS = DELT) = THE AMOUNT OF TIME IT
C TAKES THE FLOW TO PASS THROUGH THE SEGMENT.
C NUMERR = NUMBER OF INPUT ERRORS
C SIMLEN = SIMULATION LENGTH = SECONDS (144)

C CALLED #1 SERATHA
C CALL #1 PUTENR
C
C INCLUDE 'ELSIZ',PEN
C BYTE HLDERR(100)
C INTEGER ENTIM,PETIM,SIMLEN
C REAL INPRAC
C LOGICAL ECHO

DIMENSION ASAI(MAXELEM), AREA(MAXELEM), AXID(MAXELEM),
DIMESL(MAXELEM), XFAREA(MAXELEM), BNID(MAXELEM), BSZ(MAXELEM),
LEN(MAXELEM)

HE=IND 4
NSETS=1
PENO .0 .0
IDADE=FIX(DELT)
REPEAT UNTIL (ENTIM .EQ. -9999)

BUS 12............HYDROLOGY DATA -- THIS DATA IS WRITTEN TO LUN 4

CUMULATIVE ENTIM...........ENDING TIME FOR THE DATA ON THE CARD. (SEC)
AN ENTRY OF -9999 TERMINATES THE DATA.
TOTAL DISCHARGE OF THIS SEGMENT (MM^3/SEC)
TOTAL DISCHARGE OUT OF THIS SEGMENT (MM^3/SEC)
FLOW DEPTH (GTR E88)
WATER TEMPERATURE

B.39
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00110  * * IF (ECHO)
00111    * WRITE(*,2) ENDTIM,NELEM,TEMPR,QI,GO,DEPTH
00112    * WRITE(*,3)
00113    * UD (IM1,NELEM)
00114    * WRITE(6,4)AIPD(I),ABAR(I),AREA(I),EL(I)
00115    * FIN
00116    * FIN
00117    * FIN
00118    * FIN
00119    * IF (PRETM .LT. SIMLEN) CALL PUTERR(25, NUMERR, HDLEN)
00120    REIND 4
00121 C
00122 RETURN
00123 C
00124 1 FORMAT(1,2,OF(1,0))
00125 2 FORMAT(1H0,50X,'HYDROLOGY DATA'/
00126       9X,110,X...DATA SET ENDING TIME'/
00127 3 7X,1PE15,5,...NUMBER OF ELEMENTS WITHIN THE FLOW DEPTH'/
00128 4 7X,1PE12,5,...MATER TEMPERATURE'/
00129 5 7X,1PE12,5,...TOTAL DISCHARGE OF THIS SEGMENT'/
00130 6 7X,1PE12,5,...TOTAL DISCHARGE OUT OF THIS SEGMENT'/
00131 7 7X,1PE12,5,...FLOW DEPTH'
00132 8 7X,1PE12,5,...ELEMENT')
00133 9 7X,1PE12,5,...TOTAL DISCHARGE OUT OF THIS SEGMENT'/
00134 10 7X,1PE12,5,...FLOOD DEPTH')
00135 11 7X,1PE12,5,...TOTAL DISCHARGE OUT OF THIS SEGMENT'/
00136 12 7X,1PE12,5,...FLOOD DEPTH')
00137 C
00138 } END 

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----------------------------------------------------------
SUBROUTINE HYDRODATA, AREA, AMID, DELZ, DEPTH, DSM,
ELEV, ENDHYD, ETIME, FENOM, HRAD, NELEM,
HEWI, PELEY, QMIN, QMOUT, QV, RIVEN, SLOPE,
STRESS, TEMPP, VEL, VOL, DEPMIN,
XSHERE, SMID, AMID, DI, CROBC, SJ0, IELM)

This subroutine is called each time step to read any new hydrology data.

DATA THAT HAS BEEN written to bin A HYDRODAT file.

PARAMETERS:

ALLEN = LENGTH OF THE SEGMENT
AREA = AREA OF EACH ELEMENT
AMID = ELEMENT WIDTH
DELZ = STANDARD ELEMENT THICKNESS
DEPTH = FLOW DEPTH
DSM = MEDIAN RED SEDIMENT DIAMETER (METER)
ELEV = SEGMENT ELEVATION
ENDHYD = ENDING TIME OF THE CURRENT HYDROLOGY DATA (HOUR)
ETIME = ELAPSED TIME OF THE SIMULATION (HOUR)
ERROR = FATAL ERROR FLAG (LOGICAL)
HRAD = HYDRAULIC RADIUS
HELEM = NUMBER OF ELEMENTS
HEWII = NEW UI DATA FLAG (LOGICAL)
PELEY = ELEVATION OF THE UPSTREAM SEGMENT
QMIN = INFLOW DISCHARGE
QMOUT = OUTFLOW DISCHARGE
QV = VERTICAL FLOWS
RIVER = SHEAR STRESS COMPUTATION CONTROL VARIABLE (LOGICAL)
SLUPE = RED SLOPE
STRESS = RED SHEAR STRESS
STRESS = WATER TEMPERATURE
VEL = FLOW VELOCITY OF QMOUT
VOL = SEGMENT VOLUME

CALLED BY: BERATH
CALLED BY: SHEARR, SHEARS, MPROIL
CALLED BY: MPROIL, FEXRE

INTEGER ETIME, ENDHYD
LOGICAL NELEM, RIVEN, ERROR
DIMENSION AREA(MAXELEM), AMID(MAXELEM), QMIN(MAXELEM),
QMOUT(MAXELEM), QV(MAXELEM),
XSHERE(MAXELEM), SMID(MAXELEM), AMID(MAXELEM),
DI(MAXELEM), DUMMY(MAXELEM)

DATA DECDAY/0.00001792/
DATA HOUR/1000.0/
DATA MSEC/1.0E-05/
DATA ZERO/1.0E-05/
DATA B.42/
00051 FERNOR = .FALSE.,
00055 FERNI = .FALSE.,
00056 IF (ETME , DT, ENDTHO)
00057 • FERNI = .TRUE.,
00059 • REPEAT UNTIL (ETME , LC, ENDTHO)
00059 • • HEAT(9, END200) ENDTHO,NELEM,DELZ,W1,W2,VOL,VEL,ANID,AREA,TEMPH
00060 1 = .TRUE.,
00061 1 • FIN
00062 • IF (DEPH , GE, DEPMIN)
00063 • • MEHE (HIVER)
00064 C • • • • CALL SHEARS(ALEN,ELEY,MRAD,PELEY,SLOPE,STRESS,UBSAR)
00066 C • • • • • • FIN
00068 • • • • ELSE
00069 • • • • CALL SHEARS(DEPH,DSO,STRESS,UBSAR,VEL)
00070 • • • • • SLOPE=STRESS/(MRAD*MRAD)
00071 C • • • • FIN
00072 I • • • • CALL PROFIL(ALEN, ANID, DELZ, DEPH, NELEM, W1, UBSAR,
00073 W1, UBSAR
00074 • • • • Call PROFIL(ALEN, ANID, DELZ, DEPH, NELEM, QO, UBSAR,
00075 QO, UBSAR
00076 C • • • • *** CONVERT UNITS TO M**3/DAY ***
00077 I • • • • QO (J,1,HLEM)
00078 • • • • WHIN(J) = PWIN(J) * SECDAY
00079 • • • • WHOUT(J) = WHOUT(J) * SECDAY
00080 • • • • • FIN
00081 C • • • • *** COMPUTE VERTICAL FLOWS ***
00083 • • • • Wy(J) = 0.0
00084 • • • • DU (J,1,HLEM)
00085 • • • • WY(J) = WHIN(J) = WHOUT(J) = QV(J)
00086 • • • • • • Fin
00087 • • • • FIN
00088 • • • • FIN
00089 • • • • • • RETURN
00090 C 200 • • • • CONTINUE
00092 • • • • FERNOR = .TRUE.,
00093 • • • • • HI(J,1,1)
00094 1 • • • • FORMAT (4X,FATAL ERROR = HYDROLOGY DATA EXHAUSTED)
00095 • • • • • RETURN
00096 300 • • • • CONTINUE
00097 • • • • • • RETURN
00098 • • • • • • WRITE(6,9) (J,JW(J,1,1),J=1,NELEM)
00100 3 • • • • FORMAT (4X,FATAL ERROR = VERTICAL FLUX COMPUTATION)
00102 2 • • • • FORMAT (5X,15,1PE12.0)
00104 • • • • • • RETURN
00106 C 3 FIN

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B.43
SUBROUTINE ICFLU(CIN, DEPTH, VELZ, DFLZ, ENDIC, ETIME, FERROR, 
I, INFLU, IREG, NELEM, NINC, 
QMIN, WI, DFLIN, ALEM, 
VEL, UNID, XKNEA, AREA, AMID, DFLZ, YBET, 
ELEY, PELEY, RIVER, NENG, NEWTB, 
NM, DFLIN, CNUDE) 

C THIS ROUTINE IS CALLED EACH TIME STEP TO READ THE INITIAL 
C CONDITIONS TO THE FIRST SEGMENT OR THE INFLOWS 
C FROM THE PREVIOUS SEGMENT. 
C 
C FORMAL PARAMETERS: 
C 
C CIN = CONCENTRATION OF INFLOWS= CELL CENTERED 
C DEPTH = FLOW DEPTH OF THE CURRENT SEGMENT 
C VELZ = STANDARD ELEMENT THICKNESS OF THE CURRENT SEGMENT 
C ENDIC = ENDING TIME OF THE CURRENT INITIAL CONDITIONS DATA 
C ETIME = ELAPSED TIME OF THE SIMULATION (INH) 
C FERROR = FATAL ERROR FLAG (L=1) 
C INFLU = LOGICAL UNIT NUMBER FOR DATA FROM PREVIOUS SEGMENT 
C IREG = CURRENT SEGMENT NUMBER 
C NELEM = NUMBER OF ELEMENTS IN THE CURRENT SEGMENT 
C NINC = INITIAL CONDITIONS FLAG (L=1) 
C PUEIZ = STANDARD ELEMENT THICKNESS OF THE PREVIOUS SEGMENT 
C PUEPIZ = FLOW DEPTH OF THE PREVIOUS SEGMENT 
C QMIN = INFLOW DISCHARGE 
C QHOL = DISCHARGE INTO THE SEGMENT FROM THE PREVIOUS ONE 
C 
C CALLED BY: SEHARA 
C CALLS: DEQS, EUQPS, PROFIL, RADIUS 
C 
C INCLUDE 'ELM912.PMM' 
C 
C INTEGER ENDIC, ETIME 
C 
C DIMENSION CIN(MAXELEM, MAXCON), CNUDE(MAXELEM, MAXCON), 
C QMIN(MAXELEM), QHOLD(MAXELEM), XKNEA(MAXELEM), 
C PESR(MAXELEM), ICFL(MAXELEM), UNID(MAXELEM), UNOAVG(MAXELEM), 
C NEXR(MAXELEM), VEL(MAXELEM), PMAS(MAXCON), PMID(MAXELEM), 
C QCNUE(MAXELEM, MAXCON), 
C AREA(MAXELEM), AMID(MAXELEM), DFZ(4), YBET(3), 
C ELEY(MAXELEM), UAREA(MAXELEM) 
C 
C DATA RH0/1.091/2 / 
C DATA SECJAY/86400/ 
C 
C FERROR = .FALSE. 
C NINC = .FALSE. 
C INFLU=MAXELEM 
C 
C WHEN (186, END, 1) 

B.44
DISTRIBUTES INITIAL CONDITIONS UPSTREAM OF INITIAL SEGMENT BY
CONSERVING RELATIVE CROSS-SECTIONAL AREAS AND DISCHARGES
ASSUMES LINEAR PROFILE OF BOTH SEDIMENT AND PARTICULATE, AND
WIDTH A LINEAR FUNCTION OF DEPTH.

**INITIAL CONDITIONS **
IF (ETIME,GT, ENDC1) RETURN
IF (NEXC,ND,NEWCOORD,RENTBB)
UNTIL (ETIME .LE. ENDC1)
READ (2,ENDC2) ENDC1,ND,PDEPTH, (CNODE(I,J)) ,IM1,MAXCON,IN1,NM)

FIN
IF (PDEPTH .LE. DEPMIN) RETURN
FIN
CONTINUE/12,
DU(I1,IN)
IF (PDEPTH .LE. VEL(I)) GO TO 10
NTW=UX(I+1)
MTW=UX(I)
ETW=UX(I+1)
EMU=UX(I)
IF (PDEPTH .LE. ET)
MTW=(MT-UX0)*(PDEPTH-ER)/(ET-EB)
ET=2*PDEPTH
IF (ET .GE. RTO)
CONTINUE/19
PBAR(I)=MTW*DELTA/2.
PBAR(I)=2.*PBAR(I)
PBAR(I)=PBAR(I)*PBAR(I)
MELEM
**FIN
10 CONTINUE
DH (IM,MELEM) ASX0X*AREA(I)
RATION=ASX0X/X3
CALL EQPC(ID,PXBAR,UM10,VEL,ASX0,MELEM,MELEM,RATIO,IELP,
CALL EQPC(ID,PXBAR,UM10,VEL,ASX0,MELEM,MELEM,RATIO,IELP,
IF (ERR) RETURN
UM10(Melem-1) UM10*(UM10+UM10(I+1))/2.
UM10=UM10(I)
UDEL=UDEL(I+1)
VEL=IQ/PIX
C%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
CHANGE 3/12/81
C
DO I1 (IM,MELEM) UARIE(I)*UM10(I)*MELEM
CALL RAVLB (ALEN,UAREA,CMUSC,PDEPTH,VEL,HRA)
WHEN (K.vnEH)
CALL MFARS(ALLEN,ELEV,HRAD,PELEV,SLOPE,STRESS,USTAN)
ELSE
CALL PROFILE (ALEN,UROAVG,UDEL,PDEPTH,MELENI,USTAR,UVIL,1,UVLO,
VEL,DELTA)
00166 * * * * * PHASES
00167 IF(INDEC, GE, 0)
00168 CMASS = CMST + CMSRT
00169 IF(K, ME, 7) PHASS = PHUBT + PHSB
00170 ** FIN
00171 IF(INDEC, GE, 1)
00172 CMASS = CM95 + CMSAR
00173 IF(K, ME, 7) PHASS = PHUBT + PHSB
00174 ** FIN
00175 IF(INDEC, GE, 2)
00176 DO(J = NELMT + 1, NELMT + 1)
00177 DEL = DEL(J) = DEL(J)
00178 CT = CTNODE(J + 1, K)
00179 CT = CMODE(J, K)
00180 UPA = UPHINO(J, K)
00181 UMB = UMB(J)
00182 CHAM = CAMABB + DEL * (CT / 3 + CT * MB / 2 + CB * MB / 3) * UPA
00183 IF(K, ME, 7)
00184 DT = CTNODE(J + 1, K)
00185 CMODE(J, K)
00186 CHAM = CAMABB + DEL * (CT / 3 + CT * MB / 2 + CB * MB / 3) * UPA
00187 ** FIN
00188 CO = CM = CMAS + CMAS + CMAS
00189 CMOTES = CHAM(J)
00190 CM = CM = CMAS + CMAS + CMAS
00191 ** FIN
00192 CM = CM = CMAS + CMAS + CMAS
00193 CHAM = CHAM + CHAM
00194 CHAM = CM95 + CM95
00195 CM = CM = CMAS + CMAS + CMAS
00196 CM = CM = CMAS + CMAS + CMAS
00197 NELMT = NELMT
00198 IF(K, ME, 7)
00199 PHASS = PHUBT + PHSB
00200 PHASS = PHUBT + PHSB
00201 PHASS = PHASS + PHASS
00202 PHASS = PHASS + PHASS
00203 ** FIN
00204 C
00205 C
00206 C
00207 C
00208 C
00209 C
00210 C
00211 ** FIN
00212 ** FIN
00213 C DISTRIBUTES INITIAL CONDITIONS UPSTREAM OF SUBSEQUENT SEGMENTS BY
00214 C CONSERVING MASS FLOW AS ASSUMES LINEAR UPSTREAM DISTRIBUTIONS AND
00215 C CONSTANT WIDTHS.
00216 ELSE
00217 ELSE
00218 ** FIN
00219 ** FIN
00220 ** FIN
00221 ** FIN

B.47
00222  *  X*0.
00223  *  P*0.
0024  *  DO (i1,NELEM) X*00*XBARA(i1)
00225  *  DO (i1,NELEM) PX*PX*i1*XBAR(i1)
00226  *  RATIO*PX/KX
00227  *  CALL EUUPX(i1*PSAIR,PHID,DELZ,KSAREA,NELEM,NELEM,RATIO,IELP,
00228  *  I,MEGAS)
00229  *  ALLOCATE MAN BY CONSERVING RELATIVE CROSS-SECTIONAL AREAS
00230  *  DO (K*MAXCUN)
00231  *  IF(K,LE,3,DR,KE,7)
00232  *  IF(K,LE,3,DR,KE,7)
00233  *  UP*UP*UP(1)
00234  *  CTM(CHODE(2,K)) + OCHODE(2,K))/2,
00235  *  CMABR(CTCB)/2,UPBDU
00236  *  CMABR0.
00237  *  IF(K,NE,7)
00238  *  IF(K,NE,7)
00239  *  N(EMLTP=0)
00240  *  N(EMLTP=0)
00241  *  N(EMLTP+1)
00242  *  N(EMLTP+1)
00243  *  EMT(EMK)+DELZ
00244  *  EMT(EMK)+DELZ
00245  *  EMT(EMK)+DELZ
00246  *  EMT(EMK)+DELZ
00247  *  EMT(EMK)+DELZ
00248  *  EMT(EMK)+DELZ
00249  *  EMT(EMK)+DELZ
00250  *  EMT(EMK)+DELZ
00251  *  EMT(EMK)+DELZ
00252  *  EMT(EMK)+DELZ
00253  *  EMT(EMK)+DELZ
00254  *  EMT(EMK)+DELZ
00255  *  EMT(EMK)+DELZ
00256  *  EMT(EMK)+DELZ
00257  *  FACL*(HEL=EM)/DELZ
00258  *  FACL*(HEL=EM)/DELZ
00259  *  FACL*(HEL=EM)/DELZ
00260  *  FACL*(HEL=EM)/DELZ
00261  *  FACL*(HEL=EM)/DELZ
00262  *  FACL*(HEL=EM)/DELZ
00263  *  GTM(CHODE(NK,K)+ OCHODE(NK,K))/2,
00264  *  GTM(CHODE(NK,K)+ OCHODE(NK,K))/2,
00265  *  GTM(CHODE(NK,K)+ OCHODE(NK,K))/2,
00266  *  GTM(CHODE(NK,K)+ OCHODE(NK,K))/2,
00267  *  GTM(CHODE(NK,K)+ OCHODE(NK,K))/2,
00268  *  GTM(CHODE(NK,K)+ OCHODE(NK,K))/2,
00269  *  GTM(CHODE(NK,K)+ OCHODE(NK,K))/2,
00270  *  GTM(CHODE(NK,K)+ OCHODE(NK,K))/2,
00271  *  GTM(CHODE(NK,K)+ OCHODE(NK,K))/2,
00272  *  GTM(CHODE(NK,K)+ OCHODE(NK,K))/2,
00273  *  GTM(CHODE(NK,K)+ OCHODE(NK,K))/2,
00274  *  GTM(CHODE(NK,K)+ OCHODE(NK,K))/2,
00275  *  GTM(CHODE(NK,K)+ OCHODE(NK,K))/2,
00276  *  GTM(CHODE(NK,K)+ OCHODE(NK,K))/2,
00278 IF(K,NE.,7) PMASS=PMASS+PMAS8
00279 **FIN
00280 00281 IF(IHUIC,GE.,2)
00282 00283 DDR(IHNELEN,1,HELMP,1)
00284 **FIN
00285 CTR(DIODE(J,K)+OCNODE(J+K)/2,
00286 CB=OCNODE(J,K)+OCNODE(J+K)/2,
00287 **FIN
00288 **FIN
00289 IF(K,NE.,7)
00290 **FIN
00291 **FIN
00292 **FIN
00293 **FIN
00294 **FIN
00295 **FIN
00296 **FIN
00297 **FIN
00298 IF(K,NE.,7)
00299 **FIN
00300 **FIN
00301 **FIN
00302 **FIN
00303 **FIN
00304 **FIN
00305 **FIN
00306 **FIN
00307 **FIN
00308 **FIN
00309 **FIN
00310 **FIN
00311 **FIN
00312 **FIN
00313 **FIN
00314 **FIN
00315 **FIN
00316 **FIN
00317 **FIN
00318 **FIN
00319 **FIN
00320 **FIN
00321 **FIN

00322 TO COMPUTE=PROFILE=VALUES
00323 WHEN(1,EQL.,1)
00324 **FIN
00325 **FIN
00326 **FIN
00327 **FIN
00328 **FIN
00329 **FIN
00330 **FIN

8.49
00331 M$B$V$S$E$T(K)*$A$P$E$A$(1)/(A$N$D$(1)=A$L$E$(N)  
00332 E$W$D$F$Z$(K)  
00333 CC$I$N$(1,K)=E(2,*C$M$A$S$S=CO$E$F=DE$LZ/EZ)/(Z,*M$B=DE$LZ/EZ)  
00334 CC$I$N$(2,K)=E(2,*C$M$A$S$S=CC$I$N$(1,K)  
00335 CC$I$N$(1,KK)=E(2,*P$M$A$S$S=CC$I$N$(1,K)/(Z,*M$B=DE$LZ/EZ)  
00336 CC$I$N$(2,KK)=E(2,*P$M$A$S$S=CC$I$N$(1,KK)  
00337 ***FIN
00338 ***FIN
00339 ELSE
00340 CC$I$N$(I+1,K)=E(2,*C$M$A$S$S=CC$I$N$(I,K)  
00341 IF (K,N=7)  
00342 CC$I$N$(I+1,K+3)=E(2,*P$M$A$S$S=CC$I$N$(1,K+3)  
00343 ***FIN
00344 ***FIN
00345 ***FIN
00346 END

-------------------------  
PROCEDURE CROSS-REFERENCE TABLE  
-------------------------  
00322 $C$O$M$P$U$L$E= $P$RO$F$I$L$E= $V$A$L$U$E$S
00207 00304

(FLECS VERSION 22.46)
SUBROUTINE INITDATA(ANALH, ANALS, DELTA, ECHO, HLDERR, IPRT,  
1, NSEG, NSTEPS, NUMERR, SIMLEN, DEPHIN)

THIS ROUTINE READS THE INITIAL DATA COMMON TO ALL SEGMENTS AND IS
ONLY CALLED FOR SEGMENT NUMBER 1.

FORMAL PARAMETERS:

ANALH = ANALYSIS CONCENTRATION LIMIT
ANALS = TIME SERIES ANALYSIS CONTROL VARIABLE (L#1)
DELTA = TIME STEP LENGTH (SECONDS)
ECHO = LINE PRINTER ECHO CONTROL VARIABLE (L#1)
HLDERR = HOLDING ARRAY FOR ERROR NUMBERS (BYTE)
IPRT = PRINT FREQUENCY
NSEG = NUMBER OF SEGMENTS
NSTEPS = NUMBER OF TIME STEPS TO BE TAKEN (L#4)
NUMERR = NUMBER OF INPUT ERRORS DETECTED
SIMLEN = SIMULATION LENGTH (SECONDS = L#4)
DEPHIN = MINIMUM (CUTOFF) FLOW DEPTH (METERS)

CALLED BY IEEE BERTHA
CALLED PUTEHR

BYTE HLDENK(100)
INTEGER SIMLEN, NSTEPS
LOGICAL NERRS, ECHO, ANALYS
DIMENSION TITLE(40)
DATA MAXSEG /35/

IF (ECHO)
** PRINT HEADING **
WRITE(6,1)
WRITE(6,2)
**FIN

CARDS 1 AND 2: SIMULATION IDENTIFICATION TITLE

READ(1) TITLE(1), TITLE(2)
IF (ECHO) WRITE(6,4) (TITLE(I), I=1,40)

CARDS 3: GENERAL INFORMATION COMMON TO ALL SEGMENTS

31.41.4...NUMSTEPS...NUMBER OF TIME STEPS TO BE TAKEN
61.15.4...NSEG...NUMBER OF SEGMENTS
61.20.4...IPRT...PRINT FREQUENCY
21.41.4...ANALH...TIME SERIES ANALYSIS CONTROL VARIABLE
26.35.4...DEPHIN...TIME STEP LENGTH (SECONDS)
30.45...ANALS...LOWER LIMIT OF AVERAGE DISSOLVED
35.4...CONCENTRATION, BEFORE THE RESULTS OF A
TIME STEP ARE SAVED, THE AVERAGE
DISSOLVED CONC. MUST BE > ANALMT,

40-95...DEPN...MINIMUM (CUTOFF) FLOW DEPTH BELOW WHICH

THE CHANNEL IS CONSIDERED DRIED.

READ(1,5) NSTEPS,NSEG,ITPRAT,ANALMT,DEPTH,ANALMT,DEPN

*** COMPUTE SIMULATION LENGTH (BECAUSE) ***

BIMLEN = DEPTH
BIMLEN = BIMLEN = NSTEPS
IF (ECHO)
WRITE(6,6) NSTEPS,NSEG,ITPRAT,ANALMT,DEPTH,ANALMT,BIMLEN,DEPN

***FIN

IF (NSTEPS .LE. 0) CALL PUTERR(1,NUMERR,HLDERR)
IF (NSEG.LE.0 OR. NSEG.GT.NAYSEG) CALL PUTERR(2,NUMERR,HLDERR)
IF (ITPRAT .LE. 0) CALL PUTERR(3,NUMERR,HLDERR)
IF (DEPTH .LE. 0,0) CALL PUTERR(5,NUMERR,HLDERR)

RETURN

1 FORMAT(1HO,3X,'SEMENT AND CONTAMINANT TRANSPORT SIMULATION',
2 PROGRAM = SIMTRA1)
3 FORMAT(1HO,5X,'PHENOL SPECIFICATIONS')
5 FORMAT(1HO,25X,20A1,25X,20A1)
6 FORMAT(1HO,8X,110,1,,'NUMBER OF TIME STEPS TO BE TAKEN /
7 1X,15,'NUMBER OF SEGMENTS/
8 1X,15,'FREQUENCY (# OF TIME STEPS)/
9 1X,15,'TIME SERIES ANALYSIS CONTROL/
10 1X,15,'TIME STEP LENGTH (SECONDS)/
11 1X,15,'TIME SERIES CONCENTRATION LIMIT/
12 1X,15,'COMPUTED SIMULATION LENGTH (SECONDS)/
13 1X,15,'MINIMUM (CUTOFF) FLOW DEPTH (METERS)/

END

(FLECS VERSION 22.46)

-------------------------------
SUBROUTINE LISTER(BASE, BSEG, BSEGINT, CHAIN, DEV, EXT, FILNAM, QUIC, I, 
  ISEG, IINT, LISTSEG, LISTINT, TSFEP, UNITS, UUIC)

C THIS ROUTINE HAS THE RESPONSIBILITY OF LOCATING AND PRINTING THE 
C SPECIFIED MATERIES FROM THE SPECIFIED FILES.

C
C FORMAL PARAMETERS:
C
BSEG = 5 CHARACTER BASE FILE NAME FOR CHAINED OPERATIONS
BSEGINT = BEGINNING SEGMENT NUMBER FOR CHAINED OPERATIONS
SEGINT = BEGINNING SEGMENT INTERVAL FOR CHAINED OPERATIONS
CHAIN = LOGICAL FLAG FOR CHAINED OPERATIONS
DESEG = BASE FILE NAME DEVICE FOR CHAINED OPERATIONS
EXT = BASE FILE NAME EXTENSION FOR CHAINED OPERATIONS
FILNAM = FILE SPECIFICATION FOR UNCHAINED PROCESSING
QUIC = GROUP UIC FOR CHAINED PROCESSING
IINT = SEGMENT INTERVAL FOR CHAINED PROCESSING
INTSEG = TIME PLANE INTERVAL
LISTSEG = LAST SEGMENT NUMBER FOR CHAINED OPERATIONS
JSEGINT = LAST SEGMENT INTERVAL FOR CHAINED OPERATIONS
LISTINT = LAST TIME PLANE NUMBER
TSFEP = TIME STEP SIZE
UNITS = MNEMONICS FOR CONCENTRATION OF CONTAMINANT ATTACHED TO 
SEDIMENTS (PC OR KG)
UUIC = USER UIC FOR CHAINED PROCESSING

CALLED BY: SPH

SUBROUTINE L15TER(BASE, BSEG, BSEGINT, CHAIN, DEV, EXT, FILNAM, QUIC, I, 
  ISEG, IINT, LISTSEG, LISTINT, TSFEP, UNITS, UUIC)

DO 1 SEGINT, LISTSEG, JSEGINT
  1 CALL FCODE(FILNAM, BASE, DEV, EXT, QUIC, UUIC)
  READ(2) UNIT
  IF (CHAIN) CALL FCODE(FILNAM, BASE, DEV, EXT, QUIC, UUIC)
  OPEN(UNIT=2,NAME=FILNAM,TYPE='OLD',REUSE='OLD',FORM='UNFORMATTED')
  WRITE(1,9) FILNAM

B.53
00054          * FIN
00055          * DU (ITIM,NESTIM,INITIM,INITIM)
00056          * IF(INITIM,NE,1,IN,INIT,NE,RESTIM)
00057          * NM = INITIM + 1
00058          * SKIP=NAMEMATRICES
00059          * FIN
00060          * READ(2) NSTEP,HELM,HBED,ELEV,DEL2,STRESS
00061          * READ(2) (HELEV(J),C(J,K),K=1,7),CMOB(J),CVOL(J),CTOT(J)
00062          * J=1,HELM
00063          * READ(2) (C(J,K),K=1,3),J=1,HELM
00064          * READ(2) (HEL(J),B(J,K),K=1,6),BA(G(J),J=1,HELM)
00065          * NELM=NELEM+1
00066          * VOLT=V1,HELM) J=1,HELM
00067          * READ(3) VOLUME
00068          * READ(2) ((DEL(J,K),K=1,MAXCON), J=1,HELM)
00069          * READ(2) (C(J,K),K=1,MAXCON), J=1,HELM
00070          * READ(2) ((UCMIN(J,K),K=1,MAXCON), J=1,HELM)
00071          * READ(2) ((UCMAX(J,K),K=1,MAXCON), J=1,HELM)
00072          * READ(2) ((UCMIN(J,K),K=1,MAXCON), J=1,HELM)
00073          * READ(2) (TAL(J),J=1,MAXCON)
00074          * READ(2) (NELEM(J),J=1,MAXCON)
00075          * READ(2) ((RELAV(J,K),K=1,MAXCON), J=1,HELM)
00076          * READ(2) (TBED(J),J=1,MAXCON)
00077          * READ(2) (TOTSTF(J),J=1,MAXCON)
00078          * ELAPSE = TSTEP+STEP
00079          * WRITE(3,11)
00080          * WRITE(3,2) NUMSEG,STEP,ELAPSE,HEL ER,BED,DEL,STRESS
00081          * WRITE(3,3)
00082          * WRITE(3,4) (UNITS,J=1,6)
00083          * WRITE(3,4) DU,J=1,HELM
00084          * WRITE(3,5) (Hel(J),C(J,K),K=1,6),BAvg(J)
00085          * WRITE(3,6)
00086          * WRITE(3,7) (UNITS,J=1,6)
00087          * WRITE(3,8) HEL(J),B(J,K),K=1,6),BAvg(J)
00088          * WRITE(3,9)
00089          * WRITE(3,10) (UNITS,J=1,6)
00090          * WRITE(3,11)
00091          * WRITE(3,12)
00092          * WRITE(3,13) (UNITS,J=1,4)
00093          * WRITE(3,14) ((HEL(J),B(J,K),K=1,3),CVOL(J),J=1,HELM)
00094          * WRITE(3,15)
00095          * WRITE(3,16) (UNITS,J=1,4)
00096          * WRITE(3,17) (J=1,(C(J,K),K=1,MAXCON), J=1,HELM)
00097          * WRITE(3,18)
00098          * WRITE(3,19) (UNITS,J=1,4)
00099          * WRITE(3,20) (J=1,(UCMIN(J,K),K=1,MAXCON), J=1,HELM)
00100          * WRITE(3,21)
00101          * WRITE(3,22) (J=1,(UCMAX(J,K),K=1,MAXCON), J=1,HELM)
00102          * WRITE(3,23)
00103          * WRITE(3,24)
00104          * WRITE(3,25) (UNITS,J=1,4)
00105          * WRITE(3,26) (J=1,(RELAV(J,K),K=1,MAXCON), J=1,HELM)
00110 C     WRITE(3,17) (J, (WVJF(J,K), K=1,MAXCON)) , J=1,MELNO)
00111     WRITE(3,21)
00112     WRITE(3,22) (UNIT2, J=1,3)
00113     WRITE(3,23) (J, (BELAY(J,K), K=1,MAXCON=1)) , J=1,MAXED)
00114     WRITE(3,25)
00115     WRITE(J,20) (UNIT2, J=1,5)
00116     WRITE(3,27) (HAL(J), J=1,MAXCON) , TOTAL
00117     WRITE(3,27) (DIF(J), J=1,MAXCON) , TOTAL
00118     WRITE(3,29) (DECE(J), J=1,MAXCON)
00119     WRITE(3,29) (DUPCE(J), J=1,MAXCON)
00120     ***FIN
00121     CLOSE (UNIT2)
00122     ***FIN
00123     CLOSE (UNIT3)
00124     RETURN
00125 C
00126 1 FORMAT(IHI)
00127 2 FORMAT(/10X, 'RIVER SEGMENT NUMBERS')
00128     10X, 'TIME STEP NUMBER' , '0X, 8I6/
00129     20X, 'ELEVATED TIME' , '0X, F11.2/
00130     30X, 'DAYS' , '0X, F10.4/
00131     40X, 'NUMBER OF ELEMENTS' , '0X, 8I6/
00132     50X, 'STANDARD ELEMENT THICKNESS' , '0X, F14.7/
00133     60X, 'NUMBER OF BED LAYERS' , '0X, 8I6/
00134     70X, 'STANDARD BED LAYER THICKNESS' , '0X, F14.7/
00135     80X, 'TOP LAYER THICKNESS' , '0X, F14.7/
00136     90X, 'SHALLOW STRESS VALUES' , '0X, F14.7/
00137     100X, 'MATERIAL CONCENTRATIONS' /
00138     4 FORMAT(/10X, 'SUSPENDED' , '1X, 'DISSOLVED' , '1X, '3 ( ' CONTAM' /
00139     1 INHANT ,5X, 'TOTAL' , '6X, ' TOTAL' /
00140     2 2X, 'ELEVATION' , '4X, 'BAND' , '6X /
00141     3 'SILT' , 'EX' , 'CLAY' , '5X, 'CONTAMINANT WITH BAND WITH SILT' /
00142     4 3X, 'WITH PARTICULATE' , '4X, 'CONC' /
00144     6 5X, 'AZ' , '1X, 'M WM3' , '5X, 'AZ' , '1X, 'M WM3' /
00145     5 FORMAT(/10X, 'PIctURE')
00146     6 FORMAT(/10X, 'RIVER SEGMENT NUMBERS')
00147     7 FORMAT(/10X, 'BAND HEIGHT' , '5X, 'SILT HEIGHT' , '5X, 'CLAY HEIGHT' /
00148     1 J5X, 'CONTAMINANT' , '7X, 'AVERAGE' , '2X, 'ELEVATION' , '6X /
00149     2 3X, 'FRACTION' , 'HX' , 'WITH BAND' , '7X, 'WITH SILT' , '7X, 'WITH CLAY' /
00150     3 9X, 'CONC' /
00152     8 FORMAT(/10X, 'PIctURE')
00153     9 FORMAT(/10X, 'BAND HEIGHT' , '5X, 'SILT HEIGHT' , '5X, 'CLAY HEIGHT' /
00154     10 FORMAT(/10X, 'FALL VELOCITY SCHEME')
00155     11 FORMAT(8X, 'PERTURBATION SOLUTION FALL ROUTINE')
00156     12 FORMAT(/10X, 'CONTAMINANT ASSOCIATED WITH SEDIMENT')
00157     13 FORMAT(/10X, 'MIX CONTAMINANT' , '1X, 'AVERAGE' , '2X, 'ELEVATION' /
00158     13X, 'WITH SAND' , '5X, 'WITH SILT' , '5X, 'WITH CLAY' , '2X, 'CONC' /
00160     14 FORMAT(3X, 'PIctURE')
00161     15 FORMAT(/10X, 'INTEGRATED VALUES OF TOTAL MASS OR CONTAMINANT IN EA
00162     14 CH ELEMENT')
00163     16 FORMAT(/10X, 'SUSPENDED' , '1X, 'DISSOLVED' /
00164     12X, 'ELEVATION' , '1X, 'SILT' , 'EX' , 'CLAY' , '7X, 'WITH SAND' , '5X /
00165     21X, 'WITH SILT' , 'WITH CLAY' , '3X, 'CONTAMINANT' , '3X, 'KG/MM3' , '1X, 'KG/MM3',
PROCEDURE CROSSEXREFERENCE TABLE

00192 8XIP=CM1=MATRICES
00193 00=58

(FLECS VERSION 22.4b)
This subroutine calculates coefficients of convective, decay and source terms for transport of pollutant attached to sediments.

### INPUT PARAMETERS

- **ABAR**: Average Element Area
- **B**: Bed Conditions
- **C**: Mauer Conditions
- **CCIN**: Concentration of Inflow
- **COLD**: Cell-Centered Concentration
- **DECAY**: First Order Decay
- **DELTU**: Time Step (Days)
- **DFZ**: Diffusion Coefficient
- **DELZ**: Element Thickness
- **I**: Element Index
- **J**: Parameter Index
- **NBED**: Number of Bed Layers
- **NELEM**: Number of Elements
- **QMIN**: Inflow Discharge
- **QV**: Vertical Discharge
- **SURBK**: Absorption on Sediment, (1=3) m**3/kg, (2=9) 1/day
- **ODRR**: Desorption from Sediment, (1=3) m**3/kg, (2=9) 1/day
- **SR**: Erosion Rate, kg/(pc)/m**3/day
- **SV**: Deposition Rate, kg/(pc)/m**3/day

### OUTPUT PARAMETERS

- **ALFA**: Decay Term, 1/day
- **HETA**: Source or Sink Term, kg/(pc)/m**3/day
- **BETA1**: Influent Source Term for I-th Node, kg/(pc)/m**3/day
- **BETA2**: Influent Source Term for I+1 th Node, kg/(pc)/m**3/day
- **VEL1**: First Convective Term, m/day
- **VEL2**: Second Convective Term, m/day

### CALLED BY TRANS.

### INCLUDE "ELMBIZ.PRH"
**WARNING**: CCIN IS WRITTEN INTO CBAR AS A FIRST APPROXIMATION TO THE EVENTUAL AVERAGE CONCENTRATION. THE ONLY MEANING BY WHICH ASSUMPTION IS TO IERATE TO THE CORRECT SOLUTION, AND USE NEW ITERATES TO BETTER APPROXIMATE CBAR.

### Absorption / Desorption

```plaintext
0045  C *** ABSORPTION / DESORPTION ***
0046  
0047  C     VU (IE = 1,NELEM)
0048  
0049  C   * INFRA = 0.5*CCIM[IE]*DELZ/ABAR[IE]/DELZ
0050  C   * EXFRAC = 1.0 = INFRA
0051  C   * DO IIC = 1,MAXCUM
0052  C   * CHAR[IE,IC] = CCIM[IE,IC]*INFRA+ULOC[IE,IC]*EXFRAC
0053  C   * FIN
0054  C   * FIN
0055  C  
0056  C IF(CHAM(I,J,M3) GT 0.0, AND, CHAM(I+1,J,M3) GT 0.0)
0057  C A051 = SUMB(J)*DUMH(J,M3)/12.*3.*CBAR(I,J,M3)*CBAR(I,J)
0058  C CHAM(I+1,J,M3)*CBAR(I+1,J,M3)*CBAR(I,J)
0059  C + CHAM(I,J+1,M3)*CBAR(I,J+1,M3)*CBAR(I,J) +
0060  C A051 = SUMB(J)*DUMH(J,M3)/12.*3.*CBAR(I,J,M3)*CBAR(I,J)
0061  C CHAM(I+1,J,M3)*CBAR(I+1,J,M3)*CBAR(I,J)
0062  C + CHAM(I,J+1,M3)*CBAR(I,J+1,M3)*CBAR(I,J) +
0063  C A051 = SUMB(J)*DUMH(J,M3)/12.*3.*CBAR(I,J,M3)*CBAR(I,J)
0064  C CHAM(I+1,J,M3)*CBAR(I+1,J,M3)*CBAR(I,J)
0065  C + CHAM(I,J+1,M3)*CBAR(I,J+1,M3)*CBAR(I,J) +
0066  C A051 = SUMB(J)*DUMH(J,M3)/12.*3.*CBAR(I,J,M3)*CBAR(I,J)
0067  C CHAM(I+1,J,M3)*CBAR(I+1,J,M3)*CBAR(I,J)
0068  C + CHAM(I,J+1,M3)*CBAR(I,J+1,M3)*CBAR(I,J) +
0069  C A051 = SUMB(J)*DUMH(J,M3)/12.*3.*CBAR(I,J,M3)*CBAR(I,J)
0070  C CHAM(I+1,J,M3)*CBAR(I+1,J,M3)*CBAR(I,J)
0071  C + CHAM(I,J+1,M3)*CBAR(I,J+1,M3)*CBAR(I,J) +
0072  C A051 = SUMB(J)*DUMH(J,M3)/12.*3.*CBAR(I,J,M3)*CBAR(I,J)
0073  C CHAM(I+1,J,M3)*CBAR(I+1,J,M3)*CBAR(I,J)
0074  C + CHAM(I,J+1,M3)*CBAR(I,J+1,M3)*CBAR(I,J) +
0075  C A051 = SUMB(J)*DUMH(J,M3)/12.*3.*CBAR(I,J,M3)*CBAR(I,J)
0076  C CHAM(I+1,J,M3)*CBAR(I+1,J,M3)*CBAR(I,J)
0077  C + CHAM(I,J+1,M3)*CBAR(I,J+1,M3)*CBAR(I,J) +
0078  C A051 = SUMB(J)*DUMH(J,M3)/12.*3.*CBAR(I,J,M3)*CBAR(I,J)
0079  C CHAM(I+1,J,M3)*CBAR(I+1,J,M3)*CBAR(I,J)
0080  C + CHAM(I,J+1,M3)*CBAR(I,J+1,M3)*CBAR(I,J) +
0081  C A051 = SUMB(J)*DUMH(J,M3)/12.*3.*CBAR(I,J,M3)*CBAR(I,J)
0082  C CHAM(I+1,J,M3)*CBAR(I+1,J,M3)*CBAR(I,J)
0083  C + CHAM(I,J+1,M3)*CBAR(I,J+1,M3)*CBAR(I,J) +
0084  C A051 = SUMB(J)*DUMH(J,M3)/12.*3.*CBAR(I,J,M3)*CBAR(I,J)
0085  C CHAM(I+1,J,M3)*CBAR(I+1,J,M3)*CBAR(I,J)
0086  C + CHAM(I,J+1,M3)*CBAR(I,J+1,M3)*CBAR(I,J) +
0087  C A051 = SUMB(J)*DUMH(J,M3)/12.*3.*CBAR(I,J,M3)*CBAR(I,J)
0088  C CHAM(I+1,J,M3)*CBAR(I+1,J,M3)*CBAR(I,J)
0089  C + CHAM(I,J+1,M3)*CBAR(I,J+1,M3)*CBAR(I,J) +
0090  C A051 = SUMB(J)*DUMH(J,M3)/12.*3.*CBAR(I,J,M3)*CBAR(I,J)
0091  C CHAM(I+1,J,M3)*CBAR(I+1,J,M3)*CBAR(I,J)
0092  C + CHAM(I,J+1,M3)*CBAR(I,J+1,M3)*CBAR(I,J) +
0093  C A051 = SUMB(J)*DUMH(J,M3)/12.*3.*CBAR(I,J,M3)*CBAR(I,J)
0094  C CHAM(I+1,J,M3)*CBAR(I+1,J,M3)*CBAR(I,J)
0095  C + CHAM(I,J+1,M3)*CBAR(I,J+1,M3)*CBAR(I,J) +
0096  C A051 = SUMB(J)*DUMH(J,M3)/12.*3.*CBAR(I,J,M3)*CBAR(I,J)
0097  C CHAM(I+1,J,M3)*CBAR(I+1,J,M3)*CBAR(I,J)
0098  C + CHAM(I,J+1,M3)*CBAR(I,J+1,M3)*CBAR(I,J) +
0099  C A051 = SUMB(J)*DUMH(J,M3)/12.*3.*CBAR(I,J,M3)*CBAR(I,J)
0100  C CHAM(I+1,J,M3)*CBAR(I+1,J,M3)*CBAR(I,J)
0101  C + CHAM(I,J+1,M3)*CBAR(I,J+1,M3)*CBAR(I,J) +
0102  C A051 = SUMB(J)*DUMH(J,M3)/12.*3.*CBAR(I,J,M3)*CBAR(I,J)
0103  C CHAM(I+1,J,M3)*CBAR(I+1,J,M3)*CBAR(I,J)
0104  C + CHAM(I,J+1,M3)*CBAR(I,J+1,M3)*CBAR(I,J) +
0105  C A051 = SUMB(J)*DUMH(J,M3)/12.*3.*CBAR(I,J,M3)*CBAR(I,J)
0106  C CHAM(I+1,J,M3)*CBAR(I+1,J,M3)*CBAR(I,J)
0107  C + CHAM(I,J+1,M3)*CBAR(I,J+1,M3)*CBAR(I,J) +
0108  C A051 = SUMB(J)*DUMH(J,M3)/12.*3.*CBAR(I,J,M3)*CBAR(I,J)
0109  C CHAM(I+1,J,M3)*CBAR(I+1,J,M3)*CBAR(I,J)
```

B.58
00110       IF (ADUS1 GT 0.0 OR ADUS1 EQ 0.0) BETAI + BETAI + ADUS1
00111       IF (DSAD1 LT 0.0) BETAI + BETAI + DSAD1
00112       IF (ADUS2 GT 0.0 OR ADUS2 EQ 0.0) BETAZ + BETAZ + ADUS2
00113       IF (DSAD2 LT 0.0) BETAZ + BETAZ + DSAD2
00114       *** FIN
00115       C
00116       C       *** SCOUR ON DEPOSITION ***
00117       C
00118       BETA = 3R(J) - BU(I,J)
00119       RETURN
00120       END

(FLECS VERSION 22.46)
SUBROUTINE PHOINP(ECHO, JULIAN, KAY1, KAY2, PCOEF)

C THIS SUBROUTINE IS RESPONSIBLE FOR READING THE PHOTOXYLIS INPUT
C DATA AND COMPUTING THE FIRST TERM OF THE RATE OF CHANGE EQUATION.
C
C DIMENSION E(18), 81(18, 3), ML(18), PCOEF(4)
C
C DATA ML / 300.00, 301.75, 303.75, 305.75, 307.75, 309.75, 323.10,
C 324.75, 326.00, 327.50, 329.00, 330.50, 332.00, 346.00, 370.00, 400.00, 410.00,
C 420.00, 440.00, 460.00, 490.00, 536.00, 556.50, 587.50, 617.50, 647.50, 756.00, 880.00/
C
C DATA SECST/Y6500/
C
C READ(1, 1) JULIAN, PHI, KAY1, KAY2
C WHEN (JULIAN, ECHO, 0)
C
C IF (ECHO) WRITE(0, 2)
C
C FIN
C
C
C
**SECOND DATA SET - ADSORPTION COEFFICIENTS TABLE**

This is the table of adsorption coefficients for 18 different wavelengths that are a measure of the chemical's ability to absorb light at the different wavelengths. Wavelength units are nanometers.

**RECORD 1**
- **COIL:** 1-10 E(1) COEFF, FOR WAVELENGTH OF 391.00
- **COIL:** 1-20 E(2) COEFF, FOR WAVELENGTH OF 503.75
- **COIL:** 21-30 E(3) COEFF, FOR WAVELENGTH OF 300.75
- **COIL:** 31-40 E(4) COEFF, FOR WAVELENGTH OF 313.75
- **COIL:** 41-50 E(5) COEFF, FOR WAVELENGTH OF 318.75
- **COIL:** 51-60 E(6) COEFF, FOR WAVELENGTH OF 323.10
- **COIL:** 61-70 E(7) COEFF, FOR WAVELENGTH OF 346.00
- **COIL:** 71-80 E(8) COEFF, FOR WAVELENGTH OF 370.00

**RECORD 2**
- **COIL:** 1-10 E(1) COEFF, FOR WAVELENGTH OF 400.00
- **COIL:** 11-20 E(10) COEFF, FOR WAVELENGTH OF 416.00
- **COIL:** 21-30 E(11) COEFF, FOR WAVELENGTH OF 446.00
- **COIL:** 31-40 E(12) COEFF, FOR WAVELENGTH OF 490.10
- **COIL:** 41-50 E(13) COEFF, FOR WAVELENGTH OF 536.25
- **COIL:** 51-60 E(14) COEFF, FOR WAVELENGTH OF 587.50
- **COIL:** 61-70 E(15) COEFF, FOR WAVELENGTH OF 637.30
- **COIL:** 71-80 E(16) COEFF, FOR WAVELENGTH OF 687.30

**RECORD 3**
- **COIL:** 1-10 E(17) COEFF, FOR WAVELENGTH OF 756.00
- **COIL:** 11-20 E(18) COEFF, FOR WAVELENGTH OF 800.00

**THIRD DATA SET - SOLAR INTENSITY TABLE**

This table consists of four sets of 18 values, the four sets correspond to spring, summer, fall, and winter, respectively. The 18 values correspond to the 18 wavelengths as described above in the adsorption coefficient table. The inclusive dates for each season are given below:

**CALENDAR DATES JULIAN DATES**

**SPRING**
- March 1 - May 31
  
  **SUMMER**
  - June 1 - Aug. 31
  
  **FALL**
  - Sep. 1 - Nov. 30

**WINTER**
- Dec. 1 - Feb. 28

**JULIAN**
- 355-365; 159

**HEADING**
- ((B1,L1); L18); L11; 1

**IF (ECHO)**

**WRITE (6,3)**

**WRITE (6,7)**

**WRITE (6,9).**

**DO (L1,L14)**

**WRITE (6,6)**

**FPE**

**END**
C. SPRING JULIAN DAY 1 ***
00111  WHEN (JULIAN < 60) JULIAN = JULIAN + 59
00112  ELSE JULIAN = JULIAN + 306

00113 C  *** COMPUTE THE FIRST TERM OF THE RATE OF CHANGE EQUATION ***
00114 C  FOR EACH OF THE FOUR SEASONS ***
00115 C  00 (1X!, 0)
00116 C  00 PCOEF(I) = 0.0
00117 C  00 (0 < LM < 19) PCOEF(I) = PCOEF(I) + E(L) = 31(L, 1)
00118 C  00 PCOEF(I) = PHI * PCOEF(I) = (2.103/6.02E20) * SEC/AY
00119 C  00 FIN
00120 C  00 FIN
00121 C  00 RETURN

00122 C  FORMAT(15,3F10.0)
00123 1 FORMAT(150,13X,'NO PHOTOLYSIS DEGRADATION WILL BE COMPUTED')
00124 2 FORMAT(150,13X,'NO PHOTOLYSIS TABLES AND COEFFICIENTS')
00125 3 FORMAT(150,13X,PHOTOLYSIS TABLES AND COEFFICIENTS')
00126 4 FORMAT(150,13X,'PHOTOLYSIS TABLES/30X,'ABSORPTION','
00127 5 FORMAT(150,13X,'PHOTOLYSIS TABLES/30X,'ABSORPTION','
00128 6 FORMAT(150,13X,'PHOTOLYSIS TABLES/30X,'ABSORPTION','
00129 7 FORMAT(150,13X,'PHOTOLYSIS TABLES/30X,'ABSORPTION','
00130 8 FORMAT(150,13X,'PHOTOLYSIS TABLES/30X,'ABSORPTION','
00131 9 FORMAT(150,13X,'PHOTOLYSIS TABLES/30X,'ABSORPTION','
00132 10 FORMAT(150,13X,'PHOTOLYSIS TABLES/30X,'ABSORPTION','
00133 11 FORMAT(150,13X,'PHOTOLYSIS TABLES/30X,'ABSORPTION','
00134 12 FORMAT(150,13X,'PHOTOLYSIS TABLES/30X,'ABSORPTION','
00135 13 FORMAT(150,13X,'PHOTOLYSIS TABLES/30X,'ABSORPTION','
00136 14 FORMAT(150,13X,'PHOTOLYSIS TABLES/30X,'ABSORPTION','
00137 15 FORMAT(150,13X,'PHOTOLYSIS TABLES/30X,'ABSORPTION','
00138 16 FORMAT(150,13X,'PHOTOLYSIS TABLES/30X,'ABSORPTION','

00139 C  END
SUBROUTINE PROFILE( ALEN, AMID, DELZ, DEPTH, NELEM, W,  
                    USTAK, VOL, WH, EL, IFLAG, DELTA)  

C THIS ROUTINE ASSIGN A LOGARITHMIC OR UNIFORM PROFILE FOR THE  
C BULK VOLUMETRIC FLOWS.  

C INPUT PARAMETERS:  
C ALEN = SEGMENT LENGTH  
C AMID = SEGMENT WIDTH  
C DELZ = STANDARD ELEMENT THICKNESS  
C DEPTH = FLOW DEPTH  
C NELEM = NUMBER OF VERTICAL ELEMENTS IN THE SEGMENT  
C W = FLOW TO BE DISTRIBUTED  
C USTAK = SHEAR VELOCITY  
C VOL = SEGMENT VOLUME  
C OUTPUT PARAMETERS:  
C WH = DISTRIBUTED FLOW  

C CALLED BY: HYDFLU, ICFLD  

C INCLUDE 'ELMBIZ_PRM'  

C DIMENSION DH(MXELEMENT), Z(MXELEMENT), ZI(MXELEMENT),  
C AMID(MXELEMENT),  

1 DATA XM(0.4,  
2 DATA GM(0.4,  

C DU(I = 1, MXELEMENT)  
C RH(I) = 0.0  

C FINI  

C UBARRU / VOL = ALEN  
C ZOMDEPHT (10, ** (UBARRU/(2.3*USTAK) + 1)*Z)  

C ICOUNTI = ICOUNIT  
C ZOM00 = 0.001  
C ZOMU0 = XM/USTAK + 0.0  
C EDUMDEPHT(C1=2.303*ALOG10(DEPTH))  
C REPEAT UNTIL(LABS(EPSJLT, 0.0, OR, ICOUNIT, GT, 10)  
C ICOUNIT = ICOUNIT + 1  
C ZOMDEPHT = C1 + 2.303*ALOG10(ZD)  
C ZP = Z*Z0/FPZ0  
C EPSM(ZP-Z0)/ZP  
C ZOMZP  
C IF(Z0, LT, 0.0)  
C ZOMDEPHT = (UBARRU/(2.303*USTAK) + 1)*Z  
C ICOUNIT = ICOUNIT + 1  
C FINI  

C WHEN (Z0, GT, DELZ/4.0, WA, NFLEM, EI, 1)  
C *** DISTRIBUTE VELOCITY UNIFROMLY ***  
C WHEN(IFLAG, EI, 0)  
C WHEN (1, NELEM)
00054  **  **  ** UM(1) = UBAR * DELTA * AMID(1)  
00055  **  **  ** FIN  
00056  **  **  ** FIN  
00057  ELSE  
00058  **  ** DO (IM, NELEM = 1)  
00059  **  ** UM(1) = UBAR * (EL(I+1) - EL(I)) * AMID(1)  
00060  **  **  ** FIN  
00061  **  ** UM(NELEM) = UBAR * DELTA * AMID(NELEM)  
00062  **  **  ** FIN  
00063  **  **  ** FIN  
00064  ELSE  
00065  **  ** DISTRIBUTE VELOCITY INTO A LOGARITHMIC PROFILE ***  
00066  ** NUM = NELEM + 1  
00067  ** Z(I) = I  
00068  ** Z(NUMBER) = DEPTH  
00069  ** Z(I(NUM)) = 0.  
00070  **  
00071  ** JX = 1  
00072  ** JNUM  
00073  ** REPEAT UNTIL (JX = EQ. NELEM , OR , Z(J) , EQ. ZO)  
00074  ** JX = JX + 1  
00075  ** JNUM = JX + 2  
00076  ** WHEN (IFLAG = 0) Z(I) = Z(I+1) + DELZ  
00077  ** ELSE  
00078  ** WHEN (JX = EQ. NELEM) Z(I+1) = Z(I) + Z(I+1) + DELZ  
00079  ** ELSE Z(I) = Z(I+1) + DEL(I+1) - EL(I)  
00080  **  ** FIN  
00081  **  ** Z(J) = DEPTH = Z(I)  
00082  **  **  ** FIN  
00083  **  ** WHEN (Z(J) , EQ. ZO) J = 1  
00084  ** ELSE  
00085  ** J1 = J1 + 1  
00086  ** DO (IM, J1)  
00087  **  ** UM(I) = 0.  
00088  **  **  ** FIN  
00089  **  **  ** FIN  
00090  **  
00091  **  
00092  ** AM = 2.303 * UBAR / XX  
00093  **  
00094  ** XLOGID = ALOGID(DEPTH)  
00095  **  
00096  ** DO (IM, J1)  
00097  **  ** IP1 = I+1  
00098  **  
00099  ** DLZ = Z(IP1) - Z(I)  
00100  **  
00101  ** TI = AM * DLZ * XLOGID  
00102  **  
00103  ** T2 = AM * XLOGID(Z(IP1)) = Z(I) * ALOGID(Z(I)) - DLZ  
00104  **  
00105  **  
00106  **  
00107  **  
00108  **  
00109  **  

B.64
00110       DO (I=1,MELEM)
00111           OH(I)=WH(I)/BUN * B
00112       *** FIN
00113   ***FIN
00114       RETURN
00115       END

---
SUBROUTINE PUTERM(I0, NUMERR, MLDERM)

C WHEN AN ERROR IS DETECTED IN THE INPUT BINARY,
C THIS SUBROUTINE IS CALLED TO PLACE THE ERROR IDENTIFICATION
C CODE (I0) INTO THE HOLDING ARRAY (MLDERM) AND INCREASES
C THE NUMBER OF ERRORS (NUMERR).
C
C CALLED BY: NDCAT, INIDAT, TRHDAT, UPSDAT

C
BYTE MLDERM(I0)

C NUMERR=NUMERR+1
MLDERM(NUMERR)=I0
RETURN
END

(FLECS VERSION 22.4a)
SUBROUTINE RADIUS ( ALEN, AREA, CRUSEC, DEPTH, EL, HRAD)

THIS ROUTINE CALCULATES THE HYDRAULIC RADIUS OF A CROSS-SECTION.

INPUT PARAMETERS:
- ALEN = SEGMENT LENGTH
- AREA = SURFACE AREA AT NODEAL DEPTHS
- DEPTH = DEPTH OF CROSS-SECTION
- EL = ELEVATION OF NODEAL AREAS

OUTPUT PARAMETERS:
- CRUSEC = TOTAL CROSS-SECTIONAL AREA
- HRAD = HYDRAULIC RADIUS

CALLED BY: HYDNUM, ICFL0

INCLUDE 'ELMBIZ.PRM'

DIMENSION AREA(MXELM), EL(MXELM)

CRUSEC = 0.

MLEN = 1./ALEN

HETPN = AREA(1)*MLEN

ELBTH = EL(1)

HMT = AREA(1)*MLEN

EL = (M2,*MXELEM)

ELTOP = EL(1)

IF (ELTOP,GE.DEPT0H) GO TO 10

CRUSEC = (ELTOP = ELBTH)*M2 + (MTOP = HMTM/2.,)*2 + 2,0

1.

HETPN = (HMT = MTOP)

** 4

HETPN = (H = 1) CRUSEC = HETPN, I

FORMAT ('3', ' ERROR IN SUBROUTINE RADIUS',/)

10 CRUSEC #1, E12,4,1**3/

2 **2, PERIMETER = #1, E12,4,1**2/

3 **3, ELEMENT = #1, I3)

GO TO 20

10 HTOP = HMT + (MTP = HMTM) * (DEPTH = ELBTHM/ELTOP = ELBTH)

ELTOP = DEPT0H

CRUSEC = CRUSEC + (ELTOP = ELBTH) * (HTOP = HMTM)/2.

HETPN = (HTOP = 5TMH/2.)**2 + 2,0

20 CRUSEC = CRUSEC + HETPN

RETURN

(FLICS VERSION 22.08)
SUBROUTINE RD5F0L(ALEN, AREA, ANO, C, DELZ, DFZI, NELEM, NELEM, NELEMP, 
PDELZ, PHID, PXBAR, VSET, XAREA)

THIS SUBROUTINE IS CALLED EACH TIME STEP (EXCEPT THE FIRST) WHEN THE 
DEPTH WITHIN THE SEGMENT HAS CHANGED. ITS TASK IS TO REDISTRIBUTE 
THE CONCENTRATIONS.

FORMAL PARAMETERS:

ANID = WIDTH * CURRENT TIME STEP

C = THE NELMT+1 MODAL CONCENTRATIONS THAT ARE TO BE 
REDISTRIBUTED

DELZ = THE STANDARD ELEMENT THICKNESS FOR THE CURRENT TIME STEP

DFZI = DIFFUSION-DISPERSION COEFFICIENT

NELEM = THE NUMBER OF ELEMENTS FOR THE CURRENT TIME STEP

NELEMP = THE NUMBER OF ELEMENTS DURING THE PREVIOUS TIME STEP

PDELZ = THE STANDARD ELEMENT THICKNESS USED DURING THE PREVIOUS 
TIME STEP

PXBAR = PRESS SECTION * PREVIOUS TIME STEP

PHID = WIDTH * PREVIOUS TIME STEP

XAREA = CROSS SECTION * CURRENT TIME STEP

VSET = SETTLING VELOCITY OF SEDIMENT

CALLED BY: SERASA

INCLUDE 'ELMBIS.PRN'

DIMENSION AREA(MAXELEM), ANOD(MAXELEM), C(MAXELEM,MAXCON), 
1CP(MAXELEM,MAXCON), DFZI(MAXELEM), PHID(MAXELEM), PXBAR(MAXELEM), 
VSET(3), XAREA(MAXELEM), JELP(MAXELEM), MAXXS(MAXELEM), TMABS(7)

PS = 0.
KS = 0.

DO (I=1,NELEM) XB = XS + XAREA(I)

DO (I=1,NELEMP) PXS = PK0 + PXBAR(I)

DO (I=1,NELEMP)

DO (J=1,MAXCON)

CP(I,J) = C(I,J)

***FIN

XI = PXS/XY

CALL EQUIPS(PXBAR, PHID, PDELZ, XAREA, NELEM, NELEMP, RATIO, 
1ELP, MAXXS)

DO (K=1,MAXCON)

TMABS(K) = 0.

CT = CP(Z,K)

CB = CP(1,K)

NELMT =

CMABS = (CT+C4)/2.*PXBAR(I)

CMABS = CMABS

V(I,1,NELEM)

NELMT+1ELP(I)

**********
C     NODAL VALUES ABOVE HUTTON ELEMENT
ELSE C(I+1,K) = Z*CMASS/XAREA(I)-C(I,K)
   CHASB*CHASAT
   CMASB*CMASAT
   NELMT*NELMIP
   FIN
   FIN
   FIN
   FIN
END
SUBROUTINE PTERR(NUNEK, MLDEKR, FERNO)

C THIS ROUTINE IS RESPONSIBLE FOR REPORTING ANY INPUT ERRORS
UNCOVERED BY THE INPUT ROUTINES AND DETERMINING THEIR SEVERITY.
C
C CALLED BY: SERATHA, START
C
C MLDEKR(100), HUFF(80, 2)
C
C LOGICAL* FERNO
C
C CALLED BY: SERATHA
C
C OPENUNIT=10, NAME='SERATECH', MSG='TYPE=old', ACCES='DIRECT',
C FORM='FMTMATED', MAXREC=200, RECORDIZE=00,
C 2 ASSOCIATEVARIABLES='i', (READONLY)
C
C NUMERO
C
C WRITE(6, 4)
C DO (I=1, NUMEK)
C 1 NUMEK=I+1
C READ(10,1011)(HUFF(K,1), K=1, 80)
C 1
C READ(10,1012)(HUFF(K,2), K=1, 80)
C 2 IF(HUFF(I,1), EN='N') NUMERO=NUMERO+1
C 2 IF(HUFF(I,1), EN='F') NUMERO=NUMERO+1
C 2 WRITE(6,2)(HUFF(K,2), K=1, 80), J=1, 2)
C
C FWRITE(6, 3)NUMERO, NUMERO
C CLOSE(UNIT=10)
C IF (NUMERO .GT. 0) FERRNO = .TRUE.
C RETURN
C
C FWRITE(6, 3)NUMERO, NUMERO
C 1 FWRITE(6, 1) A1
C 2 FWRITE(10, A1), Bx, 31, 1x, 10, 31, 1x, FA1/10x, 31, 1x
C 3 FWRITE(1/10x, 15, 1 ! WARNING DIAGNOSTICS'/1x, 15, 1 FATAL ERROR(8))
C 4 FWRITE(1/**** DIAGNOSTIC SUMMARY ****)
C
C END

(FLFC version 22.46)
SUBROUTINE SAND(A, ALN, AREA, B, BDIV, CCIN, DELTO, DEL3, 
1) 
DENB, DSO, HDAD, NDG, HELEN, PORN, OHIN, 
2) 
SHOUT, SCHR, SLOPE, SMETH, STRESS, TEMPR, 
3) 
VRET, VOL, XYSO, DEPO, ILAYN, BD, ER, 
4) 
XREN, COLD, C, CHSEC, BVID, ECHOT, SCDWJ 
5) 
C 

THIS SUBROUTINE COMPUTES THE SOURCE/SINK TERMS REQUIRED FOR 
SCOUR/DEPOSITION OF SAND, TRANSPORT CAPACITY IS CALCULATED 
ONCE PER SEGMENT. 

INPUT PARAMETERS: 

AAB = AVERAGE VERTICAL PROJECTION AREA 
ALN = SEGMENT LENGTH 
AREA = ELEMENT [REAL] VERTICAL PROJECTION AREA * DATA NODES 
M = BED CONDITIONS 
BDIV = STANDARD BED LAYER THICKNESS 
BMID = MEAN WIDTH AT CROSS-SECTION BREAK POINTS 
C = WATER CONDITIONS 
CCIN = CONCENTRATION OF INFLOW 
CHSEC = TOTAL CROSS-SECTIONAL AREA, INT 
DELTO = TIME STEP (DAYS) 
DELZ = STANDARD ELEMENT THICKNESS 
DELZT = THICKNESS OF THE TOP ELEMENT 
DEN = DENSITY 
DSO = MEAN HED SEDIMENT DIAMETER [METER] 
HDAD = HYDRAULIC RADIUS 
HDEG = NUMBER OF BED LAYERS 
HELEN = NUMBER OF ELEMENTS 
PORN = POROSITY 
WHIN = INFLOW DISCHARGE 
WHOUT = OUTFLOW DISCHARGE 
SCHR = CRITICAL SHEAR STRESS FOR SCOUR 
SLOPE = ENERGY OR RIVER BED SLOPE 
SMETH = METHOD TO BE USED WHEN COMPUTING SAND CAPACITY (BYTE 
*1; TOFFALE)I'S METHOD 
COLHY'S METHOD 
STRESS = BED SHEAR STRESS 
TEMPH = WATER TEMPERATURE 
VSET = PARTICLE SETTLING VELOCITY 
VOL = VOLUME 
XYSO = THICKNESS OF TOP BED LAYER 

OUTPUT PARAMETERS: 

ILAYN = NO. OF BED LAYERS AFFECTED BY SLD, DEPOSITION AND ER 
SO = DEPOSITION RATE, [KG/(PC)/**3/DAY] 
EH = EROSION RATE, [KG/(PC)/**3/DAY] 
XTN = HEIGHT OF TOP BED SEDIMENT LAYER, [KG/****2] 
DEPO = SED DEPOSITION RATE [KG/(PC)/**2/DAY] 
SOUR = NEW SED RATE [KG/(PC)/**2/DAY] 

CALLED WT HT TRANSP. 
CALLED TOFFAL, CILBET 
INCLUDE 'ELMSIL.PRM'
B.73
(FLECO VERSION 284) 17-JUN-82 15104139 PAGE 00003

09110 C IT IS IMPLICITLY ASSUMED THAT A DOWNSTREAM COUPLING NUMBER
09111 C AT OR NEAR UNITY IS EMPLOYED IN THIS ANALYSIS
09112 C
09115 C
09116 C
09117 C
09118 C
09119 C
09120 C
09121 C
09122 1. CALL TUFFALEN, D5O, GSI, HRAD, QTOT, SLOPE, TEMPR, VOL, VSET, G5U, G5M, G5L, G5H, YU, YM, YL)
09123 1. ***FIN
09124 1. (C)
09125 1. CALL COLYALEN, G, DELZ, D5O, HRAD, NELEM, WTOT, TEMPR,
09126 1. VOL, GSI, FERKUN
09127 1. IF(FERKUN) 1. ***FIN
09128 1. CALL TUFFALEN, D5O, GSI, HRAD, QTOT, SLOPE, TEMPR, VOL, VSET, G5U, G5M, G5L, G5H, YU, YM, YL)
09129 1. ***FIN
09130 1. FERKUN = 'FALRE'
09131 1. ***FIN
09132 1. ***FIN
09133 1. GSI = GSI + NMSW(NELEM + 1)
09135 C
09136 C
09137 C
09138 C
09139 C
09140 C
09141 C
09142 C
09143 50
09144 DIF = DIF / AREA(1)
09145 RATE = DIF / VOLUME
09146 JFAB(1) = 1
09147 D5U (K+N,NELEM) 1. VULK = AARB(K) + DELZ
09149 1. INFACM,5*K+EN(K) + DELD/VULK
09150 1. ERFACM,5*K+ERFACM
09151 1. SEDF*INFAC5*K+CC14(K,1)*CCIN(K+1,1)/2,
09152 1. * ERFACM*INFAC5*K+COLO(K,1)
09153 1. CONTFAC+H11(K)*CCIN(K,G)*CCIN(K+1,G)/2,
09154 1. * ERFAC3*HOUT(K)*CULU(X,4)
09155 1. RATEK = RATE + VULK
09156 1. BD(K,G) = RATEK*SED/VULK*CO4T
09157 1. DEP0(K) = DEP0(K)+BD(K,G)/AREA(1)*VULK
09158 1. ***FIN
09159 1. RETURN
09160 C
09161 C
09162 C
09163 100
09164 C
09165 C
09166 C

B.74
DETERMINE WHICH (IF ANY) RED LAYERS ARE SCOURRED

TR3USP = DIF * DELU
ILAYR(1) = 0
IF (NBED, EN, 0) GO TO 200
DU (k, ARED)
NM = ARED = K + 1
TMEN = (1.0 - POW) / (h(NB, 1)/DENB1 + h(NB, 2)/DENB2)
+ A(NB, 3)/DENB3)
DEL = BDIV
 IF (NHE, EN, NHED) DEL = XYZG
 TMNED = TMEN = DEL * h(NB, 1) * VPCdUS
 WHEN (TRUSK, 42, TMNED)
 KS = KS + TMNED
 TRUSP = TRUSP - TMNED
 TMNED = 0.0
 ILAYR(1) = ILAYR(1) + 1
 IF (ILAYR(1), EN, NHED) GO TO 175
 ELSE
 KS = RS + TRUSP
 CS = CS + TRUSP * h(NB, 8)
 TMNED = TMNED = TRUSP
 GO TO 175

FIN

SCURR(1) = RS / DELT / AREA(1)
SCURR(4) = CS / DELT / AREA(1)
ANT(1) = TMNED / VPCdUS
SK(1) = KS / DELT / VOLUME
SR(4) = CS / DELT / VOLUME
**FIN

RETURN
END

(FLECS VERSION: 22,46)

-----------------------------------------
SUBROUTINE SAVEITCH, HDIV, BED, ELEV, C, DELZ, NBED, NELEM, NXEQ, REBELM, STRESS, XYZD, ULDC
D隆 2 ALEN, UHIN, UHOUT, CCIN, VU, AHID, OHID, VSET, DEN8, DELTO, DFZ,
3 PUR, TBED)
C
C THIS ROUTINE WRITES THE SIMULATION RESULTS TO THE RESULT FILE
C (LUN 5) THAT HAS BEEN OPENED BY SENATHA

C FORMAL PARAMETERS

C - BED CONCENTRATIONS
C HDIV = STANDARD BED LAYER THICKNESS
C BED = BED THICKNESS
C C - WATER CONCENTRATIONS
C VELZ = STANDARD ELEMENT THICKNESS
C ELEV = SEGMENT ELEVATION (DATUM ELEVATION)
C NBED = NUMBER OF BED LAYERS
C NELEM = NUMBER OF ELEMENTS
C NXEU = CURRENT TIME STEP (MA)
C REBELM = WATER SURFACE ELEVATION
C STRESS = SHEAR STRESS
C XYZD = THICKNESS OF THE TOP BED LAYER
C
C CALLED BY: SENATHA.

C INCLUDE 'EMLSIZ,PR'
C
C INTEGR** NXEU
C
DIMENTION B(MAXLE,MXCON+1),HAYG(MAXLE), BEL(MAXLE),
1 C(MAXLE,MXCON), CASS(MAXLE), CYOL(MAXLE),
2 CTOTL(MAXLE), NELE(MAXLE), O(MAXLE,MXCON),
3, UHIN(MAXLE), UHOUT(MAXLE), CCIN(MAXLE,MXCON),
4, VU(MAXLE), AHID(MAXLE), OHID(MAXLE), VSET(MXCON),
5, VELZ(MAXLE), VELZ(MAXLE,MXCON), UHOT(MAXLE,MXCON),
6, GELAY(MAXLE,MXCON), NGELAY(MAXLE,MXCON),
7, ULDC(MAXLE,MXCON), DFZ(MXCON), QVOUT(MAXLE,MXCON),
8, HEBED(MAXCON), TBED(MAXCON), BAL(MAXCON), DIF(MAXCON),
9, OCLEVEL(MAXCON), TOLEVEL(MAXCON)
C
DATA EPSI1, EPSI2, EPSI3, EPSI4, EPSI5 = 0.30/
C
C NELEM = NELEM +

C *** WATER CONCEI'rATIONS ***
C
J = NELEM + 1
WHITE(5) NEQ,J,NBED,ELEV,DELZ,HDIV,XYZD,STRESS
REPEAT UNTIL (J > EQ. 0)

C CASS(J) = C(J,4) + C(J,5) + C(J,6)
C SUM = C(J,1) + C(J,2) + C(J,3)
C HEBED (SUM + SUM, 0,0) CYOLM(J) = CMASS(J) / SUM
C ELSE CYOLM(J) = 0.0
C
C CTOTL(J) = CMASS(J) + C(J,7)
C
C BRAND I(J)
00059       
00059       * * (HELEM+1) #LEVF(HELEM+1) # THIN
00059       */
00055       * (OTHER_ERIE) #LEVF(J) = #LEVF(J+1) = DELZ
00055       */
00056       * * FIN
00056       */
00057       J = J + 1
00057       */
00058       * * FIN
00058       */
00059       (KM1, MAXCON)
00060       */
00060       DO(JM1, NELEM+1)
00061       */
00061       IF (K = EQ, 7) DO(I, K) = (I, K)
00062       */
00062       ELSE
00063       */
00063       IF (C(IK) = 0, 1, 0, 0, 1) DO(I, K) = (I, K) = (I, K)
00064       */
00064       * * FIN
00065       */
00066       */
00067       * * FIN
00067       */
00068       WRITE(5) (HELEV(J), (C(J, K), KM1, MAXCON), CCHAB(J), CVOLM(J),
00069       */
00069       ) IDENT(J), JNELEM+1, 1, = 1
00070       */
00070       WRITE(5) ((J, K), KM1, MAXCON), JNELEM+1, 1, = 1
00071       */
00071       */
00072       */
00072       ** BU CONCENTRATIONS ***
00073       */
00073       */
00074       /* WELEV = (NBED+1) = BDIV + XYBO + ELEV
00074       */
00075       J = NBED
00075       */
00076       * REPEAT UNTIL (J = 0)
00077       */
00077       ** BAVG(J) = ((AVG(I,J) = AVG(J,I) = AVG(I,J)) + AVG(J,I) = AVG(I,J)
00078       */
00078       ** SELECT (J)
00079       */
00079       ACT = (NBED) = ASEL(NBED) = WELEV
00080       */
00080       ** (NBED-1) = ASEL(NBED-1) = WELEV = XYBO
00081       */
00081       ** (OTHERWISE) = ASEL(J) = (SEL(J+1) = BDIV
00082       */
00082       * * FIN
00083       */
00083       J = J-1
00084       */
00084       * * FIN
00085       */
00085       WRITE(5) ((EBEL(J), (B(J, K), KM1, MAXCON-1), BAVG(J), JNBED, 1, = 1)
00086       */
00086       ** ELEMENT MASS AND CONVEYED MASS ***
00087       */
00087       */
00087       ** BU (J, K) = MAXCON)
00087       */
00088       ** CELE(J) = 0,
00088       */
00089       ** CELE(NELMPL, J) = 0,
00089       */
00090       ** QCIN(ELMPL, J) = 0,
00090       */
00091       ** QOUT(ELMPL, J) = 0,
00091       */
00092       ** OUC(1, = i, NELEM)
00093       ** VULMAO(I) # DELM=1
00094       ** XSMAN(I) # DELZ
00095       ** VPSMAN(I) = LEN
00096       ** OMCHN2 = (ULDC(I, J) + ULDC(I+1, J))/2,
00097       ** CHMN2(C(1, J) + C(1+1, J))/2,
00098       ** CELEI(J) = VLMCHN
00099       ** QCIN(I, J) = QCIN2(I, J) = QCIN(I+1, J) = QCIN2(I+1, J)
00100       ** WOUT(I, J) = WOUT2(I, J) = WOUT2(I+1, J) = WOUT2(I+1, J)
00101       ** CELE(ELMPL, J) = CELE(ELMPL, J) = CELE(I, J)
00102       ** QCIN(ELMPL, J) = QCIN(ELMPL, J) = QCIN(I, J)
00103       ** WOUT(ELMPL, J) = WOUT(ELMPL, J) = WOUT(I, J)
00104       ** CELE(J) = CELE(J) + ONCCHN2
00105       ** WOUT(J) = WOUT(J) + OMCHN2
00106       ** IF(J = 0, 1, K = 1)
00107       ** WHEN (K, EU, G) MS=0,
00108       ** ELSE SMVET(K)
00109       ** WHEN(I, EQ, 1) VCBM#MUY(I) = (C(I, J) + OLDC(I, J))/2,
00166           *       TRED(MAXCN) = TRED(MAXCN) * TRED(J)
00167           ***FIN
00168           WRITE(5) (TRED(J), J=I, MAXCN)
00169           N(J) = MAXCN-1
00170           *       TOIF(J) = TRED(J) - OTRED(J) + HIF(J)
00171           ***FIN
00172           TOIF(MAXCN) = TRED(MAXCN) = OTRED(MAXCN) + TOIF
00173           RETURN (TOIF(J), J=I, MAXCN)
00175           RETURN

(FLECS VERSION 22.4a)
SUBROUTINE SEDATA (DECAV, DENS, UPZ, QIAM, DBHR, D50, ECHO, 
ERDUE, HDLERR, NUMERR, BCCHR, SORB, VSET, 
1 USRERR)

This subroutine is responsible for reading and processing the 
sement characteristics.

FORMAL PARAMETERS:

DECAV  = DECAY PARAMETERS
DENS  = SPECIFIC WEIGHT
UPZ  = VERTICAL DIFFUSION COEFFICIENTS
QIAM  = PARTICLE DIAMETERS
DBHR  = CRITICAL SHEAR STRESS VALUE FOR DEPOSITION
D50  = MEDIAN BED SEEDIMENT DIAMETER
ERDUE  = LINE PRINTER ECHO CONTROL VARIABLE (L=1)
HDLERR  = ERGODABILITY
NUMERR  = HOLDING ARRAY FOR ERROR NUMBERS (BYTE)
BCCHR  = NUMBER OF INPUT ERRORS
SORB  = CRITICAL SHEAR STRESS VALUE FOR SEDIMENT
VSET  = ADOPTION VALUES
USRERR  = ADOPTION VALUES
V:Set  = VERTICAL SETTLING VELOCITIES

CALLED BY:

CALLED PUT

PROCEDURE:

WRITE (100)

LOGICAL = 1 ECHO

DIMENSION DECAV(6), DENS(3), UPZ(9), QIAM(3), DBHR(3), 
ERDUE(3), BCCHR(9), SORB(9), VSET(3)

PARTICLE SETTLING VELOCITY (M/SEC)

CUL  = 1-10  VSET(1), SAND SETTLING VELOCITY
11-20  VSET(2), SILT SETTLING VELOCITY
21-30  VSET(3), CLAY SETTLING VELOCITY

HEAD(1), (VSET(1), I=1, 3)

IF (ECHO)

WRITE(6, 2)

WRITE (6, 12) (VSET(I), I=1, 3)

*FIN

DENSITY (KG/MM3)

CUL  = 1-10  DENS(1), DENSITY OF SAND
11-20  DENS(2), DENSITY OF SILT
21-30  DENS(3), DENSITY OF CLAY

HEAD(1), (DENS(I), I=1, 3)

IF (ECHO)
**DIAMETER (METERS)**

```
CUL.   1-10,   DIAM(1)   DIAMETER OF SAND
       11-20,   DIAM(2)   DIAMETER OF SILT
       21-30,   DIAM(3)   DIAMETER OF CLAY

CUL.   31-40, D50,   MEDIAN BED SEDIMENT DIAMETER
```

**CRITICAL SHEAR STRESS FOR SCOUR (KG/MM**2**)**

```
CUL.   1-10, SCHR(1), CRITICAL SHEAR STRESS FOR SAND
       11-20, SCHR(2), CRITICAL SHEAR STRESS FOR SILT
       21-30, SCHR(3), CRITICAL SHEAR STRESS FOR CLAY
```

**CRITICAL SHEAR STRESS FOR DEPOSITION (KG/MM**2**)**

```
CUL.   1-10, DSHR(1), CRITICAL SHEAR STRESS FOR SAND
       11-20, DSHR(2), CRITICAL SHEAR STRESS FOR SILT
       21-30, DSHR(3), CRITICAL SHEAR STRESS FOR CLAY
```

**ENHARMONY (KG/MM2/SEC)**

```
```
**Application of Flow Models to Geohydrological Systems**

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**VERIFICATION OF THE SOLUTION**

- **Step 1:** Read ground-water level data from file.
  - **File:** input.dat
  - **Data:**
    - **Column 1:** Depth
    - **Column 2:** Ground-water level
    - **Column 3:** Time

- **Step 2:** Analyze flow excess conditions.
  - **Equation:**
    - **Coefficient for Band:** \( K_B \)
    - **Coefficient for Silt:** \( K_S \)
    - **Coefficient for Clay:** \( K_C \)
  - **Data:**
    - **Column 1:** \( K_B \)
    - **Column 2:** \( K_S \)
    - **Column 3:** \( K_C \)

- **Step 3:** Check for steady-state conditions.
  - **Equation:**
    - **Coefficient:** \( K \)
    - **Data:**
      - **Column 1:** \( K \)

---

**Boundary Conditions**

- **Ground-water table:**
  - **Type:** Constant head
  - **Data:**
    - **Column 1:** Depth
    - **Column 2:** Head

---

**Simulation Parameters**

- **Simulation Time:** 100 days
- **Time Step:** 1 day

---

**Output**

- **Results:**
  - **Column 1:** Simulation time
  - **Column 2:** Ground-water level
  - **Column 3:** Error

---

**References**

1. **Title:** Application of Flow Models to Geohydrological Systems
2. **Authors:** [List of authors]
3. **Publication:** [Journal/Conference]

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**Contact Information**

- **Author:** [Name]
  - **Email:** [Email]
  - **Institution:** [Institution]

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**Notes**

- **Note 1:** Additional details on model implementation.
- **Note 2:** Validation results.
- **Note 3:** Future work directions.
**DECAY PARAMETERS (2 CARDS)**

**CARD #1**
- COL 1-10, DECAY(1), RADIOISOTOPE DECAY (1/SEC)
- COL 11-20, DECAY(2), TOTAL DECAY, SUM OF ALL DECAY EXCEPT RADON DECAY
- COL 21-30, DECAY(3), REMAINING DECAY PARAMETERS ARE NOT TO BE SUPPLIED
- COL 31-40, DECAY(4), PESTICIDE ONLY (1/SEC)
- COL 41-50, DECAY(5), DEGREE OF ACIDITY OF ALKALINITY
- COL 51-60, DECAY(6), SECOND ORDER ACID RATE CONSTANT
- COL 61-70, DECAY(7), SECONDS UNDER BASE RATE CONSTANT FOR HYDROLYSIS
- COL 71-80, DECAY(8), SECOND ORDER RATE CONSTANT OF NEUTRAL REACTION WITH WATER
- COL 81-90, DECAY(9), SECOND ORDER RATE CONSTANT OF FREE RADICAL FOR OXIDATION

**CARD #2**
- COL 1-10, H2O2, CONCENTRATION OF FREE RADICAL OXYGEN
- COL 11-20, AKR1, SECOND ORDER RATE CONSTANT
- COL 21-30, BIONAS, BIOMASS PER UNIT VOLUME

**PROCEDURE**
- READ(1,1) DECAY(1), DECAY(2), DECAY(6), PH, AKR, AKB, AKN, AKUX, RO2,
- IF(ECHI) WHITE(6,11) DECAY(1), DECAY(2)
- ELSE
- BEGIN
- CADIC 
- *** COMPUTE: DECAY(3) - CHEMICAL DEGRADATION DUE TO HYDROLYSIS
- DECAY(4) - CHEMICAL DEGRADATION DUE TO OXIDATION
- DECAY(5) - MINDEGRADATION ***
- DECAY(3) = 1.0*(PH-14.0)*AKB + 10**(-PH)*AKR + AKN
- DECAY(4) = AKUX + RO2
- DECAY(5) = ANBI + BIONAS
- IF(ECHI)
- ELSE
- WHITE(6,11) DECAY(1), PH, AKR, AKB, AKN, DECAY(3), AKUX, RO2, DECAY(4),
- 1.
- DECAY(5) = AKUX, BIONAS, DECAY(3), DECAY(6)
- END
- ***FIN
- ***FIN
- END
- END
- END
0001 SUBROUTINE SEDIM(ABAR, ALN, CCIN, DELT, I, J, NELEM)
0002       1 QIN, QHOUT, QV, SQ, SR, ALFA, BETA, VELI,
0003  2 VEL2, VBET, DEL2, MMID, AMID, DEPTH,
0004  3 RETAI, BETA2)
0005 C
0006 C THIS ROUTINE CALCULATES COEFFICIENTS OF CONVECTION, DIFFUSION,
0007 C DECAY AND SOURCE TERMS IN THE SEDIMENT TRANSPORT EQUATION
0008 C =DIFFUSION EQUATION
0009 C
0010 C INPUT PARAMETERS:
0011 C
0012 C  ABAR = AVERAGE AREA
0013 C  CCIN = CONCENTRATION OF INFLOW
0014 C  DELT = TIME STEP IN DAYS
0015 C  DEPTH = DEPTH OF RIVER SEGMENT
0016 C  I = ELEMENT INDEX
0017 C  J = PARAMETER INDEX
0018 C  NELEM = NUMBER OF ELEMENTS
0019 C  QIN = INFLOW DISCHARGE
0020 C  QHOUT = OUTFLOW DISCHARGE
0021 C  QV = VERTICAL DISCHARGE
0022 C  SQ = SEDIMENT DEPOSITION RATE, (KG/M^2/DAY)
0023 C  SR = SEDIMENT EROSION RATE, (KG/M^2/DAY)
0024 C
0025 C OUTPUT PARAMETERS:
0026 C  ALFA = DECAY TERM, (1/DAY)
0027 C  BETA = SOURCE OR SINK TERM, (KG/M^2/DAY)
0028 C  BETA1 = INFLUENT SOURCE TERM FOR THE I+1TH NODE, (KG/M^2/DAY)
0029 C  BETA2 = INFLUENT SOURCE TERM FOR THE I+1TH NODE, (KG/M^2/DAY)
0030 C
0031 C CALLED BY TRANSII.
0032 C
0033 C INCLUDE 'ELEM912.PMH'
0034 C
0035 C DIMENSION ABRN(NELEM), AREA(MXLELEM), CCIN(MXLELEM,MAXCOM),
0036 C  QIN(MXLELEM), QHOUT(MXLELEM), QV(MXLELEM), SQ(MXLELEM),
0037 C  SR(MXLELEM), SQ(MXLELEM,MMID), MMID(MXLELEM), AMID(MXLELEM)
0038 C
0039 C CONVECTION TERM WITH CORRECTION FOR A CONTINUOUS SETTLING FLUX
0040 C
0041 C AU = QV(I)
0042 C VELI=(AU=VGET(I)+SQ(I)+AMID(I)+ALFA(I))/ALN(I)
0043 C
0044 C AU = QV(I+1)
0045 C VELZ=(AU=VGET(J)+SQ(J)+AMID(J+1)+ALFA(J))/ABAR(J)
0046 C
0047 C DECAY TERM
0048 C
0049 C ALFA = QHOUT(I) / (ABAR(I) * DELI)
0050 C
0051 C SOURCE OR SINK TERM
0052 C
0053 C BETA=SQ(I) = QV(I,J)
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00054heitenmin(i)/(arar(i)*delz)*(ccin(i,j)/3.+ccin(i+1,j)/6.)
00055heiten(i)/(arar(i)*delz)*(ccin(i,j)/6.+ccin(i+1,j)/3.)
00056return
00057end

(FLECS VERSION 22.40)
CALL PREDAT, COLAP, DINDAT, FCODE, HYDAT, HYDFLO, IECFL, IMDAT,
  0DIDAT, HREL, SAVEI, SEDDAT, STRUP, TRANBP, TRQDAT,
  TRQFLO, UPDAT, TRQDAT, PHQMP
C INCLUDE 'ELMBZ,PRM'
C BYTE FNAME(29), NASE(3), FTYPE(3), OEXY(3), GWIC(3), UWIC(3),
  1 ML0ERR(100), NON(8)
C LOGICAL I ECHO, ANALVS, NENDR, MENIC, FERROR, MPEND, RIVER,
  1 ECHO, ECH03, ECHO4, ECHO5, ECHO7, ECHO8, ECHO9, ECH010,
  2 SAVECH
C INTEGER I OUTFLO, TRQOPT
C INTEGER I ETIME, ENDTO, ENDIC, ENDTRG, SIMLEN, DUM2,
  1 NSTEPS, NEXOG, NPROT, DUM1, MBP, BECRY, JUJEC
C DlMENSION A10D(1XHELEM), CLST(IXHELEM,MA1CON), CTRB(1XHELEM,MA1CON),
  1 IRGAVG(1XHELEM), ELMV4L(1XHELEM),
  1 TGAVG(1XHELEM), CTRCH(MAXCON), PCOEY4, CH0D4(1XHELEM,MA1CON),
  3 EL(1XHELEM), XARE4(1XHELEM), AMID(1XHELEM), IMAB4(MAXCON),
  4 JELM(1XHELEM), YMID(1XHELEM), Y4BAR(1XHELEM), AMID(1XHELEM),
  5 P4BAR(1XHELEM), OLOC(1XHELEM,MAXCON), CD4NY4(1XHELEM),
  6 TOED4(MAXCON), JSEG(5), SAVECH(10)
C INCLUDE 'TRAN84,COM'
C DATA SECDay/86400.0/
C DATA BUCYR /1536000.0/
C DATA EXDG4/FA1LE/4
C DATA ECH04/FALSE/
C DATA ECH05/FALSE/
C DATA EZM(100)/10/
C DATA SAVEC4/FALSE, FALSE, FALSE, FALSE, FALSE, FALSE, FALSE, FALSE, FALSE
C DATA SAVECH/FALSE, FALSE, FALSE, FALSE, FALSE, FALSE, FALSE, FALSE, FALSE
C DATA IPIN1/1
C DATA IPIN2/
C CALL STRUP(0)4C, DEX, ECH04, FNAME, FTYPE, GVIC, INF4, ISEG, ISEG,
  1 NFKBT, OUTFLO, BMETH, UUC4, SAVEC4, JSEG, JSEG,
  2 NSTEPS, JSEG, ITPRT, ANALVS, DELTH, ANALNY, DEPMIN, SIMLEN,
  3 PELEY
C *** READ INPUT DATA FOR BEGINNING SEGMENT ***
C NUMXN = 0
C THIS IS THE RESTART OPTION.
WHEN (ISTR, NT, 0)  CALL PTIERN(NUMER, HLDERR, FERRON)
0142  IF (FERRON) REPORT=ERROR AND=STOP
0143  **FIN
0144  C
0145  **FIN
0146  C
0147  IF (ANALYS)
0148  OPEN(Unit,NAME=SYS.TIMESERIES,DAT={,TYPE='NEW',
0149  FORM='UNFORMATTED')
0150  FIN
0151  C=========================================================================
0152  C SEGMENT LOOP
0153  C=========================================================================
0154  DO (ISEG=ISTR,NSEG)
0155  CALL DIAG(ECHOZ, ECHOB, ECHO, ECHOS, ECHOS, ECHOB, ECHOZ, ECHOB
0156  CALL ECHOB, ECHO, ISEG, NSEG, BAYECI)
0157  3 FORMAT(1X,15X,SEGMENT NO.,I3,X,8X)
0158  CALL RESET(DAT={,TIME=CONTROLS
0159  CALL CAVG$MO, 0
0160  CALL JUHSEC=JULIAN SEC
0161  C
0162  UNLESS (ISEG ,EW, 1)
0163  IF (ECHOB)
0164  CALL TIME(WRT)
0165  WRITE (6,5) ISEG, NON

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00166  ** ***FIN
00167  ** \$EMRR = \$FALSE.
00168  ** \$NUMMR = 0
00169  ** CALL DIMDAT{ALE, AREA, NOED, RED, DLZBAY, ECHO, ELEV, HLDERR),
00170  1. ** (ELE, NELEM, NUMMR, PELE, PUR, RIVER),
00171  2. ** XYS, EL},
00172  ** CALL SFDUAT{DECA, DENS, N0Z, DIAM, DSR, DS, ECHO, ERUDE},
00173  1. ** MLDERR, NUMMR, SC5HR, BORRA, VSET, DSMB.}
00174  ** CALL RNDAT{N, ECHO, NOED, AREA, SDIV, DENS, PUR, XYS, TBLU}
00175  C ** READS INITIAL CONDITIONS FOR SEDIMENT AND CONTAMINANT
00176  C **
00177  C ** CALL HTRDAT{E, ECHO, NELEM})
00179  ** CALL TRADAT(ECHU, HLDERM, NELEM, NTRIBS, NUMMR},
00180  C ** BIMLEN, THOPT})
00181  1. ** CALL HYODAT{ALE, AREA, DEPTH, DELZ, D50, ECHO, HLDERM, XSET),
00182  1. ** NUMMR, SIMLEN, DEPMIN, DLZBAY, EL}
00183  C **
00184  ** IF (NUMMR \$ GT. 0)
00185  ** CALL RTERR{NUMMR, HLDERM, FEHROR)
00186  ** IF (FERROR) HEPDAT=FATAL-ERROR-AND-STOP
00187  ** ***FIN
00188  ** ***FIN
00189  ** NEBEL=NELEV+BE0
00190  C **
00191  C ** *** READ THE HYDROLOGICAL DATA ***
00192  C ** READ{4) DOU{1,NELEM,DELP,01,DS, VUL,VEL,SWID,AREA,TEMPP,WSAREA,IELM},
00193  1. ** DEPT1,SWID,ABAN,MRAC, CAUSEC
00194  C ** REMIND 4
00195  C **
00196  C ** PROCESSING OF INITIAL DATA
00197  C **
00198  C ** IF (NELEM \$ GT. 0)
00199  ** DO {K\$1,MAXCUN}
00200  C **
00201  C ** *** HELEN VALUES OF CLAST MUST BE CALCULATED FROM NELEM+1
00202  C **
00203  ** IF (K \$ LE. 3 OR, K \$ EQ. 7)
00204  C **
00205  C ** PROVIDES A CONSISTENT INITIAL CONDITION FOR THE DELZ DEFINED
00206  C **
00207  C ** IN HYODAT = BOTH NORMAL VALUES [BNODEE=], AND ELEMENT
00208  C ** AVERAGES (CLAST\$COLD)
00209  C **
00210  C ** CALL COLLAP(ALE, AREA, C,DELP, EL,IELM, K,NELEM,CLAST,THABS,AMID,
00211  1. ** VRET, D50, CUNDE, WSAREA)
00216  C ** ***FIN
00217  ** ***FIN
00218  **
00219  ** DIAGNOSTIC VALIDITY
00220  C **
00221  ** IF (ECHU(5)
00222  ** WRITE{5,1505)
00223  ** WRITE{5,1510)
00224  **
00225  **
00226  **
00227  **
00228  **
00229  **
00230  **
00231  **
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```
     00222      *       WRITE(*,1540)
     00223      *       WRITE(*,1540) (I,(CMODE(I,J),J,MAXCON),I,NELEM))
     00224      *       WRITE(*,1550)
     00225      *       WRITE(*,1550) (I,(CLAST(I,J),J,MAXCON),I,NELEM)
     00226      1500      *       FORMAT(10) IMMEDIATELY FOLLOWING COLLAP, THE INITIAL CONDITION
     00227      1510      *       FORMAT(10) ELEMENT/MODULE, 5X, AREA, 10X, LEL, 12X, ABAM
     00228      1520      *       FORMAT(2X,15X,1P7E15.4)
     00229      1530      *       FORMAT(10) CONDENTIAL CONCENTRATIONS PRIOR TO COLLAP
     00230      1540      *       FORMAT(10) CONCENTRATIONS FOLLOWING COLLAP
     00231      1550      *       FORMAT(10) ELEMENT AVERAGE CONCENTRATION FOLLOWING COLLAP
     00232      FIN
     00233      *       DO (I,NELEM)
     00234      *       DO (J,MAXCON)
     00235      *       COLD(I,J)=CLAST(I,J)
     00236      *       C(I,J)=CMODE(I,J)
     00237      *       *FIN
     00238      *       DO (J,MAXCON)
     00239      *       FIN
     00240      *       DO (J,MAXCON) CNELEM+1,J)=CMODE(I,J)
     00241      *       DO (J,MAXCON) CNELEM+1,J)=0.0
     00242      *       IF (NELEM+1,J,MAXCON)
     00243      *       DO (J,MAXCON)
     00244      *       *FIN
     00245      *       FILE NAME, SAGE, SEG, FTYPE, DEV, QUC, UUCI
     00246      *       OPEN(UNIT,10) NAME/NAME, FNAME/TYPE=NAME, FORM=UNFORMATTED
     00247      *       OPEN(UNIT,10) NAME=NAME, FNAME=FNAM, TYPE=NAME, FORM=UNFORMATTED
     00248      *       WRITE(9) ISEG
     00249      *       *** CONVERT INPUT VALUES TO THFSE: UNTHY USED BY MODEL ***
     00250      *       *CONV
c     00251      • CALL READ(UNIT,10) NAME/NAME, FNAME/TYPE=NAME, FORM=UNFORMATTED
     00252      *       OPEN(UNIT,10) NAME=NAME, FNAME=FNAM, TYPE=NAME, FORM=UNFORMATTED
     00253      *       WRITE(9) ISEG
     00254      *       *** CONVERT INPUT VALUES TO THFSE: UNTHY USED BY MODEL ***
     00255      *       *CONV
     00256      • DO (J,MAXCON) VET(J)=VET(J) * SECOY
     00257      • DO (J,MAXCON) VET(J)=VET(J) * SECOY
     00258      • DO (J,MAXCON) VET(J)=VET(J) * SECOY
     00259      • DO (J,MAXCON) VET(J)=VET(J) * SECOY
     00260      • DO (J,MAXCON) VET(J)=VET(J) * SECOY
     00261      • DO (J,MAXCON) VET(J)=VET(J) * SECOY
     00262      *       C** C** **TIME STEP LOOP **
     00263      C** C** **TIME STEP LOOP **
     00264      *       *C* C* C* C* C* C* C* C*
     00265      *       *C* C* C* C* C* C* C* C*
     00266      *       *C* C* C* C* C* C* C* C*
     00267      *       *C* C* C* C* C* C* C* C*
     00268      *       *C* C* C* C* C* C* C* C*
     00269      *       *C* C* C* C* C* C* C* C*
     00270      *       *C* C* C* C* C* C* C* C*
     00271      *       *C* C* C* C* C* C* C* C*
     00272      *       *C* C* C* C* C* C* C* C*
     00273      *       *C* C* C* C* C* C* C* C*
     00274      *       *C* C* C* C* C* C* C* C*
     00275      *       *C* C* C* C* C* C* C* C*
     00276      *       *C* C* C* C* C* C* C* C*
     00277      *       *C* C* C* C* C* C* C* C*
```
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00278 C
00279 *** UPDATE THE FLOW AND CONCENTRATION ARRAYS ***
00280 1.
00281 CALL MYFLOCLEM, AREL, AMID, DELZ, DEPTH, DSO, ELEY,
00282 2.
00283 CALL TSFLO(CLTRB, CLTRA, ENDTIM, ETIME, EJPER, DEPTH, NELEM,
00284 3.
00285 IF (EJPER) REPORT=FATAL-ERROR-AND-STOP
00286 4.
00287 CALL TSFLO(CTRB, CTTRA, ENDTIM, ETIME, EPER, DEPTH, NELEM,
00288 5.
00289 IF (EJPER) REPORT=FATAL-ERROR-AND-STOP
00290 6.
00291 WRITE(6,1100)
00292 7.
00293 WRITE(6,1110)
00294 8.
00295 WRITE(6,1120)
00296 9.
00297 WRITE(6,1130)
00298 10.
00299 WRITE(6,1140)
00300 11.
00301 WRITE(6,1150)
00302 12.
00303 WRITE(6,1160)
00304 13.
00305 WRITE(6,1170)
00306 14.
00307 WRITE(6,1180)
00308 15.
00309 WRITE(6,1190)
00310 16.
00311 WRITE(6,1200)
00312 17.
00313 WRITE(6,1210)
00314 18.
00315 IF (EJPER) REPORT=FATAL-ERROR-AND-STOP
00316 19.
00317 WRITE(6,1220)
00318 20.
00319 WRITE(6,1230)
00320 21.
00321 WRITE(6,1240)
00322 22.
00323 WRITE(6,1250)
00324 23.
00325 WRITE(6,1260)
00326 24.
00327 WRITE(6,1270)
00328 25.
00329 WRITE(6,1280)
00330 26.
00331 WRITE(6,1290)
00332 27.
00333 WRITE(6,1300)

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00334 1580    FORMAT('DELEMT AVERAGE CONCENTRATIIONS PRIOR TO RD8FLO')
00335     *** FIN
00336 ** IF (DEPHT<ST, DEPMIN)
00337         IF (ABS(PITUPTH/DEPTH-1.)
00338          IF (DEPHT, 1. AND. T<ST, ZERO)
00339 Oct 1. = PTDEL3, PDX, PXAR, VSET, XAREA)
00340           DO (J=1, MAXCON)
00341          DO (K=1, HELEN)
00342 . . . . . COLD(I,J)=C(I,J)+C(I+1,J)/8.
00343 . . . . . *** FIN
00344 00345      *** FIN
00346 ** IF (ECOBE)
00347         WRITE(0,1590)
00348 . . . . . WRITE(10,1010)
00349 ** IF (COLD(I,J),K=1, MAXCON), J=1, HELEN+1)
00350          WRITE(0,1600)
00351          ** WRITE(0,1110)
00352 . . . . . WRITE(0,1020) (J, (COLD(I,J),K=1, MAXCON), J=1, HELEN+1)
00353 1590  FORMAT('NORMAL CONCENTRATIONS FOLLOWING RD8FLO')
00354 1600  FORMAT('DELEMT AVERAGE CONCENTRATIONS FOLLOWING RD8FLO')
00355     *** FIN
00356 . . . . . *** FIN
00357 . ** COMPUTE WED AND WATER SURFACE ELEVATIONS
00358 . ** FIN
00359 00360 C ** AVERAGE THE INFLOW CONCENTRATIONS INTO THE SEGMENT BY TAKING
00361 . . . . . INTO ACCOUNT THE TERTIARY INPUT.
00362 00363 C ** IF (DEPHT<ST, DEPMIN)
00364 00365 WHEN (INTSN, SMT, 0)
00366 . . . . . IF (INTSN, SMT, NENV, SMT, MEO)
00367 . . . . . DO (K=1, MAXCON)
00368 . . . . . DO (J=1, HELEN+1)
00369 . . . . . DD (J=1, CIN(J,K))
00370 . . . . . DD (J=1, CIN(J,K))
00371 . . . . . CIN(J,K) = CIN(J,K)/2.0
00372 . . . . . \CHASS\(CDUMMY(J)*CDUMMY(J+1))/2.0
00373 . . . . . \CHASS\(CDUMMY(J)*CDUMMY(J+1))/2.0
00374 . . . . . \CHASS\(CDUMMY(J)*CDUMMY(J+1))/2.0
00375 C ** NOTE: CMAB IS IN (KG/KM**3)
00376 00377 C ** WHEN (J,EQ,1)
00378 . . . . . WHEN (K,EQ,7)
00379 . . . . . CCIN(J,K)=CMAB
00380 . . . . . CCIN(J,K)=CMAB
00381 . . . . . *** FIN
00382 . . . . . ELSE
00383 . . . . . \KKE=K
00384 . . . . . IF (K<GT,3) \KKE=K
00385 . . . . . \COEF=0.
00386 . . . . . \CMAB=CMAB
00387 . . . . . \CMAB=CMAB
00388 . . . . . \CMAB=CMAB
00389 . . . . . \CMAB=CMAB
00390 . . . . . *** FIN

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0350     ELSE                  ***FIN
0351     IF (ECHO3)            ***FIN
0352     WRITE(6,1300)          ***FIN
0353     1300     WRITE('AFTER TRIBUTARY INFLOW, CCIN AND QHIN')
0354     ***FIN
0355     ***FIN
0356     1310     FORMAT('ELEMENT/MODE',3(I1,'CONC. OF',K1,'X',I1,'CONC. ')
0357          1,        'ASSOL.',2X,'CONTAMINANT',7X,'FLOW',1/X,'FROM BOTTOM ')
0358          2,        'SUSPENDED BAND SUSPENDED BLY SUSPENDED CLAY WITH ',
0359          3,        'BAND',3X,'WITH CLAY DISSOLED CONC. ',
0360          4,        '2X',1HM=3/BECl ')
0361          5,        8.94
0362          6,        WRITE(6,1320)(J,CCIN(J,K),K=1,MAXCON),QHIN(J,J=1,NCLELI+1)
0363          7,        ***FIN
0364          8,        1320     FORMAT(2X,15,4X,PMSE15,S)
0365          9,        ***FIN
0366          10,       ELSE
0367          11,       DO (J=1,NCLELI)
0368          12,       DO (K=1,MAXCON) CTMB(J,K)=0.0
0369          13,       ***FIN
0370          14,       XTRM=0.0
0371          15,       ***FIN
0372          16,       ELSE
0373          17,       ***DETERMINE THE PROPER PHOTOLYSIS COEFFICIENT TO BE USED ***
0374          18,       JUDEC = JUDEC + DELTH
0375          19,       HSB = HSB(JUDEC,SECYR)
0376          20,       ***CONDITIONAL
0377          21,       (NSP,GE,1),AND,NSP,LE,7948000) IPC = 1
0378          22,       (NSP,GE,7948000),AND,NSP,LE,15947600) IPC = 2
0379          23,       (NSP,GE,15947600),AND,NSP,LE,23760000) IPC = 3
0380          24,       (NSP,GE,23760000),AND,NSP,LE,98760000) IPC = 4
0381          25,       (NSP,LE,0) IPC = N
0382          26,       ***FIN
0383          27,       ***FIN
0384          28,       WHEN (DEPTH,LE,DEPMIN)
0385          29,       ***FIN
0386          30,       ELSE
0387          31,       BECAY = 1.
0388          32,       ***FIN
0389          33,       ***FIN
0390          34,       ***FIN
0391          35,       IF (DECAY(L),L,0)
0392          36,       ***FIN
0393          37,       ***FIN
0394          38,       ***FIN
0395          39,       ***FIN
0396          40,       ELSE
0397          41,       FERKUR = 'FALSE',
0398          42,       ***FIN
0399          43,       ***FIN
0400          44,       ***FIN
0401          45,       ***FIN
0402          46,       ***FIN
0403          47,       ***FIN
0404          48,       ***FIN
0405          49,       ***FIN
0406          50,       ***FIN
0407          51,       ***FIN
0408          52,       ***FIN
0409          53,       ***FIN
0410          54,       ***FIN
0411          55,       ***FIN
0412          56,       ***FIN
0413          57,       ***FIN
0414          58,       ***FIN
0415          59,       ***FIN
0416          60,       ***FIN
0417          61,       ***FIN
0418          62,       ***FIN
0419          63,       ***FIN
0420          64,       ***FIN
0421          65,       ***FIN
0422          66,       ***FIN
0423          67,       ***FIN
0424          68,       ***FIN
0425          69,       ***FIN
0426          70,       ***FIN
0427          71,       ***FIN
0428          72,       ***FIN
0429          73,       ***FIN
0430          74,       ***FIN
0431          75,       ***FIN
0432          76,       ***FIN
0433          77,       ***FIN
0434          78,       ***FIN
0435          79,       ***FIN
0436          80,       ***FIN
0437          81,       ***FIN
0438          82,       ***FIN
0439          83,       ***FIN
0440          84,       ***FIN
0441          85,       ***FIN
0442          86,       ***FIN
0443          87,       ***FIN
0444          88,       ***FIN
0445          89,       ***FIN

8.94
1200 1.

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1720 1.

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2222 1.

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1112 1.

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00502 2.  ; ALEN, QHIN, GOUT, CCLIN, QV, AMID, BND, VSET, DENS, DELTD, DFI,
00503 3.  ; PON, THED)
00504   ; **FIN
00505 C  ;
00506 C  ; HELMPT=NELEM
00507 C  ; PDOPT=DEPTH
00508 C  ; DO [I=1,NELEM)
00509 C  ; = PABAR[I]=SANEA[I)
00510 C  ; = ANID[I]=AMID[I)
00511 C  ; **FIN
00512 C  ;
00513 C  ; ** CHECK BRIDGE SWITCH #2 TO SEE IF THE RUN IS TO BE STOPPED **
00514 C  ; IF [I$EQ,1]
00515 C  ; = CLOSE-THE-OPEN-FILES
00516 C  ; = UOPEN(UNIT=1,NAME='T771')
00517 C  ; = WRITE(1,2) NXEG, IBEQ
00518 C  ; = FORMAT('/2X,1X,*** BEGIN ALPHAabble ***)
00519 C  ; 1, = 3X, TERMINATED BY OPERATOR AFTER TIME PLANE #', I10/
00520 C  ; 2, = 3X, IN SEGMENT #', I15)
00521 C  ; STOP
00522 C  ; **FIN
00523 C  ; END OF TIME STEP LOOP
00524 C  ; NXEG = NXEG + 1
00525 C  ; **FIN
00526 C  ; END OF SEGMENT LOOP
00527 C  ; PELEY = ELEV
00528 C  ; NFST = I
00529 C  ; LUNTMP=INFLO
00530 C  ; INFLO=OUTFLO
00531 C  ; OUTFLO=LUNTMP
00532 C  ; REMIN INFLO
00533 C  ; REMING OUTFLO
00534 C  ; CLOSE(UNIT=1)
00535 C  ; CLOSE(UNIT=2)
00536 C  ; CLOSE(UNIT=3)
00537 C  ; **FIN
00538 C  ; CLOSE-THE-OPEN-FILES
00539 C  ; STOP
00540 C  ;

===============================================

00541 C  ; TO COMPUTE=RED=AND=MATEN=SURFACE=ELEVATIONS
00542 C  ; HELVY = ELEV + BES
00543 C  ; RELN = DEPTH + BELEV
00544 C  ; **FIN

===============================================

00545 C  ; TO CLOSE-THE-OPEN-FILES
00546 C  ; CLOSE(UNIT=1)
00547 C  ; CLOSE(UNIT=2)
00548 C  ; CLOSE(UNIT=3)
00549 C  ; CLOSE(UNIT=4)
00550 C  ; CLOSE(UNIT=5)
00551 C  ; CLOSE(UNIT=9)

B.96
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00552   CLOSE(UNIT1)
00553   CLOSE(UNIT2)
00554   CLOSE(UNIT3)
00555   *FIN

---------------------------------------------

00556   TO REPORT=FAIL=ERROR=AND=STOP
00557   CLOSE=THE=OPEN=FILES
00558   OPEN (UNIT1,NAMES='TT1')
00559   WRITE(1,1)
00560   I     FORMAT('10X','G07.0 G07.0=FAILURE == FATAL ERROR ***
00561   I     1    PRINT *ED,LET FOR DETAILS ***
00562   C     *** THE IF STATEMENT BELOW IS A CONCESSION TO THE COMPILER ***
00563   IF(FAIL) STOP
00564   *FIN

---------------------------------------------

00565   TO RESTART=DATA=TIME=CONTROLS
00566   ENDIC =0
00567   ENUM=0
00568   ENDTAG =0
00569   *FIN

---------------------------------------------

00570   TO SAVE-THE-RESULTS-FOR-TIME-SERIES=ANALYSIS
00571   C     ***
00572   C     *** COMPUTE THE VOLUME OF EACH ELEMENT AND THE TOTAL VOLUME
00573   C     OF THE RATE COLUMN ***
00574   C     ***
00575   C     AVUL=0
00576   DO (1=1,HELEN)
00577     ELVOL(I) = ELZ*ABAR(I)
00578     AVOL=AVOL+ELVOL(I)
00579     *FIN
00580   C     *** AVERAGE DISSOLVED (KG/M=3) ***
00581   C     AVGDS = 0.0
00582   C     AVGDS=AVGDS+(C(I,7)+C(I+1,7))*ELVOL(I)/2
00583   C     AVGDS = AVGDS / AVOL
00584   C     IF (AVGDS *GT, ANALMT)
00585   C     *** AVERAGE SEDIMENT (KG/M=3) ***
00586   C     AVGSE = 0.0
00587   C     AVGSE=AVGSE+(C(I,1)+C(I+1,1)+C(I,2)+C(I+1,2)+
00588   C     AVGSE=AVGSE+(C(I,3)+C(I+1,3))/2
00589   C     ***
00590   C     AVGSE = AVGSE / AVOL
00591   C     *** AVERAGE (PARTICULATE (PC/TRUE))SEDIMENT (KG/M=3) ***
00592   C     PARPC = 0.0
00593   C     DO (I=1,HELEN)
00594   C     PARPC = PARPC +ELVOL(I)*(C(I,4)+C(I,5)+C(I,6)+
00595   B.97
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00549 1. . .  \[C(I+1,4) + C(I+1,5) + C(I+1,6)\]/2
00580 . . .  FIN
00601 . . .  PARPCM = PARPCM / AVOL
00605 C . . .  \[\***:\text{AVERAGE PARTICULATE (PC/KG)}\]**
00604 C . . .  PARPC = PARPC / AVGSEM
00607 C . . .  TOTKG = ( PARPC + AVGDIS )\#AVOL
00608 C . . .  CAVGXM = MAX(CAVGMX, AVGDIS)
00609 . . .  TIFFLW = 0.0
00610 . . .  DO (I=1,NELEM) TIFFLW = TIFFLW + PTOAVG(I)
00611 . . .  TIFFLW = TIFFLW / BEOY
00612 . . .  WRITE(8) ISEG, IRED, TIFFLW, AVGED, AVGDIS, PARPC, PARPC, TOTKG
00613 . . .  ***FIN
00614 C . . .  ***FIN
00615 C . . .  END

---------------------------------------------

PROCEDURE CROSS-REFERENCE TABLE

00565 RESET=DATA-TIME-CONTROLS
00566
00570 SAVE-THE-RESULTS-FOR-TIME-SERIES-ANALYSIS
00571
00576 CLOSE-TIME-OPE-NUM-FILES
00577
00581 COMPUTE-BED-AND-WATER-SURFACE-ELEVATIONS
00582
00587 REPORT=FAULT-ERROR-AND-STOP
00588

(FLECS VERSION 22.46)

---------------------------------------------
SUBROUTINE SETUP(I1, DD, P, B, R, VEL, NELEM, ECHOD, WIDTH)

THIS SUBROUTINE SETS UP THE FINITE ELEMENT MATRICES

CALLED BY TRANS.

LOGICAL= ECHOD

REAL= SEL, P, K, R

INCLUDE 'SIELDIZ.FRM'

DIMENSION DD(10), P(MXELM,3), VEL(2,2), R(MXELM), S(MXELM,3)

SEl(2,2)

PEl(1,1) = 1.0/3.

PEl(1,2) = 1.0/6.

PEl(2,1) = 1.0/6.

PEl(2,2) = 1.0/3.

SEL(1,1) = DD(1) + DD(3) + DD(7)/3.

SELECT(1,2) = DD(1) + DD(4) + DD(7)/6.

SEL(2,1) = DD(1) + DD(5) + DD(7)/6.

SEL(2,2) = DD(1) + DD(6) + DD(7)/3.

IF(SEL(1,1) SEL(1,1) SEL(1,1) VEL)

IF(SEL(2,2) SEL(2,2) SEL(2,2) VEL)

DO (I=1,2)

DO (J=1,2)

PEl(I,J) = SEL(I,J) * WIDTH

BEL(I,J) = SEL(I,J) * WIDTH

FIN

FIN

DD(I*10,1) DD(I) = DD(I) * WIDTH

DD(2*DO(1/2,0)

DO (J=1,2)

MAII + J = I

DD = DO(1,2)

MC = 2*(I + K = 1) - NR

PP(NH,MC) PP(NR,MC) - SEL(J,K)

SEL(J,K)

FIN

FIN

WRITE(NR, MC)

R(NR) + DOZ + DO(B+J)

FIN

IF (ECHOD)

WRITE(NR, MC)

FORMAT(11, 100)

FORMAT(11, 100)

WRITE(1200)

1000

WRITE(1200)

1000

WRITE(1200)

1000

WRITE(1200)

1000

WRITE(1200)

FIN
RETURN

END
SUBROUTINE SHEAR(DEPTH, D50, STRESS, USTAR, VEL)

C THIS SUBROUTINE CALCULATES BED SHEAR STRESS AND SHEAR VELOCITY FOR
A SEDIMENT LADEN FLOW. METHOD IS APPLICABLE FOR RESERVOIRS.

REF. HYDRAULICS OF SEDIMENT TRANSPORT BY K.H. GHAH, YS 849

C FORMAL PARAMETERS:
C DEPTH = FLOW DEPTH (METERS)
C D50 = MEDIAN BED SEDIMENT DIAMETER (METERS)
C STRESS = BED SHEAR STRESS (KG/M^2)
C USTAR = SHEAR VELOCITY (M/SEC)
C VEL = AVERAGE VELOCITY (M/SEC)

C CALLED BY: HYDFLO, ICFO

RHO = WATER DENSITY (KG(FORCE)/M^3)
DATA RHO /10001/;

AKAPPA = KAMMAN CONSTANT
DATA AKAPPA /0.41/;

USTAR=VEL/(17.64+((ALUG1V(DEPTH/(D50*.5)))*.31/AKAPPA))

RETURN
END

(FLECS VERSION 22.48)
SUBROUTINE SHEAR(LEN,ELEV, MRAH, PELEV, SLOPE, STRESS, USTAR)

C THIS METHOD OF COMPUTING BED SHEAR STRESS AND SHEAR VELOCITY
C IS APPLICABLE TO RIVERS AND STREAMS.

C FORMAL PARAMETERS:

C ALEN = SEGMENT LENGTH
C ELEV = ELEVATION OF THE CURRENT SEGMENT
C MRAH = HYDRAULIC RADIUS OF THE SEGMENT
C PELEV = ELEVATION OF THE PREVIOUS SEGMENT
C SLOPE = BED SLOPE
C STRESS = BED SHEAR STRESS
C USTAR = SHEAR VELOCITY

C CALLED BY MYOFLO

C G = GRAVITY (M/SEC**2)
C MHO = DENSITY OF WATER (KG/FORCE)/M**3

DATA MHO/1000./
DATA G/9.801/

SLOPE = (PELEV - ELEV) / ALEN
STRESS = SLOPE * MHO * MRAH
USTAR = SIGMA (G * SLOPE * MRAH)

RETURN
END

---

B.102
SUBROUTINE SLCLA(ARAH, B, RDLV, CCIN, DELTD, DELZ, DEPTH, NENS, DBHR, ENDR, NDAJ, NDBD, COLD, HELM, PQR, WMIN, QMOUT, SCMHR, STRESS, VSET, XYB, DEPO, ILAYR, BD, BN, XNT, CRCSEC, B*10, ALEN, ECHO7, BCOUR)

C
THIS SUBROUTINE COMPUTES THE RATE AND SOURCE TERMS FOR THE TRANSPORT OF SILT (J1=2) AND CLAY (J1=3)

C
INPUT PARAMETERS:

C
ARAH = AVERAGE AREA
B = BED CONDITIONS
RDLV = STANDARD BED LAYER THICKNESS
CCIN = CONCENTRATION OF INFLOW
HEL0 = TIME STEP (DAY)
HELM = STANDARD ELEMENT THICKNESS
DEPH = DEPTH OF FLOW
CCHR = CRITICAL SHEAR STRESS FOR DEPOSITION
ENDR = ENDUAHILITY, (KG/M**2/SEC)
KRAJ = HYDRAULIC RADIUS
JI = Ji: Silt, #2: Clay
HEPL = NUMBER OF BED LAYERS
HELE = NUMBER OF ELEMENTS
POJ = POROSITY
OHIN = INFLOW DISCHARGE
QHOUT = OUTFLOW DISCHARGE
SCBH = CRITICAL SHEAR STRESS FOR SCOUR
STRESS = BED SHEAR STRESS
VSET = PARTICLE SETTLING VELOCITY
XV50 = THICKNESS OF TOP BED LAYER

C
OUTPUT PARAMETERS:

C
ILAYH = NO. OF BED LAYERS AFFECTED BY DEPOSITION AND EROSION
BD = DEPOSITION RATE, (KG/(PC)/M**3/DAY)
BN = EROSION RATE, (KG/(PC)/M**3/DAY)
XNT = HEIGHT OF TOP BED SEDIMENT LAYER, (KG/M**2)
DEPO = BED DEPOSITION RATE (KG/(PC)/M**2/DAY)
BCOUR = BED SCOUR RATE (KG/(PC)/M**2/DAY)
C
C
C
CALLED BY1 TRANSP
C
CALLED DEPCAL
C
C
INCLUDE 'ELM52Z,PKM1
C
C
REAL KAFUNC,KJ,INFRA
C
LOGICAL*1 ECHO7
C
C
DIMENSION ARAH(MAXELE), B(MAXLEV,MAXCON-1), CULU(MAXELE,MAXCON),
RDN(3), DBHR(3), EDR2(3), ILAYH(3),
CRSCD(MAXELE), QMOUT(MAXELE), BSCHR(3),
CCIN(MAXELE,MAXCON), RHO(MAXELE), DEPO(6), BCOUR(6)

B.103
**DATA SEGMENT**

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00050  C  J2=J1+1
00051  C  XNT(J1)=0.
00052  IF (NBED+LT,0).
00053  XTOP((1,0+P03)/(B(NBED,1)/DEN$1)+B(NBED,2)/DEN$2)
00054  IF (NBED,S)/DEN$3)
00055  C  XNT(J1) = XTOP * R(NBED,J1) * XBO
00056  ***FIN
00057  DEPN(J1) = 0.0
00058  DEPO(J2) = 0.0
00059  SR(J1) = 0.0
00060  SR(J2) = 0.0
00061  SCOM(J1) = 0.0
00062  SCOM(J2) = 0.0
00063  RB = 0.0
00064  CG = 0.0
00065  VOLUME = CROGIC + ALEM
00066  DO (1X = 1,NELEM)
00067  SD(IX,J1) = 0.0
00068  SN(IX,J2) = 0.0
00069  ***FIN
00070  ILAYR(J1) = 0
00071  IF(ECHUT)
00072  C  IF (STRESS,LT, OHMR(J1))
00073  C  SEDIMENT DEPOSITION
00074  C  ILAYR(J1) = 1
00075  AVGC = 0.0
00076  TOTW = 0.0
00077  DU (IX = 1,NELEM)
00078  C  IT IS IMPLICITLY ASSUMED THAT A DOWNSTREAM CORRANT NUMBER
00079  C  AT OR NEAR UNITY IS EMPLOYED IN THIS ANALYSIS
00080  C  INFrac0$SUMMIN(IX)*DELTD/AVG(X)/DELZ
00081  C  EXFHAC0=INFRC
00082  TOTD = TOTD + INFRC*MIN(IX)*EXFHAC*QHOUT(IX)
00083  AVG0=AVGC*INFRC*MIN(IX)*(CINC(IX,J1)+CINC(IX+1,J1))/Zs
00084  I = EXFHAC*QHOUT(IX)*CULD(IX,J1)
00085  ***FIN
00086  C  AVGC = AVG / TOTD
00087  C  DEPO(J1) = VSET(J1) * AVG * (1.0-(STRESS/DHMR(J1)))
00088  C  RATE = DEPO(J1) * SHIND(I) * ALEM / VOLUME
00089  C  DO (K = 1,NELEM)
00090  C  SD(K,J1) = RATE
00091  C  VOLK = AAR(K) * DELZ
00092  C  INFRC0=MIN(K)*DELTO/VOLK
00093  C  EXFHAC0=INFRC
00094  C  B=INFRC*MIN(K)*((CINC(K,J1)+CINC(K+1,J1))/Zs)
00095  I = EXFHAC*QHOUT(K)*CULD(K,J1)
00096  C  CONT*INFRC=MIN(K)*((CINC(K,J2)+CINC(K+1,J2))/Zs)
00097  C  ***FIN

**B.104**
00110  RATEK * RATE * VOLK
00111  BK(J2) = RATEK / BED / VOLK * CONT
00112  DEP(J2) = DEP(J2) + RD(K,J2) / BMID(J1) * VOLK
00113  ***FIN
00114
00115  IF (STRESS / UT. > B0MR(J1) .STUt. NBED. GT. 0)
00116  C BEDIMENT SCOURING
00117  C
00118  RS = BMWDE(J1) * BETADAY * (STRESS / BM0R(J1)) = 1.0
00119  ILYR(J1) = 0
00120  C
00121  C COMPUTE AVAILABILITY OF GRAVITE SEDIMENT IN BED LAYERS.
00122  C MAXIMUM NUMBER OF LAYERS SCOURED IS RESTRICTED BY BAND SCOURING.
00123  C
00124  RS = RS * DELTO
00125  WHEN LNYR(J1) = GT. 0 .AND. ILYR(J1) .LT. 01 )
00126  RS = AMINI(RS,XLYR(J1))
00127  CS = RS = B(NBED,J2)
00128  XNT(J1) = XNT(J1) = RS
00129  ***FIN
00130  ELSE
00131  FACBN(MUSD,J2)
00132  RBSRH = RS
00133  WB = 0
00134  I40  ILYR(J1) = ILYR(J1) + 1
00135  NB = MUSD = ILYR(J1)
00136  RBSRH = RBSRH = XNT(J1)
00137  WB = R3 + XNT(J1)
00138  CS = C6 = FACNXNT(J1)
00139  XNT(J1) = 0.0
00140  FAC = 0.0
00141  IF (NB, NE, 0)
00142  YNM(J1) = NB1/J(B(NB,1) - B(NB,2) - B(NB,3) - B(NB,4))/NB
00143  XNT(J1) = SOLV * B(NB,1) * 1ND
00144  FAC = B(NB,2)
00145  ***FIN
00146  C
00147  IF (ILYR(J1),EQ,0) XLYR(J1) GO TO 155
00148  IF (RBSRH,GE,XNT(J1),AND,ILYR(J1).GT,ILYR(J1))
00149  GO TO 140
00150  ***FIN
00151  C
00152  155  CONTINUE
00153  DEL = AMIN(RSUSP,2XNT(J1))
00154  WB = RS * DEL
00155  CS = CS + DEL * FAC
00156  XNT(J1) = XNT(J1) * DEL
00157  ***FIN
00158  C
00159  SCOUR(J1) = RS / DELTO
00160  BCOUN(J2) = CS / DELTO
00161  BR(J1) = RS / DELTO * XNYR(J1) * ALEN / VOLUME
00162  BS(J2) = CS / DELTO * XNYR(J1) * ALEN / VOLUME
00163  C
00164  ***FIN
00165  RETURN

B.105
SERAKRA POST PROCESSING PROGRAM

---

00001 C
00002 C (10L,5)BPPM.FLP
00003 C
00004 C SERAKRA POST PROCESSING PROGRAM
00005 C
00006 C
00007 C THIS PROGRAM IS USED TO MANIPULATE THE RESULT FILES FROM THE
00008 C SEDIMENT TRANSPORT MODEL, SERAKRA. LISTED BELOW ARE THE FUNCTIONS
00009 C THAT IT CAN PERFORM:
00010 C
00011 C (1) LIST = READ THE SPECIFIED FILES AND PRINT PROPER MATRICES.
00012 C
00013 C "CALLS: GETSPC, LISTER"
00014 C
00015 C
00016 C BYTE FILMAM(30),PASE(5),EXT(3),DEV(3),GUIC(3),UUIC(3)
00017 C
00018 C INTEGER#2 NREGER,UNITS
00019 C INTEGER#4 BEGIN,LSTIM
00020 C
00021 C
00022 C LOGICAL#1 LIB1,CHAIN
00023 C
00024 C DATA FILMAM(29),FILNAM(30),LPAT, "T"
00025 C
00026 C CALL GETSPC(3ABE,REGSEG,BEGIN,CHAIN,EXT,DEV,FILNAM,GUIC,INTSEG,
00027 C 1, BEGIN,LSTIM,LSTIM,STEP,UNITS,UUIC)
00028 C
00029 C LIST = TRUE,
00030 C CALL LISTER(3ABE,REGSEG,BEGIN,CHAIN,EXT,DEV,FILNAM,GUIC,INTSEG,
00031 C 1, BEGIN,LSTIM,LSTIM,STEP,UNITS,UUIC)
00032 C
00033 C STOP
00034 C END

---

(FLECS VERSION 2.41)

B.107
SUBROUTINE BTRUPR(BABE, DEV, ECHO, FNAM, FTYPE, QUIC, IMPFL,  
        1  IBIT, NFIRST, OUTFLO, SMTH, UIUC,  
        2  SAVech, JSEG, NSTEPS, NSEG, ITPT, ANALY,  
        3  DELT, ANALYT, DMEM, SIMLEN, PELEV)

THIS ROUTINE IS RESPONSIBLE FOR THE INTERACTIVE I/O AND OPENING THE  
PROPER FILES,

FORMAL PARAMETERS:

BASE = 5-CHARACTER BASE FILE NAME (BYTE)
DEV = BASE OUTPUT FILE DEICE (BYTE)
ECHO = LINE PRINTER ECHO CONTROL VARIABLE (L#1)
SMTH = ECHO CONTROL FOR SET-UP OF ELEMENT MATRIX
SAVech = ECHO CONTROL FOR INFLUENT CONCENTRATIONS
SAVech = ECHO CONTROL FOR SETUP OF ELEMENT MATRIX
SAVech = ECHO CONTROL FOR GEOMETRY AND CONCENTRATIONS
SAVech = ECHO CONTROL FOR ROBFLU, BEFORE AND AFTER
SMTH = ECHO CONTROL FOR SEDIMENTATION
SAVech = ECHO CONTROL FOR DIAGNOSTICS WITHIN SAND, BILCLA
SAVech = ECHO CONTROL FOR PRINTOUT OF SEDIM. DEPOSITION DETAIL
SAVech = ECHO CONTROL = UNDEFINED = TRANSFER TO TRANSP
SAVech = ECHO CONTROL = UNDEFINED
SAVech = ECHO CONTROL = UNDEFINED
SAVech = ECHO CONTROL FOR DEPOSITION FILE (BYTE)
SAVech = BASE OUTPUT FILE EXTENSION (BYTE)
QUIC = GROUP NUMBER FROM UIUC OF BASE FILE NAME (BYTE)
INFLO = LUN NUMBER TO THE DATA FROM THE PREVIOUS SEGMENT
IBIT = STARTING SEGMENT NUMBER
NFIRST = STARTING TIME PLANE NUMBER (I#9)
OUTFLO = LUN NUMBER TO THE FILE RECEIVING THE RESULTS OF THE
CURRENT SEGMENT (I#2)
SMTH = METHOD TO BE USED TO CALCULATE THE SAND CAPACITY (BYTE)
UIUC = USE NUMBER FROM UIUC OF BASE FILE NAME (BYTE)

CALLED BY SI5 BEATRA

DATA FTYPE, FNAME

DATA YES,NO

DATA YES/NO/

C     DECLARE COMMON BLOCK NAMES

BYTE ANSWER,YES,NO,FNAME(29),FTYPE(3),DEV(3),QUIC(3),UIUC(3),  
BABE(5),SMTH,IMPL(30)

INTENDE4 OUTFLO

INTENDE4 NFIRST,SIMLEN,NSTEPS

LOGICAL ECHO,SAVech,WRITSEG,ANALY

DIMENSION JSEG(4),SAVech(10)

DATA FRAME/

DATA YES/NO/

DATA WRITE/FILE/

DATA WRITSEG,FALSE/
WRITE(9,4) ANS$H
00070 IF (ANS$H.EQ., 'YES') SAVECH(4) = 'TRUE
00074 C WRITE(9,7)
00075 HEAD(8,4) ANS$H
00076 IF (ANS$H.EQ., 'YES') SAVECH(5) = 'TRUE
00079 C WRITE(9,10)
00080 HEAD(8,4) ANS$H
00081 IF (ANS$H.EQ., 'YES') SAVECH(6) = 'TRUE
00084 C WRITE(9,11)
00085 HEAD(8,4) ANS$H
00086 IF (ANS$H.EQ., 'YES') SAVECH(7) = 'TRUE
00089 C WRITE(9,12)
00090 HEAD(8,4) ANS$H
00091 IF (ANS$H.EQ., 'YES') SAVECH(8) = 'TRUE
00094 C WRITE(9,13)
00095 HEAD(8,4) ANS$H
00096 IF (ANS$H.EQ., 'YES') SAVECH(9) = 'TRUE
00099 C WRITE(9,14)
00100 HEAD(8,4) ANS$H
00101 IF (ANS$H.EQ., 'YES') ORSCON = 'TRUE
00105 C WRITE(9,15)
00108 ELSE
00109 WRITE(9,16)
00112 * WRITE(9,17) (JSEG(J), J=1,5)
00115 * FIN
00118 C
00110   WRITE(B,19)
00111   READ(A,2) NCHR,(INPFL(1),INL,NCHR)
00112   INPFL(NCHR+1) = 0
00113   OPEN(UNIT=2,NAME=INPFL,TYP=9,FORM=UNFORMATTED)
00114   C
00115   WRITE(B,20)
00116   READ(A,17) IJNT
00117   C
00118   WRITE(B,21)
00119   READ(A,17) ITOK
00120   C
00121   WRITE(A,22)
00122   READ(A,17) IPK
00123   C
00124   WRITE(A,23)
00125   READ(A,17) ITPK
00126   C
00127   WRITE(A,24)
00128   READ(A,17) ITPM
00129   C
00130   WRITE(A,25)
00131   READ(A,4) ANSWER
00132   IF(ANSWER.EQ.YES) ANALYST = TRUE
00133   C
00134   WRITE(A,26)
00135   READ(A,27) DELTA
00136   C
00137   BIMLEN = DELTH * NSTEPS
00138   C
00139   WRITE(A,28)
00140   READ(A,27) ANALYT
00141   C
00142   WRITE(A,29)
00143   READ(A,27) JEPKIN
00144   C
00145   WRITE(A,30)
00146   READ(A,27) PEKEY
00147   C
00148   ...FIN
00149   ELSE
00150   NFORMS = 1
00151   IF INM = 1
00152   OPEN(UNIT=2,NAME=DUMMY,D11,TYP=9,FORM=UNFORMATTED)
00153   ***FIN
00154   END UNIT 1
00155   INFORM = 2
00156   UNIT = 3
00157   OPEN(UNIT=3,NAME=UNMK,D12,TYP=9,FORM=UNFORMATTED)
00158   OPEN(UNIT=4,NAME=HYDROLOGIC,TYP=9,FORM=UNFORMATTED)
00159   OPEN(UNIT=5,NAME=INITIAL,TYP=9,FORM=UNFORMATTED)
00160   OPEN(UNIT=6,NAME=START,TYP=9,FORM=UNFORMATTED)
00161   RETURN
00162   C
00163   * FORMAT **
00164   1 FORMAT('ENTER NAME OF INPUT FILE')
00165   2 FORMAT('000')
00166  3 FORMAT('DO YOU WANT THE INPUT FILE ECHOED (Y OR N)?')
00167  4 FORMAT(29911)
00168  6 FORMAT('ENTER BASE FILE NAME')
00169  7 FORMAT(' WHICH SAMPLING METHOD IS TO BE USED?')
00170  9 'ENTER t (TOPOGRAPHY) OR C (COLEY)'
00171  8 FORMAT('DO YOU WANT SEPARATE HEADINGS ECHOED (Y OR N)?')
00172  9 FORMAT('DO YOU WANT INFLUENT CONCENTRATIONS ECHOED (Y OR N)?')
00173 10 FORMAT('DO YOU WANT ELEMNT MATRICES ECHOED (Y OR N)?')
00174 11 FORMAT('DO YOU WANT GEOMETRY AND CONCENTRATIONS ECHOED (Y OR N)?')
00175 12 FORMAT('DO YOU WANT CONCENTRATION ECHOED BEFORE AND AFTER RENormalization')
00176 13 FORMAT('DO YOU WANT SCOUR/Deposition TO OCCur? (Y OR N)?')
00177 14 FORMAT('DO YOU WANT COMPLETE SCOUR/Deposition INFORMATION?')
00178 15 'RECompUte? (Y OR N)'
00179 16 FORMAT('DO YOU WANT COMPLETE ECHO INFORMATION FOR ALL?')
00180 17 'ENTER SEGMENT NUMBER' (Y OR N)
00181 18 FORMAT('DO WHICH SEGMENT DO YOU WANT COMPLETE ECHO?')
00182 19 FORMAT('ENTER INFORMATION? (MAXIMUM OF 5)')
00183 20 FORMAT('ENTER NUMBER TO BE A RESTART OF A PREVIOUS RUN (Y OR N)?')
00184 21 FORMAT('ENTER NAME OF RESTART FILE')
00185 22 FORMAT('ENTER THE BEGINNING SEGMENT NUMBER')
00186 23 FORMAT('ENTER THE ENDING SEGMENT NUMBER')
00187 24 FORMAT('ENTER THE BEGINNING TIME PLANE NUMBER')
00188 25 FORMAT('ENTER THE ENDING TIME PLANE NUMBER')
00189 26 FORMAT('ENTER THE TIME INCREMENT')
00190 27 FORMAT(F20.0)
00191 28 FORMAT('ENTER THE MINIMUM CONCENTRATION LIMIT?')
00192 29 FORMAT('ENTER THE MINIMUM DEPTH LIMIT?')
00193 30 FORMAT('ENTER THE UPSTREAM ELEVATION?')
00194 31 C
00195 32 END

(FLECS VERSION 22.4b)
SUBROUTINE TOFFALETL (LEN, D50, G00, HRAD, GTOT, SLOPE, TPR, VOL, YET, G04, G05, G06, G07, G08, G09, YH, YL)

C THIS SUBROUTINE USES TOFFALETTL'S METHOD TO CALCULATE THE CAPACITY
OF THE FLOW TO TRANSPORT BAND, A SUMMARY OF THIS METHOD CAN BE
FOUND IN THE ASCE 1975 EDITION OF "SEDIMENTATION ENGINEERING"

C PAGE 209 = 211.

C

C FORMAL PARAMETERS:
C ALEN - SEGMENT LENGTH
C D50 = MEDIAN BED SEDIMENT DIAMETER (METERS)
C G01 = TOTAL CAPACITY OF THE SEGMENT (KG/DAY/M)
C HRAD = HYDRAULIC RADIUS
C GTOT = TOTAL FLOW IN THE SEGMENT
C SLOPE = ENERGY OR RIVER BED SLOPE
C TPR = WATER TEMPERATURE
C VOL = VOLUME
C YET = SETTLING VELOCITY
C YHL = CALLED Y1 BAND

C REAL KAFUN, KG
C DIMENSION VSET(3)

C HRAO = HYDRAULIC RADIUS
C QHRO = TOTAL QUANTITY WITHIN THE SEGMENT
C SLOPE = ENERGY OR RIVER BED SLOPE
C TPR = WATER TEMPERATURE
C VOL = VOLUME
C YET = SETTLING VELOCITY

C FOR WATER TEMPERATURES GREATER THAN 32F AND LESS THAN 100F
C THE KINEMATIC VISCOSITY CAN BE WRITTEN AS THE FOLLOWING:

C VIS = 1065e-9 * (TMPR ** 0.864)

C ASSUMING THE D50 GRAIN SIZE (DIAM) IS APPROXIMATELY
C EQUAL TO THE GEOMETRIC MEAN GRAIN SIZE AND BDIAM = 1.5,
C THE D50 GRAIN SIZE CAN BE DETERMINED TO BE 1.17 * D50.

C THE MANNING-BRICKLER EQUATION IS USED HERE TO
C DETERMINE THE HYDRAULIC DIAMETRIC COMPONENT DUE TO
C GRAIN ROUNINESS (DIAM), TAKEN FROM THE 1975 ASCE
C "SEDIMENTATION ENGINEERING", PG. 128.

B.112
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C 0055 C SUBSTITUTIONS ARE MADE IN EQUATION 2.141 FOR SHEAR VELOCITY
C 0046 C AND K(SUBS). THE FORMULA IS REPLACED BY EQUATION 2.142, AND
C 0047 C THE LATTER BY DESUBS.
C 0048 C
C 0049 C 4PMFm(F**1.9) = (0.65 * 0.25) / (SLOPE ** 0.75) * 0.06349
C 0050 C USUBS(APMFR) = SLOPE ** 52.32 ** 0.5
C 0051 C AFUNCT(V**1 = 1.05) ** 0.333 / (1 + 0.0 UB1AH)
C 0052 C
C 0053 C CONDITIONAL
C 0054 C 4 (AFUNCT,LE,0.500) AC = (AFUNCT/4.009)** = 1.49
C 0055 C (AFUNCT,LE,0.600) AC = (AFUNCT/0.3036)**0.67
C 0056 C (AFUNCT,LE,0.700) AC = (AFUNCT/0.29)**4.17
C 0057 C (AFUNCT,LE,1.25) AC = 48.5
C 0058 C (AFUNCT,GT,1.25) AC = (AFUNCT/0.104)**2.74
C 0059 C ***FIN
C 0060 C
C 0061 C 4AFUNCT*AFUNCT * SLOPE * 0.65 * 1.05
C 0062 C
C 0063 C CONDITIONAL
C 0064 C (AFUNCT,LE,0.25) K4 = 1.0
C 0065 C (AFUNCT,LE,1.30) K4 = (AFUNCT**1.10)**4.51
C 0066 C (AFUNCT,LE,1.39) K4 = (AFUNCT**1.05)**4.09
C 0067 C ***FIN
C 0068 C
C 0069 C 4AC = AC = K4
C 0070 C IF (ACK4 .LT. 1.0)
C 0071 C 4AC = AC = 1.0
C 0072 C ELSE
C 0073 C 4AC = AC = K4
C 0074 C ***FIN
C 0075 C
C 0076 C DCZUM1.0 + CVN = 1.5 * ZI
C 0077 C DCZM1.0 + CVN = ZI
C 0078 C DCZM1.0 + CVN = 0.754 * ZI
C 0079 C ZI-CNVC = 0.754 * ZI
C 0080 C ZH=ZINV
C 0081 C ZM=ZINV
C 0082 C ZM=ZINV
C 0083 C ZH=ZINV
C 0084 C ZH=ZINV
C 0085 C ZH=ZINV
C 0086 C ZH=ZINV
C 0087 C ZH=ZINV
C 0088 C ZH=ZINV
C 0089 C ZH=ZINV
C 0090 C ZH=ZINV
C 0091 C
C 0092 C CL1 HAS BEEN MULTIPLIED BY 1.0630 TO KEEP IT FROM
C 0093 C EXCEEDING THE COMPUTER OVERFLOW LIMIT
C 0094 C
C 0095 C WHEN(DCL=ALDG10(2.0*FDIAM)=20.0,GT,38.0) CL1=0.0
C 0096 C ELSE
C 0097 C CL1=(1.0*20.0)*CN397*DCZL*CVN ** Z.5333 / FMNAD ** (ZM) /
C 0098 C 1. ((ZM+AC+K4*FDIAM)**1.667) / (ZM+AC+CVN) /
C 0099 C 2. (FMNAD/11.24) ** (ZM=20.0/ALUG10(FMNAD/11.24)) =
C 0100 C 3. ((ZM*FDIAM)**(DCZL=20.0/ALUG10(2.0*FDIAM)))
C 0101 C ***FIN
C 0102 C WHEN(CL1,LE,0.0) CL1=0.0
C 0103 C ELSE
C 0104 C CL1=(2.0*FDIAM*FMNAD)**(Z0=30.0/ALUG10(2.0*FDIAM*FMNAD))
C 0105 C ***FIN
C 0106 C
C 0107 C CHECK TO SEE IF THE CALCULATED VALUE IS REASONABLE
C 0108 C (< 100.0), AND ADJUST IF IT IS NOT.
C 0109 C

B.113
00110 IF(CZU.GI.*100.0) CLZ=CLZ+100.0/CZU
00115 C CHI HAS BEEN MULTIPLIED BY 1.0E10 TO KEEP IT FROM
00116 C EXCEEDING THE COMPUTER OVERFLOW LIMIT
00117 C
00118 C
00119 C IN THE WEIGHT FRACTION OF TOTAL SAND THAT THE I-TH
00120 C SIZE FRACTION CONTAINS. SINCE WE ARE MODELING ALL
00121 C SAND AS A SINGLE SIZE FRACTION = PIUBCl). 0 AND
00122 C HENCE DOES NOT APPEAR IN THE MODEL EQUATIONS.
00123 C
00124 C
00125 C WHEN(ELI,ER,0,0) CHIM=0
00126 ELSE
00127 C CHIN=Z*CLI*(1.0+CNV) + V*(PHRAD*Z12)
00128 C
00129 C
00130 C
00131 C
00132 C
00133 C
00134 C
00135 C C INSTALLS TRANSPORT CAPACITY OF THE UPPER LAYER
00136 C
00137 C
00138 C
00139 C
00140 C
00141 C
00142 C
00143 C
00144 C
00145 C
00146 C
00147 C
00148 C
00149 C
00150 C
00151 C
00152 C
00153 C
00154 C
00155 C
00156 C
00157 C C TOTAL CAPACITY OF THE SEGMENT (HSI HAS UNITS OF TONS/DAY/FT)
00158 C
00159 C
00160 C
00161 C
00162 C
00163 C
00164 C
00165 C
00160   YU = HRAD / 2.5
00165   YM = HRAD / 11.29
00168   YL = Z / L5U
00169   G0 = G(5) = CONS13
00170   C
00171   RETURN
00172   END

(FLECS VERSION 22.46)
00001 SUBROUTINE TRANSFER(PEROH,PCOF,BYID,AM,ABAR,DEPTH,OLDC,ECHO, 
00002 CRUDE,ECHO7, ECHO8, ECHO9)
00003 C THIS ROUTINE SOLVES THE MASS TRANSPORT EQUATIONS BY AN IMPLICIT
00004 C FINITE-ELEMENT METHOD. A CRANK-NICHOLSON METHOD IS USED TO
00005 C APPROXIMATE THE SOLUTION THROUGH TIME.
00006 C
00007 C VARIABLE DEFINITIONS:
00008 C
00009 ALM = SEGMENT LENGTH
00010 AREA = ELEMENT AREAS
00011 H = BED CONDITIONS
00012 HLV = STANDARD RED LAYER THICKNESS
00013 HED = BED THICKNESS
00014 C = WATER CONDITIONS
00015 CCIN = CONCENTRATION OF INFLUX
00016 COLD = CELL-CENTERED CONCENTRATION
00017 CHU$n = TOTAL CROSS-SECTIONAL AREA, m$2
00018 DECAY = FIRST ORDER DECAY
00019 DELT = TIME STEP (SECONDS)
00020 DLT$ = STANDARD ELEMENT THICKNESS
00021 DENS = DENSITY
00022 DFZ = DIFFUSION COEFFICIENT
00023 DIAM = DIAMETER
00024 DSSN = CRITICAL SHEAR STRESS FOR DEPOSITION
00025 DSO = MEDIAN BED ELEMENT DIAMETER (m)
00026 ENVO = ERODABILITY
00027 FERROR = FATAL ERROR FLAG (L#1)
00028 HMAQ = HYDRAULIC MOUTH
00029 I = LIGHT EXTINCTION COEFFICIENT OF WATER
00030 KATZ = LIGHT EXTINCTION OF SUSPENDED SEDIMENT IN WATER
00031 NRED = NUMBER OF BED LAYERS
00032 NELEM = NUMBER OF ELEMENTS
00033 PCOF = FIRST TERM OF THE PREDICTION RATE OF CHANGE EQUATION
00034 POR = POROSITY
00035 QIN = INFLUX DISCHARGE
00036 QOUT = OUTFLOW DISCHARGE
00037 UY = VERTICAL DISCHARGE
00038 SC$$H = CRITICAL SHEAR STRESS FOR SCURR
00039 SLOPE = ENERGY ON RIVER BED SLOPE
00040 SMETH = CONTROL VARIABLE TO SELECT THE METHOD TO BE USED
00041 SPHEN = WHEN COMPUTING THE SAND CARRYING CAPACITY. (BYTE)
00042 SP = SEDIMENT EROSION RATE
00043 STRESS = NEW SHEAR STRESS
00044 TEMPR = WATER TEMPERATURE
00045 VOL = VOLUME
00046 VSIN = PARTICLE SETTLING VELOCITY
00047 VSO = THICKNESS OF TOP BED LAYER
00048 C
00049 C CALLED BY: BAPRAT
00050 C CALLS: UHMD, BEMHD, COLAPS, CUNH, VISLRY, FALL, PRTC, SAND, 
00051 C BEMDE, SETUP, UICSAL, THID
00052 C
00053 INCLUDE 'FELSIZ'
00004 C
00005  LOGICAL I, PRAIN, ECHO2, ECHU7, ECHOB, ECHO9
00006 REAL*8 PRAIN, H, B
00007 C
00008 DIMENSION (NMELEM), AREA(NMELEM), O0(10), ILAYR(3), P(NMELEM), 3,
00009 1 R(NXLEM), 3(NXLEM), 3(6XLEM,3), 30(NXLEM,6),
00010 2 S(4), X1(3), Z(NXLEM), 410(NXLEM), ANI0(NXLEM)
00011 5 , DLOC(NXLEM, MAXCON), DEP(N), SCOUR(N), BEDB(3)
00012 C
00013 INCLUDE 'INANG.COM'
00014 C
00015 DATA EPS1/L,DE=30/
00016 C
00017 MP1 = MELEN + 1
00018 MM1 = MELEN + 1
00019 C
00020 *** PERFORM CALCULATION OVER THE TIME STEP DELT ***
00021 C
00022 DELTO = DELTH / 60.00,
00023 C
00024 IF (MP1.LE.1) THEN
00025  DO (NM1, MKCON)
00026     DO (NL1 = 1, MP1)
00027     DO (NM2 = 1, MM1)
00028     DO (NL2 = 1, MP1)
00029     DO (NM3 = 1, MM1)
00030     DO (NL3 = 1, MP1)
00031     IF (NL1.NE.1) THEN
00032     IF (NL2.NE.1) THEN
00033     IF (NL3.NE.1) THEN
00034     ***FIN
00035     ***FIN
00036     ***FIN
00037     ***FIN
00038     ***FIN
00039     ***FIN
00040 C
00041 C
00042 C
00043 C
00044 C
00045 C
00046 C
00047 C
00048 C
00049 C
00050 C
00051 C
00052 C
00053 C
00054 C
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00091 C
00092 C
00093 C
00094 C
00095 C
00096 C
00097 C
00098 C
00099 C
00100 C
00101 C
00102 C
00103 C
00104 C
00105 C
00106 C
00107 C
00108 C
00109 C

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00110          WRITE(10,1020) J,ILAY(1),DEPO(1),DEPO(4),SU(1,1),XNT(1),
00111           (SU(1,9),II,HELEM)
00112   1.                 ***FIN
00113
00114           ELSE
00115           WRITE(6,1015) J,ILAY(1),BCOUR(1),BR(1),XNT(1),BCOUR(4),SK(4),
00116           (SU(1,9),II,HELEM)
00117   1.                 ***FIN
00118   2.                 (SU(6,15),7)
00119   1.                 ***FIN
00120          ***FIN
00121
00122          1020          FORMAT('FIN TRANSP FOLLOWING BILT')
00123   1.                 ***FIN
00124     (2)
00125          CALL SICLCL(ABAR, A, BOIV, CCIN, DELTO, DELZ, DEPTH, USEK),
00126     1.          SHRK, ENDOE, MRAD, Z, SBOC, ECOLOR, PUN, OMIN,
00127          2.          GHOUT, SCSHR, STRESS, VSET, XTOO, DEPO, ILAY,
00128     3.          SD, SH, XNT, CHOBEC, B40D, ALEM, ECOUT, ACWUM)
00129
00130          WRITE(6,1020)
00131   1.          WHEN(ILAY(2),LT,0)
00132          WRITE(6,1020) J,ILAY(2),DEPO(2),DEPO(5),BD(1,2),XNT(2),
00133   (SU(11,6),II,HELEM)
00134   1.                 ***FIN
00135             ELSE
00136          WRITE(6,1015) J,ILAY(2),BCOUR(2),BR(2),XNT(2),BCOUR(5),SR(5),
00137   1.                 ***FIN
00138     1.                 ***FIN
00139     1020          FORMAT('FIN TRANSP FOLLOWING BILT')
00140   1.                 ***FIN
00141     (3)
00142          CALL SICLCL(ABAR, A, BOIV, CCIN, DELTO, DELZ, DEPTH, USEK),
00143     1.          SHRK, ENDOE, MRAD, Z, SBOC, ECOLOR, PUN, OMIN,
00144          2.          GHOUT, SCSHR, STRESS, VSET, XTOO, DEPO, ILAY,
00145          3.          SD, SH, XNT, CHOBEC, B40D, ALEM, ECOUT, ACWUM)
00146
00147          WRITE(6,1030)
00148   1.          WHEN(ILAY(3),LT,0)
00149          WRITE(6,1030) J,ILAY(3),DEPO(3),DEPO(6),BD(1,3),XNT(3),
00150   (SU(11,6),II,HELEM)
00151   1.                 ***FIN
00152             ELSE
00153          WRITE(6,1015) J,ILAY(3),SCDUR(3),SR(3),XNT(3),BCOUR(6),SR(6),
00154   1.                 ***FIN
00155     (2)
00156     1030          FORMAT('FIN TRANSP FOLLOWING (BILT CLAY')
00157   1.                 ***FIN
00158     (4)
00159
00160          C               ***FIN
00161
00162          C 1.          DELP,DEPM,UTAL,ETAX, 1/ (EFIN(5)+1),M1,7,J1,30(9,9),
00163   1.          WRITE(6,1177) II,HELEM,ALLEN,DELTU,ALFA,META,VEL1,VEL2,
00164   2.          WRITE(6,1177) ALFA,META,VEL1,VEL2
00165   3.          WRITE(6,1177) II,HELEM,ALLEN,DELTU,ALFA,META,VEL1,VEL2,
00222  * WIDTH = AM1(I)
00223  CALL SETUP(I, DD, P, S, R, VEL, MELEM, ECMOD, WIDTH)
00224  ***FIN
00225  C
00226  MALFD = DELT0 / 2.0
00227  DO (L = 1, ML1)
00228  R(L) = R(L) = DELT0
00229  Z(L) = CL(J)
00230  DO (M = 1, M1)
00231  PI = D(M)*MALFD
00232  PI BAR = P(L,M) + PI
00233  B(L,N) = P(L,N) = PI
00234  P(L,N) = PI BAR
00235  ***FIN
00236  ***FIN
00237  C
00238  IF (ECMOD)
00239     WRITE(6,5760)
00240  5760     FORMAT(1, BEFORE COMB**************BEFORE COMB**)
00241     WRITE(6,5761)
00242  5761     FORMAT(1,4,16X,'P(1,1)',10X,'P(1,2)',10X,'P(1,3)',10X,
00243           1, 'IN1,114',10X,'IN1,115',10X,'IN1,116',10X,
00244                         WRITE(6,5762)(1,(P(I,K),K=1,3),B(I>K),K=1,3),B(I,K),K=1,3),B(I,K)
00245  1, ' IN1,MPI')
00246  5762     FORMAT(1,Z,DPE16.5)
00247  ***FIN
00248  C     WRITE(6,1113)MPI,((B(M,N),M=1,3),Z(M),R(M),M=1,10)
00249  1113     FORMAT(5X,B4,100010)(10E10,3/)
00250  C     CALL COMB(MPI, B, Z, R)
00251  C     WRITE(6,1114)MPI,((B(M,N),M=1,3),Z(M),R(M),M=1,10)
00252  1114     FORMAT(5X,AFTER COMB1/10(10E10,3/))
00253  C     IF (ECMOD) WRITE(6,6000)(R(L),L=1, MPI)
00254  6000     FORMAT(1, AFTER COMB1,8(DP16.5,2X))
00255  C
00256  C     *** SOLVE THE SYSTEM OF EQUATIONS BY GAUSSIAN ELIMINATION ***
00257  C
00258  C     WRITE(6,1111)MPI,PI(2,1),PI(1,2),PI(1,3),(R(M),M=1,10)
00259  1111     FORMAT(5X,B4,100010)(10E10,3/)
00260  C     CALL TRILOSEMPI,PI(2,1),PI(1,2),PI(1,3),R)
00261  C     WRITE(6,1112)MPI,PI(2,1),PI(1,2),PI(1,3),(R(M),M=1,10)
00262  1112     FORMAT(5X,AFTER TRILOSE,10(10E10,3/))
00263  C
00264  C     DO (I=1,MPI)
00265  C     UNOC(I,J)=M(I,J)
00266  C     C(I,J)=M(I)
00267  C     ***FIN
00268  C     COMPUTE-CELL-CENTERED-VALUES
00269  C
00270  ***FIN
00271  C     CALL HELI(O, H0IV, ME0, COLD, DELT0, DELZ, DENB)
00272  1 FERMN, TLY, AHE0, ME00, PARK, XM!, KTB0,
00273  2  DE0, SC0M, ME00)
00274  C     IF (DECAY(1), Z=1,0) CALL DEN00(1, DECAY*DELT0*ME00)
00275  RETURN

-------------------------------------------------------------------

B.120
TO COMPUTE CELL-CENTERED VALUES

*** COLLAPSE THE NODAL VALUES OF C INTO CELL CENTERED VALUES

DO (I=1, NELEM)
  COLD(I,J) = C(I,J) + C(I+1,J)/2.
FIN

6200 FORMAT(C IN PROCEDURE IM, IZ, 2X, 1PE16.4)

IF (ECNN4)
  IF(JE, ED, MAXCUN)
  WRITE(6, 6200)(C(I,J), J=1, MAXCUN), I=1, MPI)
  WRITE(6, 6300)(COLD(I,J), J=1, MAXCUN), #1, NELEM)
FIN

END

-------------------------------------------
PROCEDURE CROSS-REFERENCE TABLE
-------------------------------------------

00276 COMPUTE-CELL-CENTERED VALUES
00277

(FLECS VERSION 22.46)

-------------------------------------------
B.121
SUBROUTINE TRIBAT( ECHO, MLDEHN, NELEM, NTRIBS, NUMERR, SIMLEN, TRIBFT )

This routine is responsible for reading and processing the
tributary inflow mass flux data. The data is read from
the input stream (LUN 1) and written to "tributary,tmp" (LUN 7)
for use during the simulation.

FORMAL PARAMETERS:

ECHO = Line printer echo option control variable (L#1)
MLDEHN = Holding array for error numbers (BYTE)
NELEM = Number of vertical elements
NOTE: MLDEHN is later redefined in MYDAI
NTRIBS = Number of tributaries (0 or 1)
NUMERR = Number of input errors
SIMLEN = Simulation length (seconds = 1#)
TRIBFT = Tributary input control variable

Called by SERATA

include 'elmsiz.phm'

byte MLDEHN(100)
integer# TRIBFT
integer# ENDIM, PNETIM, SIMLEN

logical# ECHO

dimension TRIB(MXLEM, MAXCON)


***TRIBUTARY INFLOW MASS FLUX
FIRST RECORD....

COL. 1-5...NTRIBS...Number of tributaries (0 UN 1)
6=10...INRIB,...Tributary input option
#1: THE USER WANTS THE MODEL TO
DISTRIBUTE THE MASS FLUX THRU
THE ELEMENTS.
#1: THE USER WILL SUPPLY THE
MASS FLUX VALUES FOR EACH ELEMENT

REWRITE 7

READ(1,2) NTRIBS, INRIB

if (ECHO) WRITE(3) NTRIBS, INRIB

if (NTRIBS .EQ. 0)

IF(ECHO) WRITE(9,3)

B.122
*REPEAT UNTIL (ENDTIM, -9999)
00055 C
00056 C
00057 C . . . . CAN0 IM8
00058 C
00059 C
00060 C
00061 C
00062 C . . . . READ (1, M) ENDTIM
00063 C
00064 C
00065 C
00066 C
00067 C
00068 C
00069 C
00070 C
00071 C
00072 C
00073 C
00074 C
00075 C
00076 C
00077 C
00078 C
00079 C
00080 C
00081 C
00082 C
00083 C
00084 C
00085 C
00086 C . ELSE N = NELEM
00087 C
00088 C
00089 C
00090 C
00091 C
00092 C
00093 C
00094 C
00095 C
00096 C
00097 C
00098 C
00099 C
01000 C
01001 C . . . . RETURN
01002 C
01003 C
01004 C
01005 C
01006 C
01007 C
01008 C
01009 C

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B.123
00110   F 'WITH SILT', 6X, 'WITH CLAY', 4X, 'DISTRIBUTED CONC', 2X,
00111          ' (M=3/SEC)' )
00112   5 FORMAT(2X, 110, 7X,7(1PE12.9, 3X), 1PE12.3)
00113   b FORMAT(110)
00114       C END

(FLECS VERSION 22.46)
SUBROUTINE TRBFLX(CTHR, CTRB, ENTRB, ETIME, FERROR, DEPTH, 
HELM, NEIG1, NEIG2, GHIN, TBOPT, DEPHIN)

When there is a tributary to the segment this subroutine is 
called each time step to read the data from LUN 7.
Which has written by subroutine TRBUAD.

Formal Parameters:
CTHR = redistributed concentrations
CTRB = original tributary mass flux
ENTRB = ending time of the current tributary data (IAG)
ETIME = elapsed time of the simulation (IAG)
FERROR = fatal error flag
HELM = number of elements
CAUTION: HELM has been redefined in HYDAT

SINCE ITS USE IN TRBUAD
NEIG1 = new ghin data flag (L*)
NEIG2 = new tributary data flag (L*)
WHIN = inflow to current segment
TBOPT = tributary input option control variable (IAG)

Called by: SEIRATA

Include 'STELMBIZ,PRM'

INTEGER TBOPr

INTEGER ENTRB,ETIME

LOGICAL! NEIG1,NEIG2,FERROR

DIMENSION CTRB(HELM,MAXCDN), CTRB(HELM,MAXCDN), WHIN(MAXCDN)

HELM = .FALSE.,
IF (ETIME GE ENTRB)
  NEIG1 = .TRUE.,
  NEIG2 = .FALSE.,
  RETURN
IF (DEPTH GE DEPHIN) RETURN

IF (DEPTH LE DEPHIN) RETURN

IF (TIME EQ 0.0) MOUSE = 0.0
If (TIME LE DEPHIN) RETURN

DISTRIBUTION THE MASS FLUX THROUGHOUT THE ELEMENTS

NOTE: WHIHY ARE

Sediment KG/SEC
PANCULAR PC/SEC OH KG/SEC
Dissolved PC/SEC

B.125
(FLECS VERSION 22,46) 17-JUN-82 15:10:01 PAGE 00002

00054  * DO (K=1,MAXCOM)
00055  *   U (I=1,NELEM)
00056  *   * CTMIN(I,K) = CTMIN(K) * QMIN(I) / QHTOT
00057  *   * FIN
00058  *   * FIN
00059  *   * FIN
00060  RETURN
00061 C
00062 200 CONTINUE
00063 FERROR = .TRUE.
00064 WRITE(*,1)
00065 1 FORMAT(10X,'FATAL ERROR = TRIBUTARY DATA EXHAUSTED')
00066 RETURN
00067 C
00068 END

(FLECS VERSION 22,46)

----------------------------------------

B.126
SUBROUTINE THSUL(HR,DI,DR,D2,R)

C ALLED BY TRANS.

C USED IN ORIGINAL VERSION OF SELTRA.

INCLUDE 'FLECSIZ.PRM'

C REAL D,D,D2

DIMENSION D(MXELEM), DI(MXELEM), D2(MXELEM), R(MXELEM)

C

C HMP1

C

C

C

C FNEARO ELIMINATION

C

DO (I=1,NT)

DI(I)=DI(I)/DI(I)

R(I+1)=R(I+1)-D2(I)*DI(I)

R(I+1)=R(I+1)+D(I)*DI(I)

FIN

C

C BACKWARD SUBSTITUTION

C

R(N)=R(N)/DI(N)

DO (I=1,N)

K=I

R(K)=R(K)-D2(K)*R(K+1)/DI(K)

FIN

C

RETURN

END

(FLECS VERSION 22.4b)

--------------------------------------------------
SUBROUTINE T1NPSDARRA,E,AREA,MID,DELz,EL,
  IELM, MLEMB, XAREA, TOL)

THIS SUBROUTINE CONSERVE THE CROSS-SECTIONAL AREA AS A FUNCTION
OF DEPTH DURING THE CONVERSION OF THE REAL CROSS-SECTION TO ITS
IDEALIZED RECTILINEAR SHAPE.

INCLUDE 'BSCFELM4Z,PRM'

DIMENSION ARR(KNELEM), AREA(KXLEMB), MID(KXLEMB),
  IELM(KXLEMB), EL(KXLEMB), XAREA(KXLEMB)

4 2 XAREA(KXLEMB)

BEGIN

XLEN=L*ALEN
ELTOP=NDELZ

WHXAREA(K)=ALEN

ANAB=(X+Y)*ZLEN)*(EL(2)-EL(1))/2.

AKB=0.

NB=1

DETERMINE LOCATION OF TOP NOOE WITH RESPECT TO ORIGINAL DATA

OD(I+1,KXLEMB)

DD(J*1,KXLEMB=1)

IF (ELTOP.GE. EL(J) ,AND, ELTOP.LE. EL(J+1))

EMAX(J)

EJMAX(J+1)

NMAX(J)=XMAXA(J)=XLEN

IEN=AERA(J+1)*ALEN

NBJ

IEN(J)=

G0 TO 10

***FIN

***FIN

CONTINUE

LINEARLY INTERPOLATE WIDTH AT ELEMENT'S TOP NOOE

MTOP=MT+(ELTOP-EB)*(MT-MN)/(ET-EB)

ASSUME TRAPZOIDAL SHAPES TO FIND CROSS-SECTIONAL AREAS

ARAIN=MT+MTOP)/(ET-ELTOP)/2.

ARAIM=(MT+MTOP)*(ET-ELTOP)/2.

ARAIM=(MT+MTOP)*(ET-ELTOP)/2.

DETERMINE IF NEAR ELEMENT SURFACES HAVE BEEN FOUND TO

(a) LIE WITHIN A SINGLE DATA SET

(b) LIE IN SEQUENTIAL DATA SETS, OR

(c) BE SEPARATED BY ONE OR MORE DATA SETS

FINALLY, FORM THE CROSS-SECTIONAL AREA

STOP
00054 C INDICANT=NO
00055 IF (INDIC.EQ.0) XBARA(1)=ARNT+ARNB
00056 IF (INDIC.GE.1) XBARA(1)=ARNT+ARNB
00057 IF (INDIC.GT.2)
00058 XBARA(*)
00059 UN(II+1,NT-I)
00060 XBARA(1)=AREA(II)+AREA(II+1))*(EL(II+1)-EL(II))*BLEN/Eo
00061 ***FIN
00062 XBARA(1)=AREA(II+1)*XBAR
00063 ***FIN
00064 C DETERM}
00065 C AVERAGE VERTICAL PROJECTION, AVERAGE WIDTH, REAL WIDTH/VOLUME
00066 C
00067 AMID(II)=AREA(II)/DELZ
00068 AMID(II+1)=AMID(II)*ALEM
00069 AMID(II+1)=TUP
00070 VOL=VOL+XBARA(I)*ALEM
00071 C OVERWRITE INITIAL INFORMATION FOR NEXT ELEMENT
00072 C
00073 C ELTOP=ELTOP+DELZ
00074 ARA=ARA+AT
00075 ARA=AAB*
00077 JA
00078 ***FIN
00079 RETURN
00080 END

(FLECS VERSION 22.46)
SUBROUTINE USHAT(ECHO, HLDEMA, NUMERR, SIMLEN, UMID, UEL)

THIS ROUTINE IS RESPONSIBLE FOR READING THE UPSTREAM INFLOW

CONDITIONS TO SEGMENT 1. THE DATA IS READ FROM THE INPUT STREAM
(LUN 1) AND THEN WRITTEN TO "DUMMY.DTL" (LUN 2) FOR SUBSEQUENT
USE DURING THE SIMULATION.

FORMAL PARAMETERS:
ECHO = LIKE PRINTER ECHO OPTION CONTROL VARIABLE (L*1)
HLDEMA = HOLDING ARRAY FOR ERROR NUMBERS (BYTE)
NUMERR = NUMBER OF INPUT ERRORS
SIMLEN = SIMULATION LENGTH (SECONDS = 1*9)

CALLED BY SCRATHA
CALLS PUTENV

INCLUDE 'ELSIZ.PRM'
BYTE HLDEMA(100)
INTEGER ENDTIM, PFR, SIMLEN
LOGICAL ECHO
DIMENSION XLEMA, XAXCUM, UMID, XLEMA, UEL
REVERSE 2
IF (ECHO) WRITE(6,6)

UPSTREAM INFLOW CONDITIONS TO SEGMENT 1

REPEAT UNTIL (ENDTIM, EN, = 0999)

RECORD ONE:

COL. 1-10: ENDTIM, .... ENDING TIME FOR DATA THAT PLOWS...
A VALUE OF 0999 TERMINATES THE DATA
SECONDS)

11-15: NUM = NUMBER OF ELEMENTS
16-25: UFLNTH = ELEVATION OF FREE SURFACE ABOVE BED
READ(1,5) NUM, EN, UFLNTH

READ(1,5) ENDTIM, UM, UFLNTH
IF ENDTIM, UM, = 0999
RECORD THINKING ABOUT CONDITIONS, THE CARD IS READ FOR EACH NODE.
THE UNITS OF THE CONTAMINANT CONCENTRATIONS DEPEND
UPON THE TYPE OF CONTAMINANT (RADIOACTIVITY, PC/ KG
OR PESTICIDE, KG/KG). THE PARAMETERS ARE READ IN
THE FOLLOWING ORDER:

PARAMETER 1**CONCENTRATION OF SAND (KG/M**3)
PARAMETER 2**CONCENTRATION OF SILT (KG/M**3)
ELSE
  READ(1,1) (UNIT(I),I=1,NUMID)
  READ(1,1) (NEL(I),I=1,NMID)
  IF(NMID,LT,NXELEM)
  DO (I = NUMID + 1,NXELEM)
  UDIM(I) = UDIM(I) + DEL
  UEL(I) = UEL(I-1) + DEL
  END
  FIN
  WRITE(6,9) (I,UDIM(I),I=1,NXELEM)
  WRITE(6,9) (I,UEL(I),I=1,NXELEM)
  END
  RETURN
  FORMAT(8F10.0)
  FORMAT(2X,13,1X,4(1X,PE12.5),4X,PE12.5)
  FORMAT(7X,1X)
  1 (3X,'CUMC',OF,'X'),1(JX,'CUMC',ABSCC,'X'),2X,'CONTAMINANT'/
  2 9X,'SUBSPED SAND','X','SUBSPED BILT','X','SUSPENDED CLAY'/
  3 6X,'WITH SAND','X','WITH BILT','X','WITH CLAY','X','DISSOLVED'/
  4 ('COMC')
  FORMAT(1HO,6X,110,'DATA SET ENDING TIME')
  FORMAT(1HO,6X,150,'UPSTREAM INFLOW WATER CONDITIONS')
  FORMAT(1HO,6X,150,'SECTION ELEVATIONS')
END
**SUBROUTINE WNDAT(C, ECHO, NELEM)**

**THIS ROUTINE IS RESPONSIBLE FOR READING THE INITIAL WATER CONDITIONS.**

**FORMAL PARAMETERS:**
- **C** = INITIAL WATER CONDITIONS
- **ECHO** = LINE PRINT ECHO OPTION CONTROL VARIABLE (L=1)
- **NELEM** = NUMBER OF VERTICAL ELEMENTS

**CALLED BY**

**INITIAL WATER CONDITIONS**

**A SET OF INITIAL WATER CONDITIONS ARE READ FOR EACH NODE**
- **OF THE SEGMENT (ELEMENTS ARE NUMBERED BEGINNING AT THE BOTTOM, ELEMENT 1, AND ENDING WITH THE SURFACE ELEMENT, ELEMENT #NELEM)**
- **IF THERE IS NO VERTICAL VARIATION, COLUMNS 1-9 CONTAIN A NEGATIVE VALUE AND COLUMNS 10-15 CONTAIN THE CONSTANT VALUE, WHEN THE DATA UNITS VARY WITH DEPTH, A VALUE IS READ FOR EACH ELEMENT, THE UNITS**
- **OF THE CONTAMINANT CONCENTRATIONS DEPEND UPON THE TYPE OF CONTAMINANT (RADIOISOTOPE, PC/M3 OR PESTICIDE, KG/KG), THE PARAMETERS ARE READ IN THE FOLLOWING ORDER:**

**PARAMETER 1. CONCENTRATION OF SAND (KG/M3)**
- **2. CONCENTRATION OF Silt (KG/M3)**
- **3. CONCENTRATION OF CLAY (KG/M3)**
- **4. CONCENTRATION OF CONTAMINANT ASSOCIATED WITH BAND**
- **5. CONCENTRATION OF CONTAMINANT ASSOCIATED WITH SILT**
- **6. CONCENTRATION OF CONTAMINANT ASSOCIATED WITH CLAY**
- **7. CONCENTRATION OF DISSOLVED CONTAMINANT**

**W0(K1,MAXCON)**

**DO(J=1,MAXLEN) C(J,K)=0.0**

**FIN**

**DIMENSIONS C(MXEM,MAXCON)**

**INPUT**
- **READ(1,2) SWITCH, VALV1**
- **WRITE(8,4) VALV1**

***** PARAMETER DOES NOT VARY VERTICALLY ***
**FLECS VERSION 22.4b**

00054        DO (J=1,NELEM) C(J,K) = VALUE
00055        ELSE FIN
00056        C        *** PARAMETER VARIES VERTICALLY ***
00057        READ(1,1) (C(J,K), K=1, NLEM+1)
00058        *** FIN
00059        IF (ECHO)
00060        WRITE(6,5)
00061        WRITE(6,5)
00062        DO (J=1,NELEM+1)
00063        WRITE(K,5)
00064        WRITE(K,5)
00065        WRITE(K,5)
00066        *** FIN
00067        *** FIN
00068        C
00069        RETURN
00070        C
00071 FORMAT(1R10,0)
00072 FORMAT(IS,10,0)
00073 FORMAT(IS,5X,'INITIAL WATER CONDITIONS')
00074 FORMAT(IS,5X,2X,'CONC. DF',2X,2X,'CONC. ASSOC.',2X,'CONTAMINANT')
00075 FORMAT(IS,5X,'SUSPENDED BAND',2X,'SUSPENDED BILT',2X,'SUSPENDED CLAY',2X('{}','DILUTED')
00076 C
00077 C
00078 C
00079 C
00080 C
00081 C
00082 C

**FLECS VERSION 22.4b**

--------------------------------------------------------
APPENDIX C

SAMPLE INPUT AND OUTPUT FOR SERATRA
INPUT

3 SELECTIONS
5 TIMESTEPS

SEGMENT 1 PARAMETERS

CROSS-SECTIONAL GEOMETRY

FALL VELOCITY

PARTICLE DENSITY

PARTICLE DIAMETER

CRITICAL BOUNDARY SHEAR STRESS

CRITICAL DEPOSITION SHEAR STRESS

C.1
### Water Concentrations

<table>
<thead>
<tr>
<th>Elevation (Meters)</th>
<th>Sand</th>
<th>Bilt</th>
<th>Clay</th>
<th>Contaminant with Sand</th>
<th>Contaminant with Bilt</th>
<th>Contaminant with Clay</th>
<th>Total Contaminant</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>120.000</td>
<td>0.5999</td>
<td>0.0180</td>
<td>0.0001</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
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<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
</tr>
</tbody>
</table>

### Sediment Concentrations

<table>
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<tr>
<th>Elevation (Meters)</th>
<th>Sand</th>
<th>Bilt</th>
<th>Clay</th>
<th>Contaminant with Sand</th>
<th>Contaminant with Bilt</th>
<th>Contaminant with Clay</th>
<th>Total Contaminant</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
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<td>0.0001</td>
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<td>0.0001</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
</tr>
<tr>
<td>120.000</td>
<td>0.5999</td>
<td>0.0180</td>
<td>0.0001</td>
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</tr>
</tbody>
</table>

### Contaminant Associated with Sediment

<table>
<thead>
<tr>
<th>Elevation (Meters)</th>
<th>Sand</th>
<th>Bilt</th>
<th>Clay</th>
<th>Contaminant with Sand</th>
<th>Contaminant with Bilt</th>
<th>Contaminant with Clay</th>
<th>Average</th>
</tr>
</thead>
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</tr>
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<td>0.5999</td>
<td>0.0180</td>
<td>0.0001</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
</tr>
<tr>
<td>ELEMENT</td>
<td>SUSPENDED SAND</td>
<td>SUSPENDED SILT</td>
<td>SUSPENDED CLAY</td>
<td>CONTAMINANT WITH SAND</td>
<td>CONTAMINANT WITH SILT</td>
<td>CONTAMINANT WITH CLAY</td>
<td>DISSOLVED</td>
</tr>
<tr>
<td>---------</td>
<td>----------------</td>
<td>----------------</td>
<td>----------------</td>
<td>----------------------</td>
<td>----------------------</td>
<td>----------------------</td>
<td>-----------</td>
</tr>
<tr>
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SERATRA, a transient, two-dimensional (laterally-averaged) computer model of sediment-contaminant transport in rivers, satisfactorily resolved the distribution of sediment and radionuclide concentrations in the Cattaraugus Creek stream system in New York. By modeling the physical processes of advection, diffusion, erosion, deposition, and bed armoring, SERATRA routed three sediment size fractions, including cohesive soils, to simulate three dynamic flow events. In conjunction with the sediment transport, SERATRA computed radionuclide levels in dissolved suspended sediment, and bed sediment forms for four radionuclides (137Cs, 90Sr, 239,240Pu, and 3H). By accounting for time dependent sediment-radionuclide interaction in the water column and bed, SERATRA is a physically explicit model of radionuclide fate and migration. Sediment and radionuclide concentrations calculated by SERATRA in the Cattaraugus Creek stream system are in reasonable agreement with measured values.