STREAM II-V7: Revision for STREAM II-V6 to include outflow from all Savannah River Site tributaries.

Grace M. Maze

January 2017

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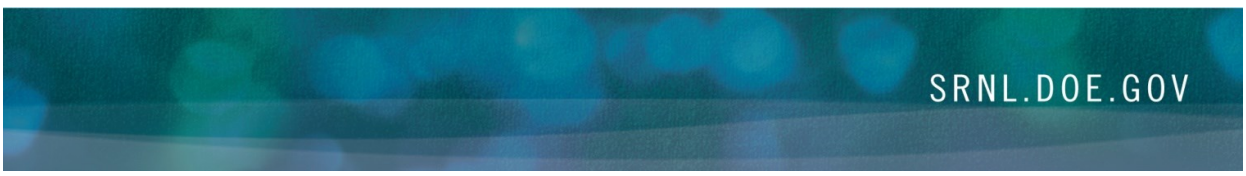

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EXECUTIVE SUMMARY

STREAM II is the aqueous transport model of the Weather Information Display (WIND) emergency response system at Savannah River Site. It is used to calculate transport in the event of a chemical or radiological spill into the waterways on the Savannah River Site. Improvements were made to the code (STREAM II V7) to include flow from all site tributaries to the Savannah River total flow and utilize a 4 digit year input.

The predicted downstream concentrations using V7 were generally on the same order of magnitude as V6 with slightly lower concentrations and quicker arrival times when all onsite stream flows are contributing to the Savannah River flow. The downstream arrival time at the Savannah River Water Plant ranges from no change to an increase of 8.77%, with minimum changes typically in March/April and maximum changes typically in October/November. The downstream concentrations are generally no more than 15% lower using V7 with the maximum percent change in January through April and minimum changes in June/July.

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LIST OF ABBREVIATIONS

SRNL	Savannah River National Laboratory
WIND	Weather Information Display
USGS	United States Geological Survey
SRS	Savannah River Site
EPA	Environmental Protection Agency
WASP5	Water Quality Analysis Simulation Program Version 5

1.0 Introduction

STREAM II-V6 [1] is the aqueous transport model currently used by the Savannah River Site (SRS) Weather Information Display (WIND) emergency response system [2]. In order to represent the flows for onsite streams and the Savannah River more realistically, the STREAM II-V6 input files were revised to include the flows from all onsite tributaries, rather than only the stream affected by the release. These tributaries were originally neglected for conservative offsite pollutant concentration predictions and for computational resource allocation. Recent advances in computing abilities have made previously impractical calculations possible. The latest version of STREAM II (V7) incorporates these changes.

STREAM II models the Savannah River, Upper Three Runs Creek, Beaver Dam Creek, Fourmile Branch, Pen Branch, Steel Creek, and Lower Three Runs Creek, and a few other smaller tributaries, which are shown in Figure 1-1 and Figure 1-2 [3] [4] [5]. The source of most of the surface water on SRS is either natural rainfall or groundwater discharge to surface streams. At the SRS boundary the Savannah River is about 100 m wide and has a depth ranging from 2.5 to 5 m. The Upper Three Runs Creek is the longest of the onsite creeks, and is the only stream to originate off site. It has a drainage area of over 500 km^2, with a floodplain that ranges in width from 400 m to 1600 m. The main tributaries to Upper Three Runs include Tinker Creek, McQueen Branch and Tims Branch. Beaver Creek was an intermittent flowing creek before SRS, and received most of its flow from the cooling water of the coal-fired power house in D-Area when the powerhouse was operational. Fourmile Branch has a drainage area of over 60 km^2 and a floodplain of up to 300 m width. Pen Branch and its tributary, Indian Grave Branch, have a drainage area of over 60 km^2 and Steel Creek has a drainage area of over 90 km^2. Pen Branch flows into Steel Creek about 0.8 km before Steel Creek discharges into a swamp adjacent to the Savannah River. Lower Three Runs has a drainage area of over 461 km^2 [6].

STREAM II utilizes the Water Quality Analysis Simulation Program (WASP5), developed by the US EPA, to calculate advective transport using a finite difference approximation. WASP5 calculates the transport by simulating the system of streams as a series of segments with a defined length. Each segment has an input volume specified, which is updated to account for changing flow rates. Segments are designated by number. Transport between adjoining segments is specified in the input file [7].

Figure 1-1. Savannah River Spanning from Augusta, Georgia to the Atlantic Ocean

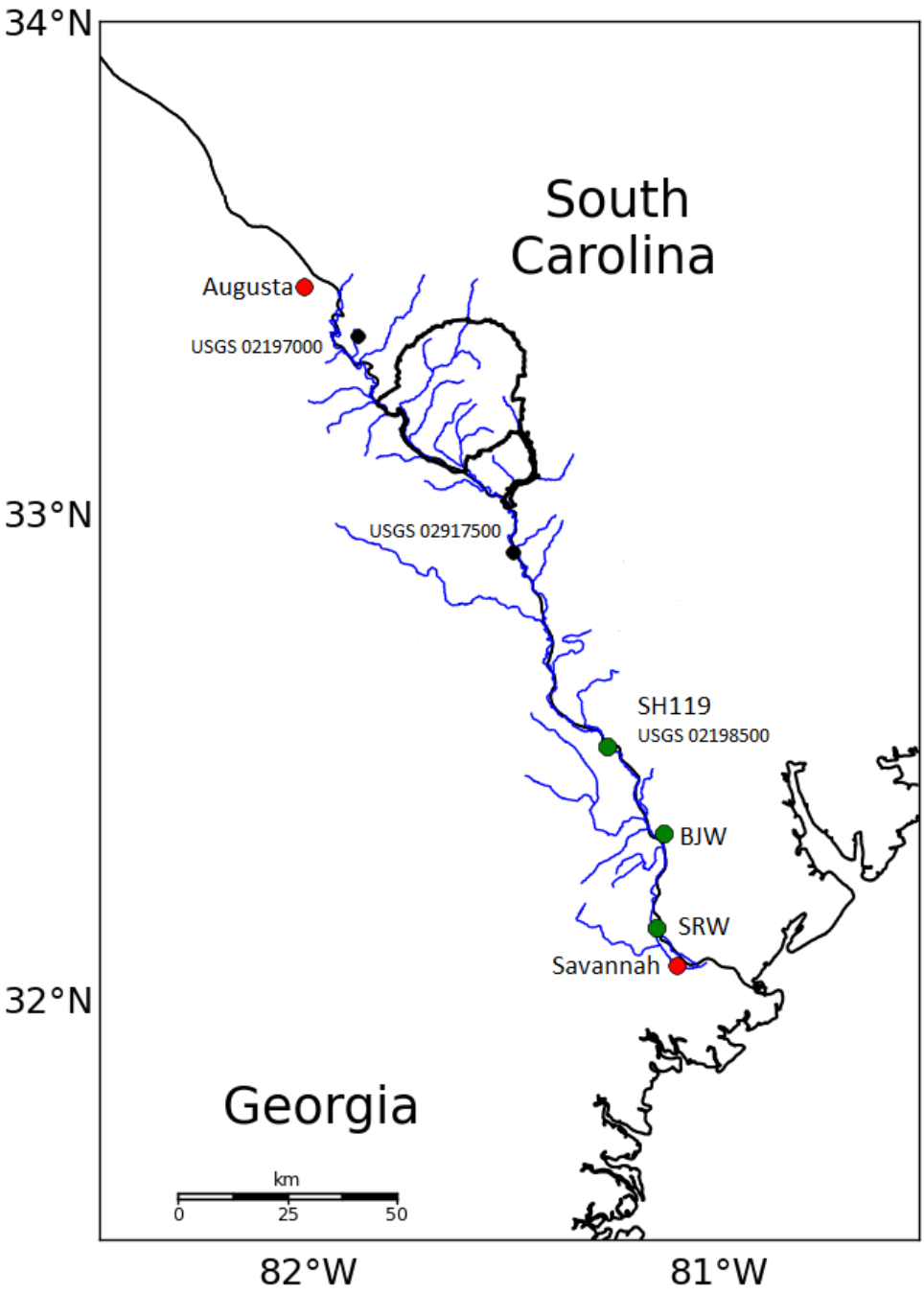
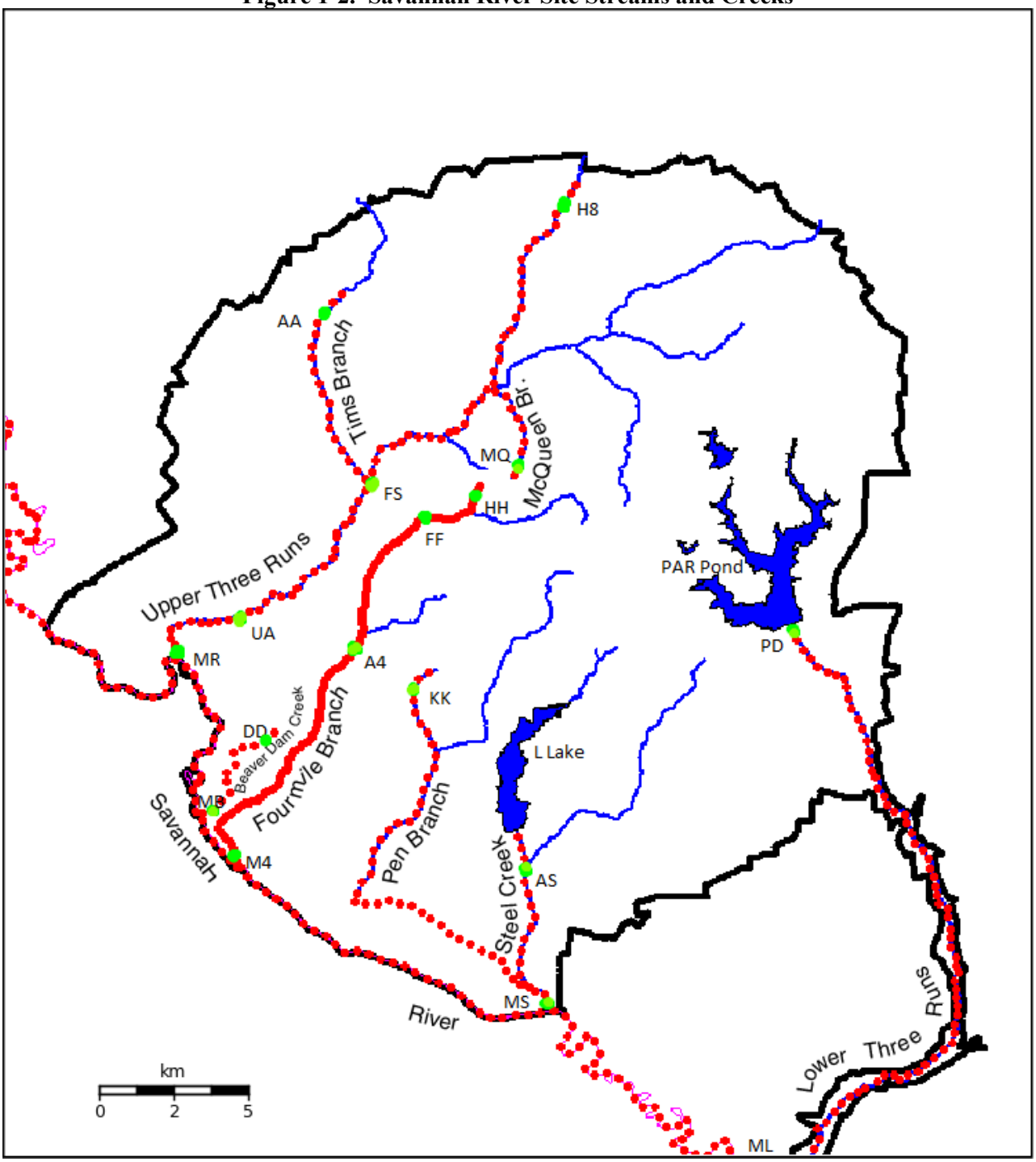


Figure 1-2. Savannah River Site Streams and Creeks



Note: Segment centers are shown in red dots. The spacing between each segment is 500 meters, except for Fourmile Branch, which has a spacing of 150 meters. Release locations (see Table 2-1 for location names) are shown with green dots.

2.0 Model Setup

The Savannah River is modeled from the New Savannah Bluff Lock and Dam, near Augusta, GA, to a point around 14 km upstream from Fort Pulaski, near Savannah, GA, with 550 segments each 500 m in length with a cross sectional area of 277.966 m^2. Two tributaries are modeled downstream from SRS at segment 214 (USGS 02917500 on Figure 1-1) and segment 391 (USGS 02198500 on Figure 1-1) [8] [9] [5]. Cross sectional areas were obtained from previous 1990 and 1991 EPA dye studies.

Upper Three Runs Creek (Figure 2-1) is modeled from where it enters onto the SRS until it empties into the Savannah River with a total of 66 segments, each with a length of 500 m. From its entry to meeting with Tinker Creek (10 km on site from the northern most point) the cross sectional area is modeled as 11.0369 m^2 and downstream of Tinker Creek it is modeled as 30.00 m^2. It flows into the Savannah River at segment 98. Cross sectional areas were estimated from USGS discharge measurements and adjusted to match the predicted dye plume traveling times using data from 1995 and 1996 dye studies [10]. Tims Branch (Figure 2-2) and McQueen Branch (Figure 2-3) flow into Upper Three Runs. The A-Area outfall flows into Tims Branch [4].

Beaver Dam Creek (Figure 2-4) is modeled with 11 segments of 500 m length and 3.0 m^2 cross sectional area. It flows into the Savannah River at segment 114. Cross sectional areas were estimated from USGS discharge measurements. D-Area outfall flows into Beaver Dam Creek [11].

Fourmile Branch (Figure 2-5) is divided into 122 segments of 150 m length with a cross sectional area of 4.5 m^2 and 18 segments of 150 m length with a cross sectional area of 5.5 m^2. It flows into the Savannah River at segment 120. Cross sectional areas were estimated from USGS discharge measurements, and adjusted to match the predicted dye plume traveling times from the 1995 dye study. F-Area and H-Area outfalls flow into Fourmile Branch. The segment length was reduced from 500 m to 150 m because the numerical diffusion became too large and the predicted plume became too wide when adjusted to match the 1995 dye study [12].

Pen Branch (Figure 2-6) includes Indian Grave Branch and Pen Branch where it flows into Steel Creek. Indian Grave Creek is modeled with 22 segments of 500 m length with a cross sectional area of 3.48715 m^2. Pen Branch is modeled with 20 segments of 500 m length with a cross sectional area of 60.6544 m^2. The discharge of the combined Pen Branch and Steel Creek flow is modeled with 3 segments of 500 m length with a cross sectional area of 60.6544 m^2. It flows into the Savannah River at segment 149. Cross sectional areas were estimated from USGS discharge measurements [13]. The K-Area outfall flows into Indian Grave Branch.

Steel Creek (Figure 2-7) is modeled with 14 segments of 500 m length with a cross sectional area of 10.4980 m^2 and 3 segments of 500 m length with a cross sectional area of 197.140 m^2. It flows into the Savannah River at segment 149. Cross sectional areas were estimated from USGS discharge measurements. Steel Creek flows from L-Lake Dam.

Lower Three Runs Creek (Figure 2-8) is modeled with 71 segments of 500 m length with a cross sectional area of 17.280 m^2. It flows into the Savannah River at segment 188. Cross sectional areas were estimated from USGS discharge measurements. Lower Three Runs flows from PAR Pond Dam.

Currently for each stream and tributary monthly averaged flows are used based on the USGS flows previously recorded onsite from flow measurements up to September 2002, when budgetary constraints

led to the cessation of regular monitoring [1]. Releases are currently controlled with previously specified locations, shown in Table 2-1, or with a user defined location by a mouse click [14].

The STREAM II [3] computer code is run in three main modules, dedicated to pre-processing, transport calculations, and post processing. Each module consists of several code components. The pre-process module of the code gathers information from the user that will be used in the model including the date, type, amount, duration, and location of the release. This information is then passed to the transport calculation module of the code which calculates pollutant transport. The pollutant transport is calculated by the advective transport equation

$$\frac{\partial C}{\partial t} = -\frac{\partial (U_x C)}{\partial x} - \frac{\partial (U_y C)}{\partial y} - \frac{\partial (U_z C)}{\partial z} + \frac{\partial}{\partial x}\left(E_x \frac{\partial C}{\partial x}\right) + \frac{\partial}{\partial y}\left(E_y \frac{\partial C}{\partial y}\right) + \frac{\partial}{\partial z}\left(E_z \frac{\partial C}{\partial z}\right) + S_L + S_B + S_K \quad \text{(Eq 2-1)}$$

where,
C= Pollutant concentration (g/m^3)
U_x= Longitudinal advective velocities (m/day)
U_y= Lateral advective velocities (m/day)
U_z= Vertical advective velocities (m/day)
E_x= Longitudinal dispersion coefficients (m^2/day)
E_y= Lateral dispersion coefficients (m^2/day)
E_z= Vertical dispersion coefficients (m^2/day)
T= time (day)
S_L= Direct and diffuse loading rate (g/m^3-day)
S_B= Boundary loading rate (g/m^3-day)
S_k= Total kinetic transformation rate (+= source, -=sink) (g/m^3·day).

Assuming vertical and lateral homogeneity, Equation 2-1 can be integrated over the y and z directions to obtain

$$\frac{\partial}{\partial t}(AC) = -\frac{\partial}{dx}(U_x AC) + \frac{\partial}{\partial x}\left(E_x A \frac{\partial C}{\partial x}\right) + A(S_L + S_B) + AS_K \quad \text{(Eq 2-2)}$$

where
A=Cross sectional area (m^2).

Using a Taylor series expansion, the concentration at $x_o \pm \Delta x$ can be expressed as

$$C(x_o + \Delta x) = C(x_o) + \frac{\partial C}{\partial x}\Big|_{x_o} \Delta x + \frac{1}{2!}\frac{\partial^2 C}{\partial x^2}\Big|_{x_o} \Delta x^2 + \frac{1}{3!}\frac{\partial^3 C}{\partial x^3}\Big|_{x_o} \Delta x^3 + \cdots \quad \text{(Eq 2-3)}$$

and

$$C(x_o - \Delta x) = C(x_o) - \frac{\partial C}{\partial x}\Big|_{x_o} \Delta x + \frac{1}{2!}\frac{\partial^2 C}{\partial x^2}\Big|_{x_o} \Delta x^2 - \frac{1}{3!}\frac{\partial^3 C}{\partial x^3}\Big|_{x_o} \Delta x^3 + \cdots . \quad \text{(Eq 2-4)}$$

By subtracting Equation 2-4 from Equation 2-3 and neglecting the higher order approximations, the central difference approximation of the concentration derivative can be expressed as

$$\left.\frac{\partial C}{\partial x}\right|_{x_o} = \frac{C(x_o+\Delta x)-C(x_o-\Delta x)}{2\Delta x} = \frac{C|_{x_o+\Delta x}-C|_{x_o-\Delta x}}{2\Delta x}. \quad \text{(Eq 2-5)}$$

The finite difference approximation of the dispersion term is expressed as

$$\frac{\partial}{\partial x}\left(E_x A\frac{\partial C}{\partial x}\right) = \frac{\left(E_x A\frac{\partial C}{\partial x}\right)\Big|_{(x_o+\Delta x)}-\left(E_x A\frac{\partial C}{\partial x}\right)\Big|_{(x_o-\Delta x)}}{2\Delta x}. \quad \text{(Eq 2-6)}$$

Substituting Equation 2-5 into Equation 2-6

$$\frac{\partial}{\partial x}\left(E_x A\frac{\partial C}{\partial x}\right) = \frac{(E_x A)|_{(x_o+\Delta x)}\frac{C(x_o+2\Delta x)-C(x_o)}{2\Delta x}-(E_x A)|_{(x_o-\Delta x)}\frac{C(x_o)-C(x_o-2\Delta x)}{2\Delta x}}{2\Delta x}. \quad \text{(Eq 2-7)}$$

The pollutant transport equation for element *j* can be expressed as

$$\begin{aligned}\frac{\partial}{\partial t}(AC)_j = &-\frac{(QC)_{j,j+1}}{L_j}+\frac{(QC)_{j-1,j}}{L_j}\\ &+\frac{(E_x A)_{j,j+1}}{L_{j,j+1}L_j}\left(C_{j+1}-C_j\right)-\frac{(E_x A)_{j-1,j}}{L_{j-1,j}L_j}\left(C_j-C_{j-1}\right)\\ &+A_j S_j^T\end{aligned} \quad \text{(Eq 2-8)}$$

where
$Q = AU$, volumetric flow (m^3/day)
$S^T = S_L+S_B+S_K$, total source and sink rates (g/m^3·day)
L= characteristic length (m).

Multiplying both sides of Equation 2-8 with L_j gives

$$\begin{aligned}\frac{\partial}{\partial t}(VC)_j = &-(QC)_{j,j+1}+(QC)_{j-1,j}\\ &+R_{j,j+1}\left(C_{j+1}-C_j\right)-R_{j-1,j}\left(C_j-C_{j-1}\right)\\ &+V_j S_j^T\end{aligned} \quad \text{(Eq 2-9)}$$

where
V= segment volume (m^3)
$R = EQ/L$, dispersive flow (m^3/day).

The concentrations at the interface of two segments are defined by WASP5 in terms of segment concentrations,

$$C_{j,j+1} = \alpha C_{j+1}+(1-\alpha)C_j \quad \text{(Eq 2-10)}$$

$$C_{j-1,j} = \alpha C_j+(1-\alpha)C_{j-1} \quad \text{(Eq 2-11)}$$

where
α= numerical weighting factor (advection factor) between 0 and 1.

When α is 0, the result is a backward difference approximation, and when α is 0.5, a central difference approximation is obtained.

WASP5 extends Equation 2-9 to the multidimensional form by including all segments adjoining segment j. Interfaces are denoted as i,j. The general equation for pollutant transport is expressed by

$$\frac{\partial}{\partial t}(VC)_j = -\sum_i (QC)_{i,j} + \sum_i R_{i,j}\left(C_i - C_j\right) + V_j S_j^T. \quad \text{(Eq 2-12)}$$

The pollutant mass of segment j is defined by

$$M_j = (VC)_j. \quad \text{(Eq 2-13)}$$

Substituting Equation 2-13 into Equation 2-12, the general equation becomes

$$\frac{\partial}{\partial t}(M)_j = -\sum_i (QC)_{i,j} + \sum_i R_{i,j}\left(C_i - C_j\right) + V_j S_j^T. \quad \text{(Eq 2-14)}$$

WASP5 uses Equation 2-14 to evaluate the mass derivatives for each segment during each time step between the initial time, t_o, and the final time, t_f. Given the volumes and concentrations at time t, WASP5 calculates new masses at $t+\Delta t$ using the one step Euler scheme

$$\left(M_j\right)_{t+\Delta t} = \left(M_j\right)_t + \frac{\partial}{\partial t}\left(M_j\right)_t \Delta t \quad \text{(Eq 2-15)}$$

where Δt is the time step.

Given the new mass at time $t+\Delta t$, WASP5 calculates the new concentrations by dividing the masses with the volumes,

$$\left(C_j\right)_{t+\Delta t} = \frac{\left(M_j\right)_{t+\Delta t}}{\left(V_j\right)_{t+\Delta t}}. \quad \text{(Eq 2-16)}$$

The downstream peak concentrations and estimated times of arrival are then passed to the post process module for graphical user display. Figure 2-9 shows an example of the Graphical User Interface (GUI) display to start a release from location H8 of 200 Ci of a radioactive substance over a 5 minute duration on August 10, 2016 at 12:00 PM. The map display can be chosen for either SRS (Figure 2-10) or a regional map (Figure 2-11). With either display the center left of the GUI shows the points of interest in the region, estimated time of arrival, and estimated maximum downstream concentration. The user then also has the option to graphically view the concentration profiles at select locations in both the linear (Figure 2-12) and the logarithmic scale (Figure 2-13). Depending on the magnitude of the release both visualizations may be important. Downstream concentrations may be significantly lower than the released amounts and points close to the release location. In this example there is a drop of 2 orders of magnitude between concentrations estimated on Upper Three Runs near the release location (Road A) and locations downstream along the Savannah River.

Figure 2-1. Schematic for Upper Three Runs

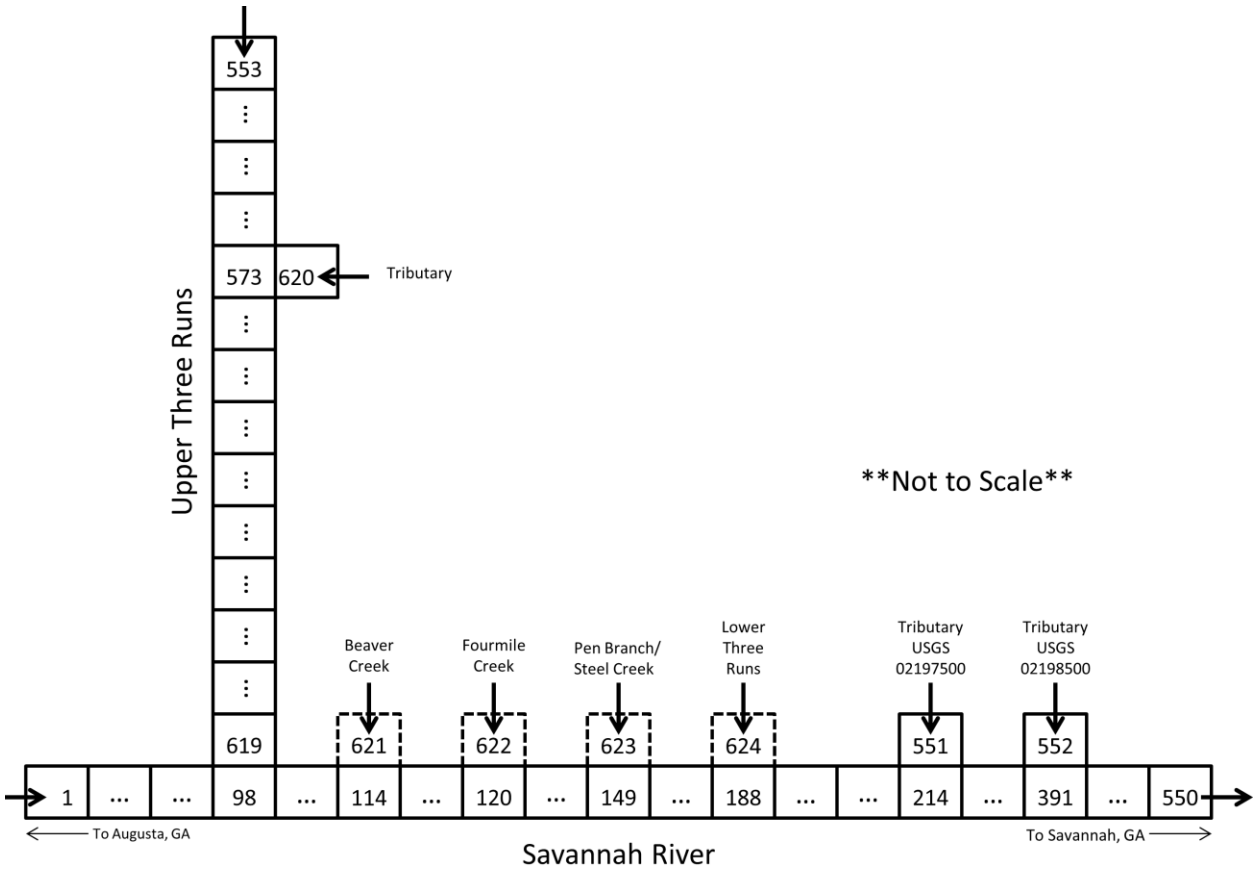


Figure 2-2. Schematic for Tims Branch

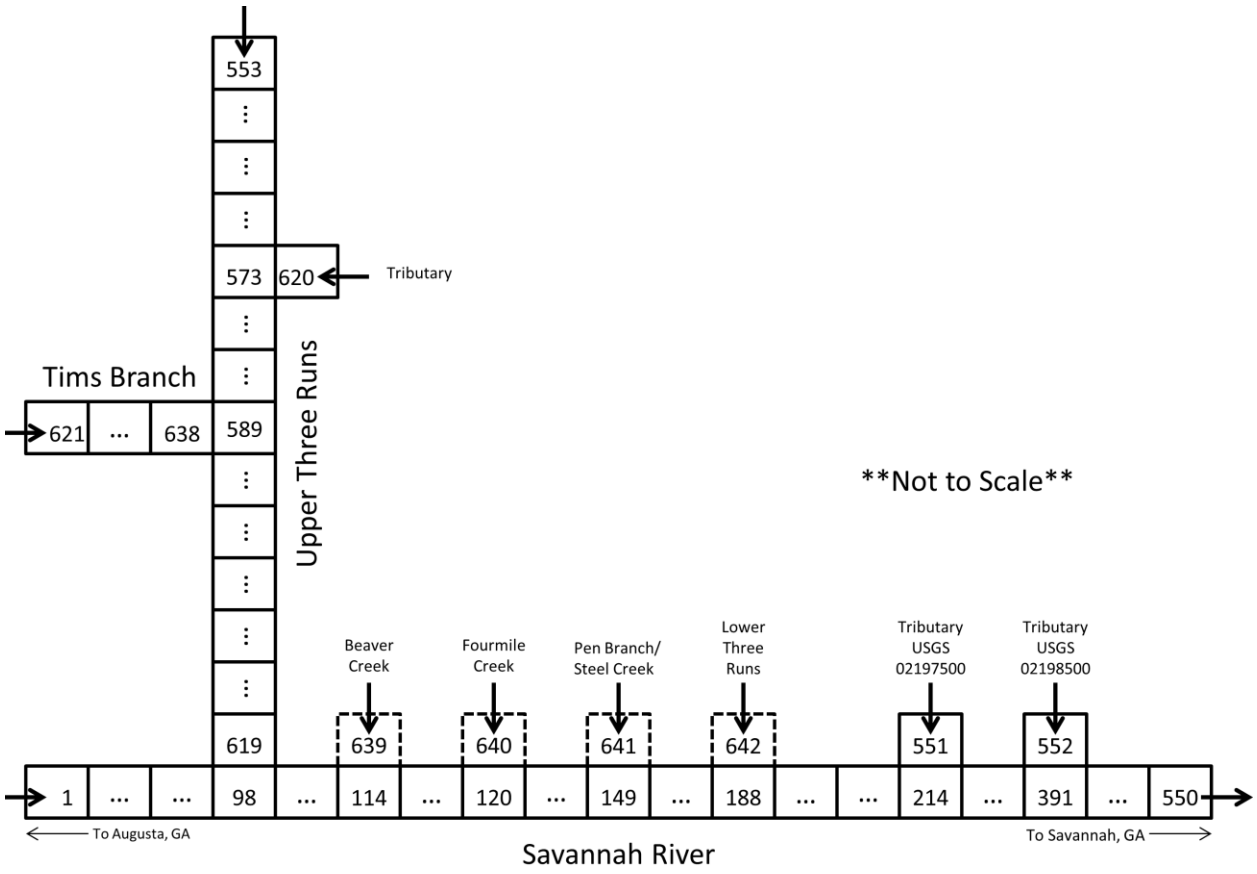


Figure 2-3. Schematic for McQueen Branch

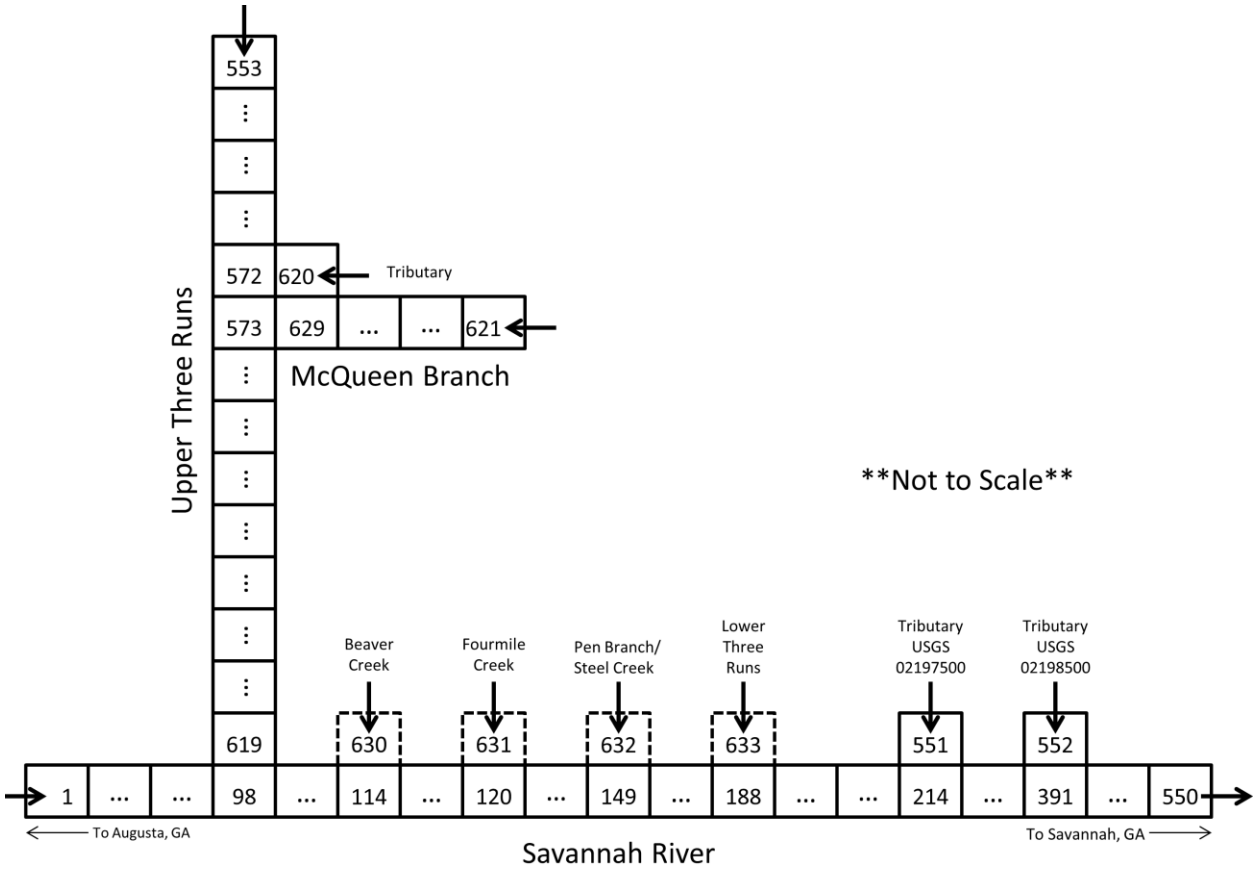


Figure 2-4. Schematic for Beaver Dam Creek

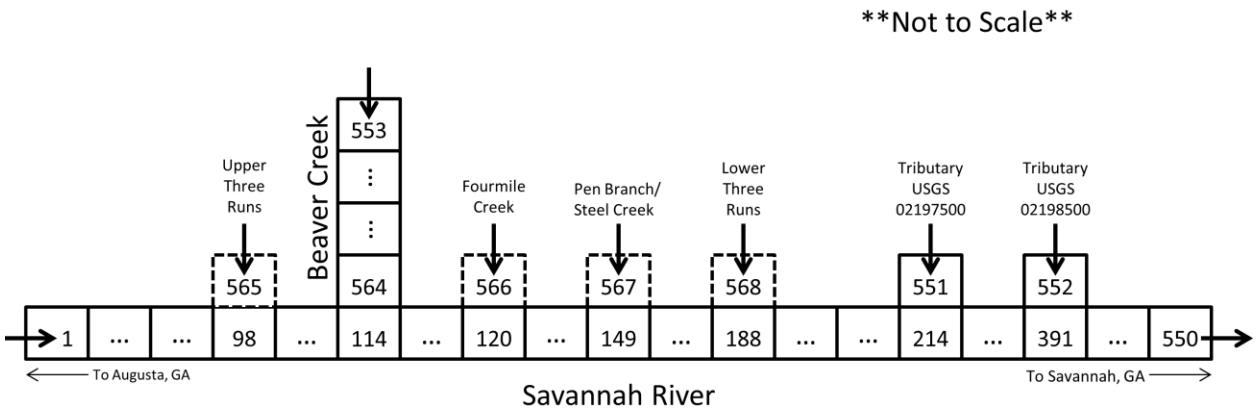


Figure 2-5. Schematic for Fourmile Branch

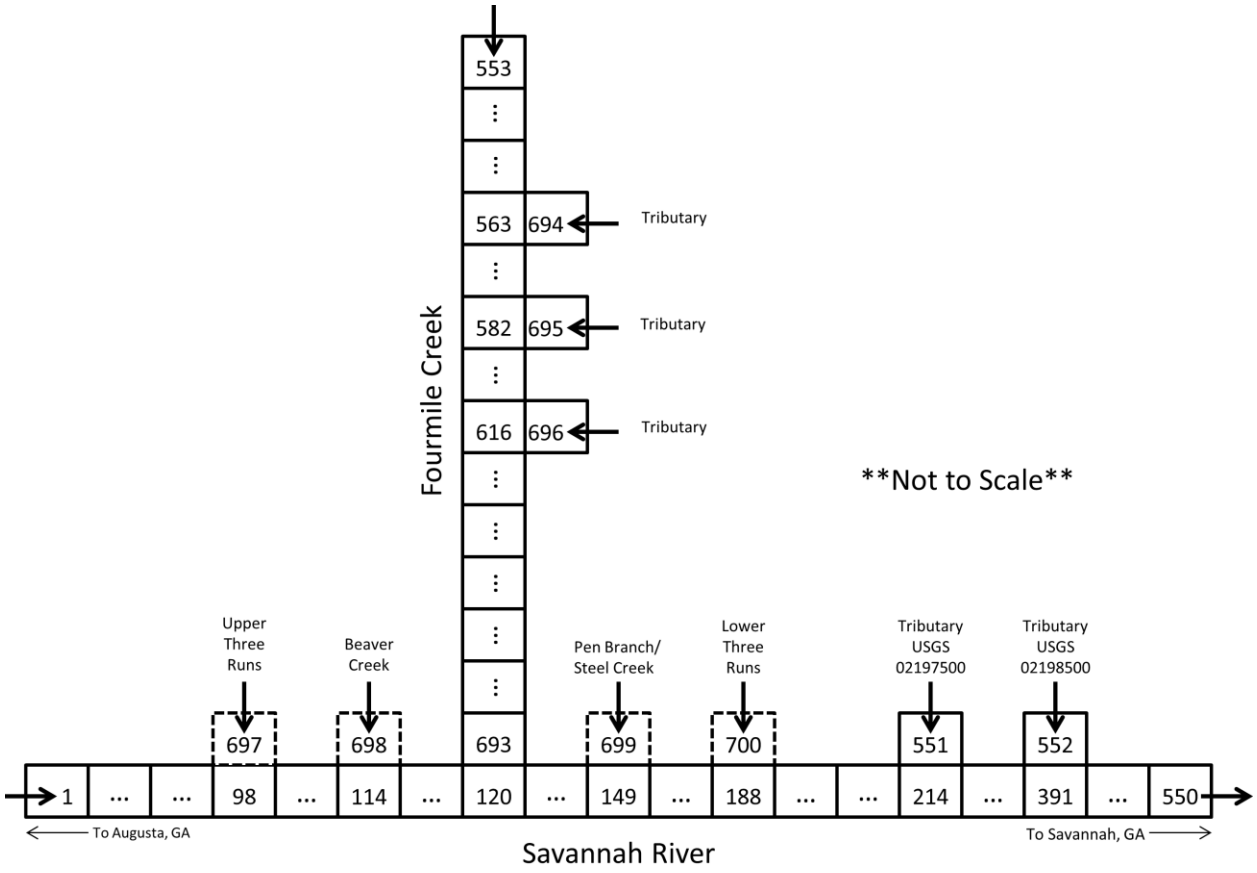


Figure 2-6. Schematic for Pen Branch

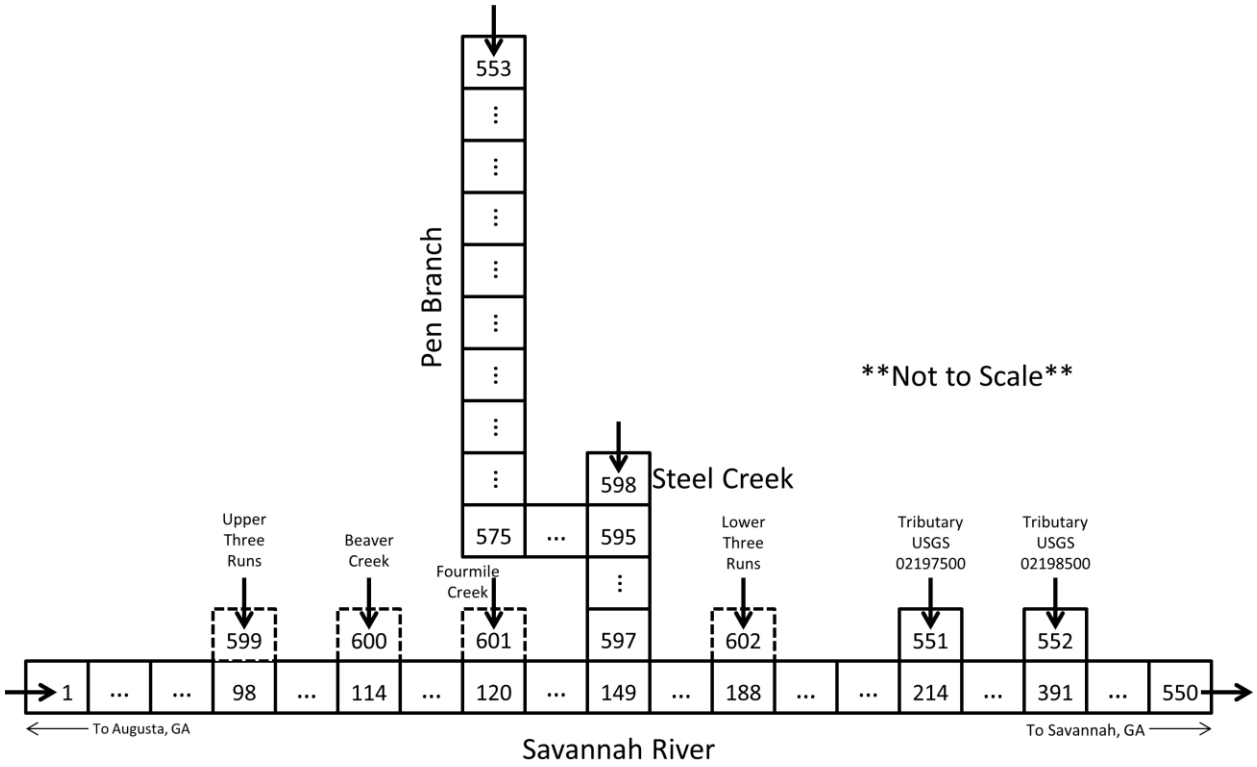


Figure 2-7. Schematic for Steel Creek

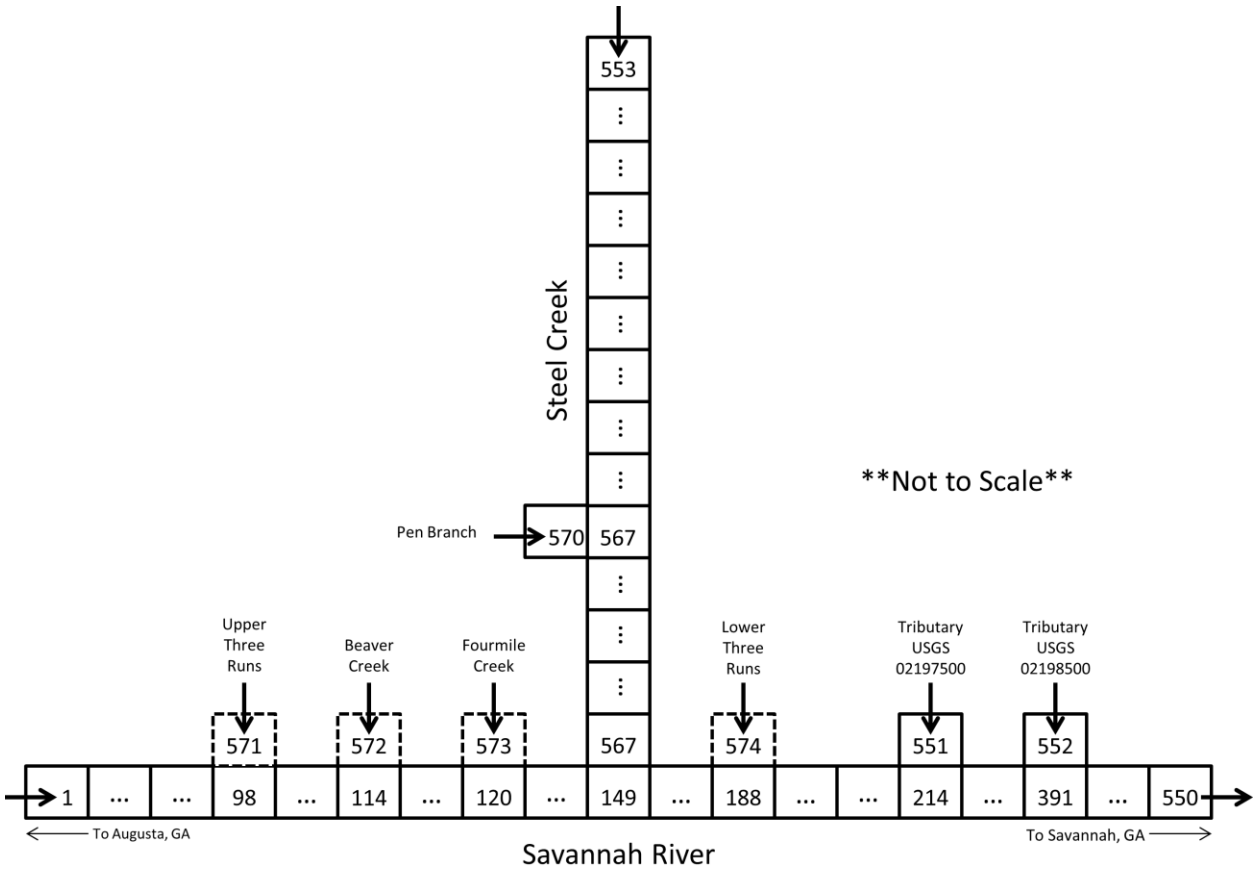


Figure 2-8. Schematic for Lower Three Runs

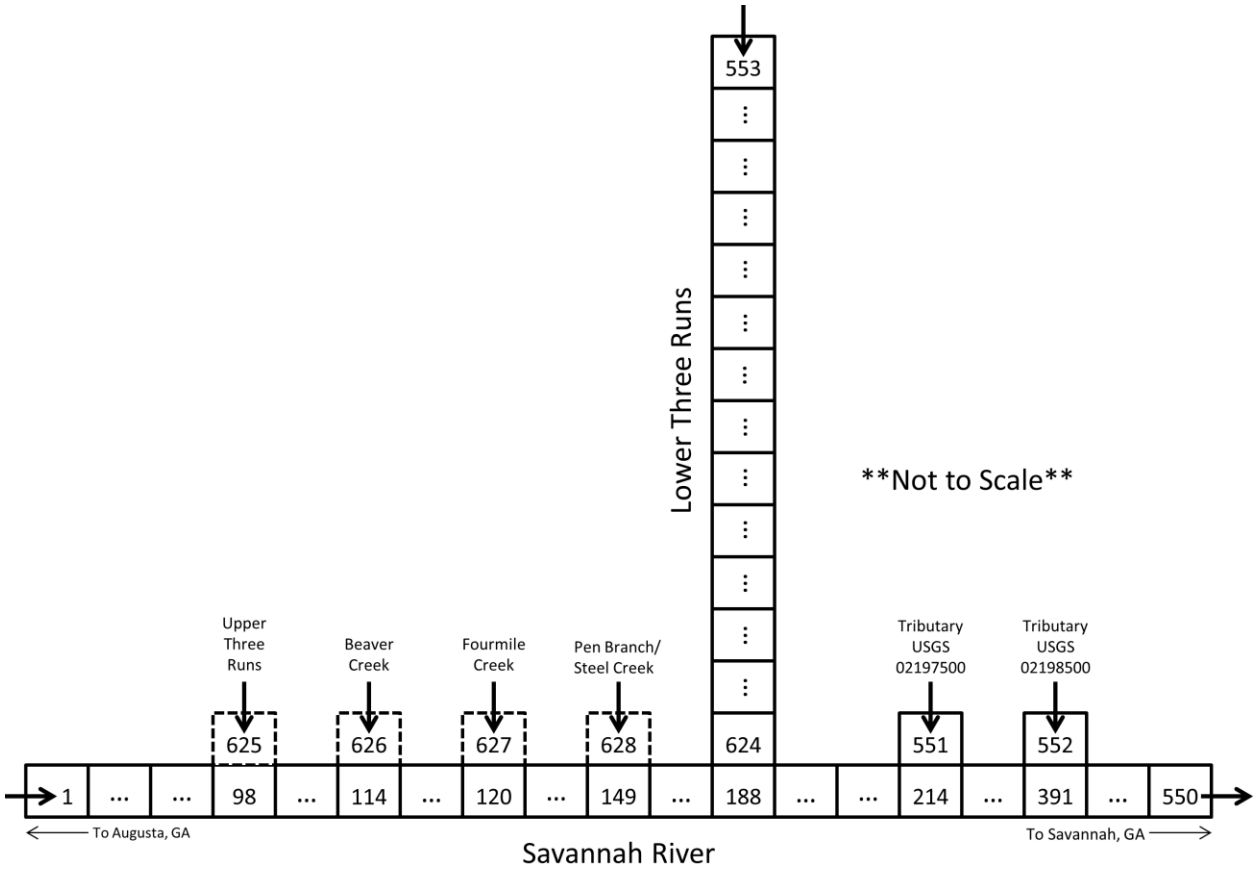


Figure 2-9. STREAM II GUI: Home screen

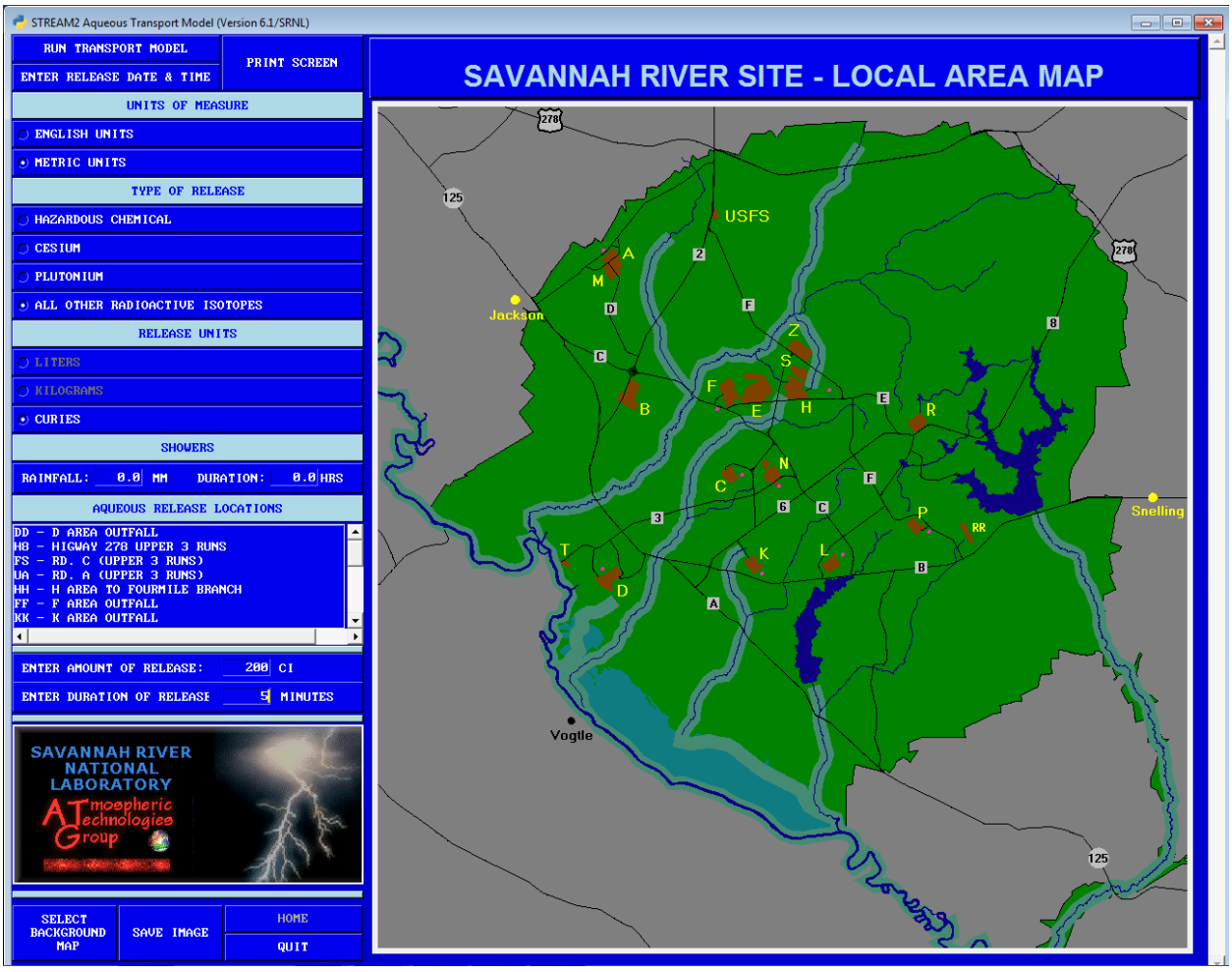


Figure 2-10. STREAM II GUI: SRS Map

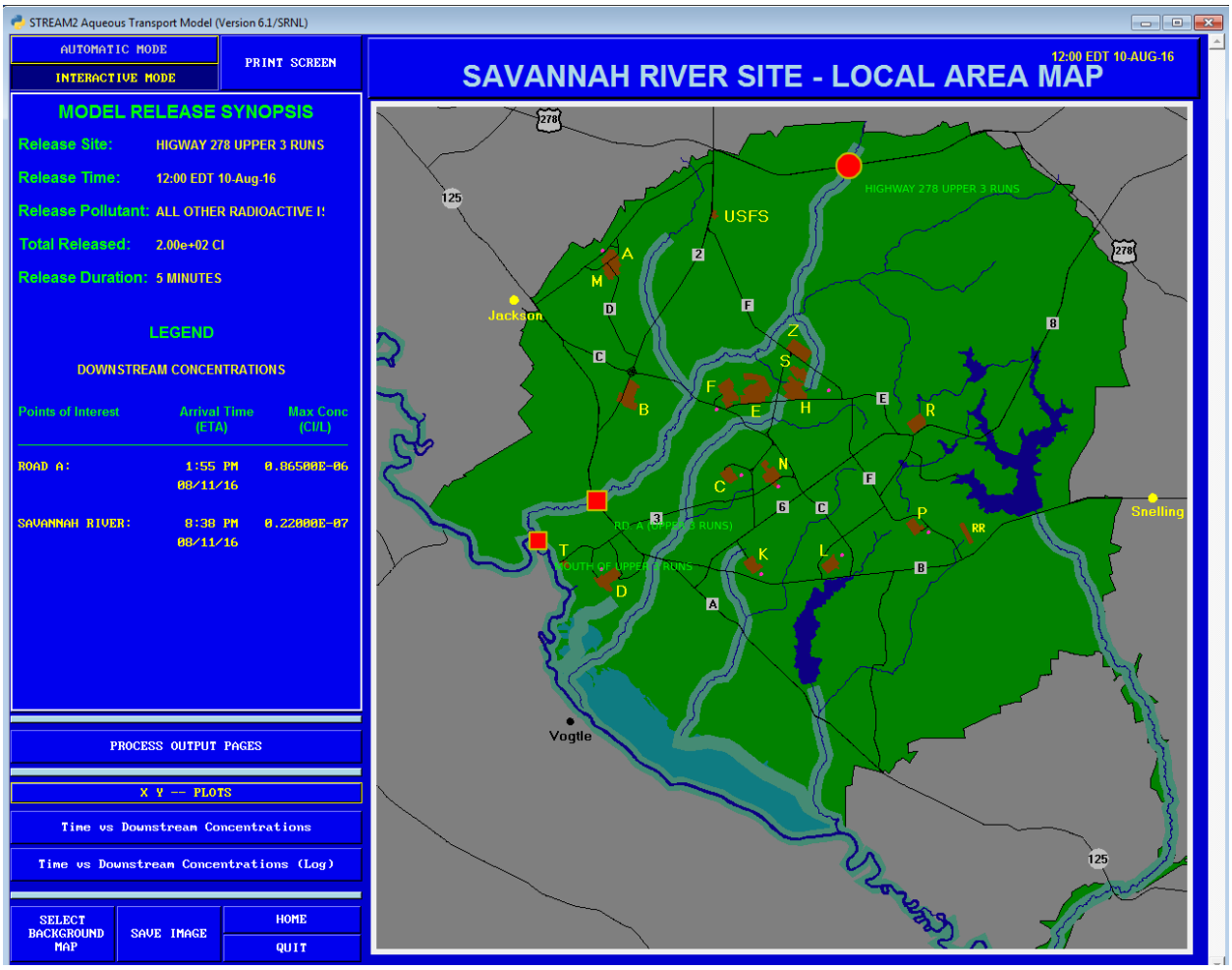


Figure 2-11. STREAM II GUI: Regional Map

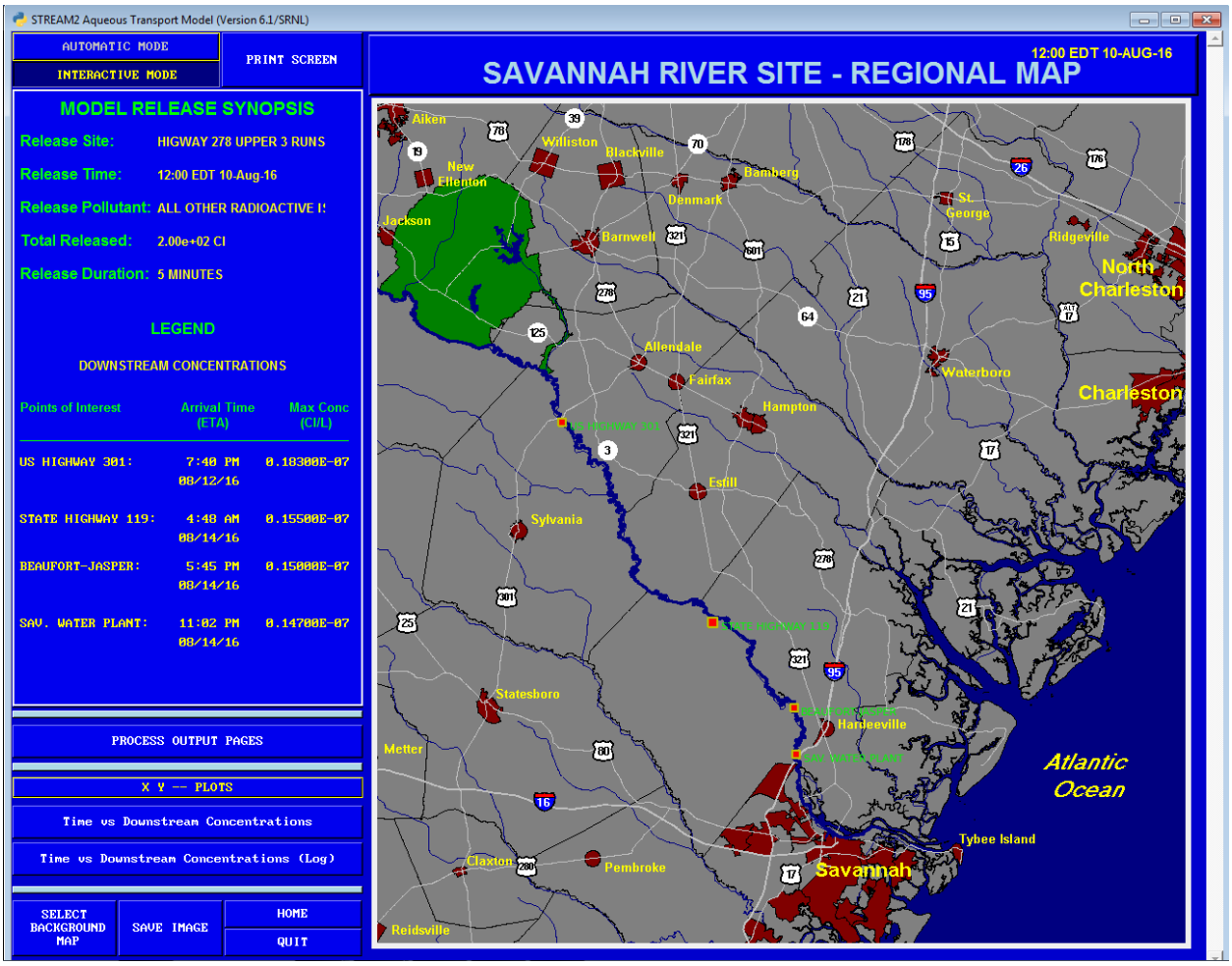


Figure 2-12. STREAM II: Linear display of downstream concentrations

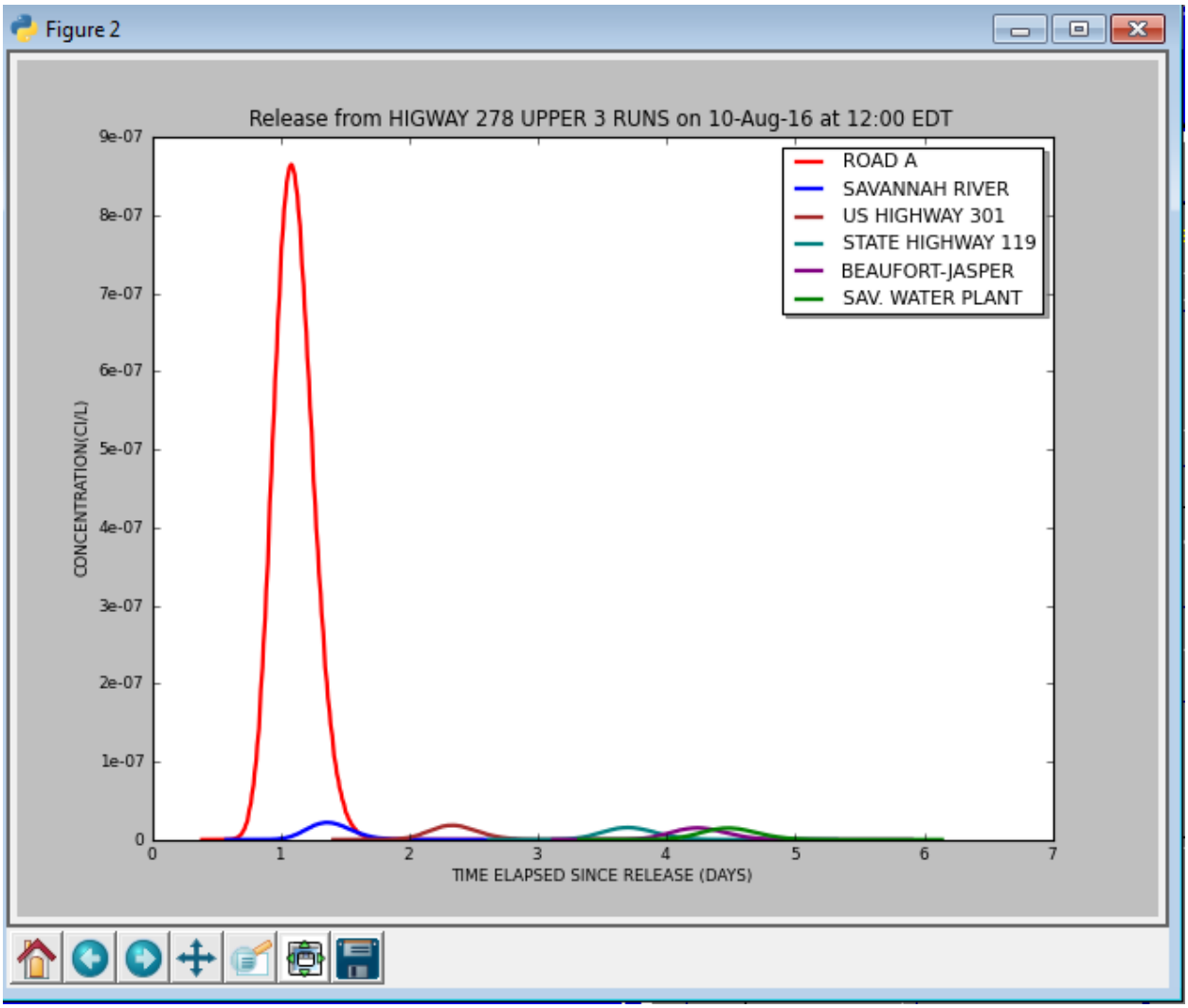


Figure 2-13. STREAM II: Logarithmic display of downstream concentrations

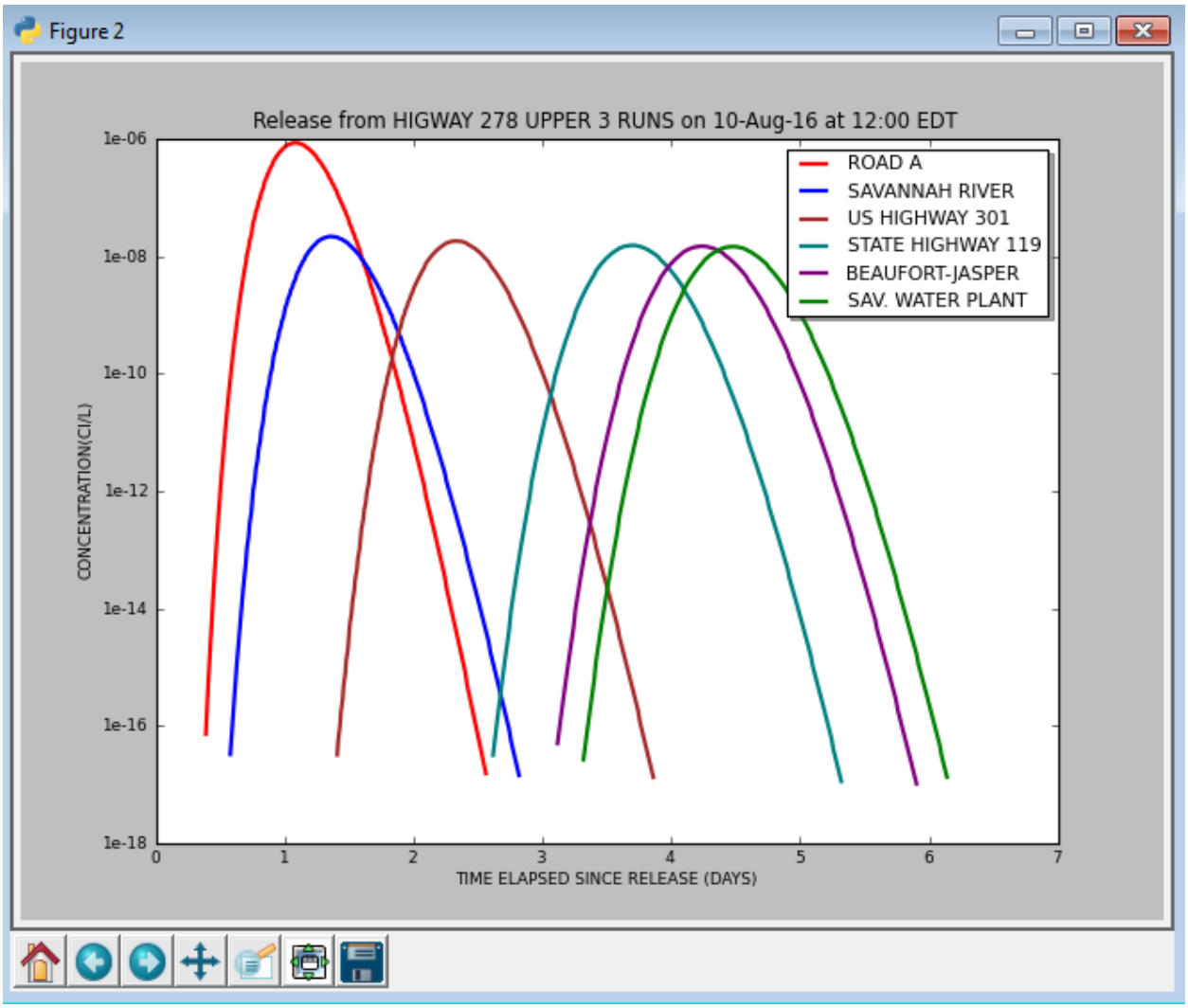


Table 2-1. Release Locations

Release Code	Release Location	Figure reference	Segment Number
A4	Road A to Fourmile Branch	2-5	627
AA	A-Area Outfall to Tims Branch	2-2	622
AS	Road A to Steel Creek	2-7	556
DD	D-Area Outfall to Beaver Dam	2-4	554
FF	F-Area Outfall to Fourmile Branch	2-5	571
FS	Road C to Upper Three Runs	2-1	589
H8	Highway 278 to Upper Three Runs	2-1	556
HH	H-Area Outfall to Fourmile Branch	2-5	557
KK	K-Area Outfall to Pen Branch	2-6	555
M4	Mouth of Fourmile Branch	2-5	693
MB	Mouth of Beaver Dam	2-4	564
ML	Mouth of Lower Three Runs	2-8	624
MQ	McQueen Branch	2-3	622
MR	Mouth of Upper Three Runs	2-1	619
MS	Mouth of Steel Creek/ Pen Branch	2-7	569
PD	Par Pond Dam to Lower Three Runs	2-8	553
UA	Road A to Upper Three Runs	2-1	608

3.0 Modifications to STREAM II V6

Alterations were made to the main fortran file, *stream.for*, and subroutines *timedate*, *gm_time*, *timadj*, *dydiff*, *talk_virtual*, *curtime*, *timecvt*, *sort*, *windw_virtual*, *m2lbl_virtual*, and *plotcon_virtual*, to allow for a four-digit year input and to eliminate the eventual failure of the model in the year 2050 during daylight savings time conversions.

Changes were made to the input files to include flow onsite streams that are downstream of the release location. For reference, Appendix A shows the input file format with descriptions of each data group listed below and Appendix B shows portions of the input file for a release at H8 on Upper Three Runs. Changes were made in Data Group A to include the new total number of segments. Changes were made in Data Group B to include all new exchanges between segments. Changes were made in Data Group C to include all segment volumes. Changes were made to Data Group D to include the monthly averaged flow for each segment. Changes were made in Data Group E to include the chemical and solid concentration boundary flow. Changes were made in Data Group J to include initial conditions of chemical and solid concentrations for all segments. New segments are shown in Figures 2-1 through 2-8 with dashed outlines.

The monthly average flows previously calculated are used as the tributary input flows (Table 3-1) [1]. Including the flow from all rivers increases the total flow off site anywhere from 2 to 7% depending on the month and release location.

Table 3-1. Savannah River Flow

This table shows the flow (m^3/s) along the Savannah River at segments directly after tributary inputs for both STREAM II V6 and STREAM II V7 for each month.

	Seg 1		Seg 99		Seg 115		Seg 121		Seg 150		Seg 189		Seg 215		Seg 392	
	V6	V7	V6	V7	V6	V7	V6	V7	V6	V7	V6	V7	V6	V7	V6	V7
Jan	8.37	8.37	8.37	8.60	8.37	8.66	8.37	8.70	8.37	8.83	8.37	8.93	9.43	10.00	10.76	11.33
Feb	10.60	10.60	10.60	10.82	10.60	10.88	10.60	10.92	10.60	11.04	10.60	11.14	11.64	12.18	12.74	13.28
Mar	11.56	11.56	11.56	11.79	11.56	11.85	11.56	11.90	11.56	12.01	11.56	12.11	13.76	14.31	15.62	16.16
Apr	8.27	8.27	8.27	8.46	8.27	8.51	8.27	8.54	8.27	8.64	8.27	8.70	10.00	10.43	11.66	12.09
May	6.53	6.53	6.53	6.68	6.53	6.74	6.53	6.76	6.53	6.85	6.53	6.91	7.50	7.89	8.37	8.75
Jun	5.64	5.64	5.64	5.82	5.64	5.88	5.64	5.91	5.64	6.01	5.64	6.08	6.25	6.68	6.88	7.32
Jul	5.61	5.61	5.61	5.79	5.61	5.86	5.61	5.89	5.61	5.99	5.61	6.03	6.21	6.63	6.71	7.14
Aug	6.89	6.89	6.89	7.09	6.89	7.16	6.89	7.21	6.89	7.30	6.89	7.39	7.51	8.02	8.05	8.55
Sep	5.59	5.59	5.59	5.76	5.59	5.82	5.59	5.85	5.59	5.94	5.59	6.01	6.19	6.62	7.07	7.50
Oct	6.41	6.41	6.41	6.63	6.41	6.69	6.41	6.73	6.41	6.84	6.41	6.91	7.07	7.57	7.61	8.11
Nov	6.21	6.21	6.21	6.41	6.21	6.47	6.21	6.50	6.21	6.60	6.21	6.67	6.58	7.05	7.16	7.63
Dec	7.66	7.66	7.66	7.86	7.66	7.92	7.66	7.95	7.66	8.07	7.66	8.13	8.70	9.17	9.59	10.06

4.0 Results

Test cases were run for the most upstream release point on each onsite stream during each month to test the differences between the old version, four-digit year inputs, and the updated version. For each test case 200 Ci of a radioactive substance was released for a duration of 5 minutes. Cases were run for releases at location H8, HH, DD, KK, AS, ML, and SR (see Table 2-1 and Figure 1-2).

Absolute differences and percent differences (Eq 4-1) were calculated in the peak concentrations and the arrival time for each release tested at the mouth of the release stream, each downstream tributary, US Highway 301, State Highway 119 (Fig 1-1), Beaufort Jasper Water Treatment plant (BJW Fig 1-1), and the Savannah River Water Plant (SRW Fig1-1).

$$\%\, Difference = \frac{(V7-V6)}{V6} \qquad \text{(Eq 4-1)}$$

where *V7* is the concentration or time of arrival of the STREAM II V7 test case, and *V6* is the concentration or time of arrival of the STREAM II V6 test case.

Results are summarized in Tables 4-1 through 4-3.

Table 4-1. Percent Differences at State Highway 119

Percent differences for concentration decrease (Con) and time of arrival increase (ToA) are shown for each upstream release location at each month.

	H8		DD		HH		KK		AS		ML	
	Con	ToA	Con	ToA	Con	ToA	Con	ToA	Con	ToA	Con	ToA
Jan	9.25	1.05	14.85	9.29	12.4	3.02	14.51	1.6	-6.32	8.59	53.53	4.57
Feb	9.11	1.10	15.85	3.83	12.50	1.61	14.69	0.01	7.32	0.95	56.03	4.25
Mar	9.02	1.70	16.35	3.03	12.11	1.67	14.79	1.60	6.52	1.48	54.24	3.37
Apr	8.31	1.03	14.05	3.14	10.06	1.90	13.50	1.42	6.84	2.10	51.29	4.21
May	8.40	1.41	13.25	3.64	8.70	1.65	11.48	0.01	7.52	2.33	45.49	4.14
Jun	8.90	2.30	12.22	5.35	9.93	2.53	11.73	1.38	8.81	2.90	40.60	5.60
Jul	8.72	2.29	12.14	5.38	10.24	3.07	10.70	1.30	8.64	3.57	39.96	5.74
Aug	9.70	2.46	13.39	4.96	11.54	2.90	12.68	1.38	8.81	3.44	46.59	5.58
Sep	9.22	2.28	12.21	4.98	9.86	2.87	11.78	1.33	8.43	3.21	40.41	5.62
Oct	9.79	2.45	12.55	5.20	11.54	3.70	12.92	1.43	9.34	3.77	44.58	5.94
Nov	9.52	2.39	12.88	5.10	11.18	3.06	12.46	1.38	9.06	2.80	42.72	5.84
Dec	8.77	1.52	13.76	3.88	10.17	2.31	12.73	0.01	8.16	2.12	50.61	4.65

Table 4-2. Percent Differences at the Beaufort-Jasper Water Treatment Plant

	H8		DD		HH		KK		AS		ML	
	Con	ToA	Con	ToA	Con	ToA	Con	ToA	Con	ToA	Con	ToA
Jan	10.00	1.41	14.97	9.29	11.97	2.70	14.51	1.48	-4.83	8.40	55.43	4.61
Feb	9.62	1.46	16.47	3.91	12.76	1.91	14.69	1.50	8.13	1.50	57.68	3.89
Mar	9.56	1.51	17.45	3.32	12.53	1.49	14.79	1.50	7.27	1.94	56.79	3.02
Apr	8.79	1.36	15.03	3.68	10.38	2.13	13.50	1.33	7.46	1.84	53.65	3.58
May	9.40	2.49	13.49	3.65	9.73	2.58	11.85	2.51	8.14	1.97	46.99	4.05
Jun	9.15	2.44	12.55	5.30	10.20	3.00	11.76	1.27	9.57	3.30	41.70	5.43
Jul	8.97	2.02	12.16	5.00	10.00	3.11	11.01	2.42	9.29	3.21	40.98	5.78
Aug	9.23	2.16	13.36	5.04	11.33	2.99	12.68	1.27	9.54	3.39	47.82	5.57
Sep	8.76	2.42	12.50	5.31	10.14	3.30	11.78	1.23	9.23	3.79	42.01	5.43
Oct	10.07	2.58	13.25	5.52	11.33	3.29	12.96	2.64	10.14	3.70	45.70	5.75
Nov	9.79	2.52	12.86	5.11	10.88	3.48	12.50	1.28	9.84	3.27	43.46	5.51
Dec	9.82	1.80	14.43	4.21	10.43	2.07	12.77	0.01	8.96	1.73	52.14	4.38

Table 4-3. Percent Differences at the Savannah River Water Plant

	H8		DD		HH		KK		AS		ML	
	Con	ToA	Con	ToA	Con	ToA	Con	ToA	Con	ToA	Con	ToA
Jan	10.19	1.79	14.92	8.77	12.93	3.41	14.51	1.44	-4.17	8.16	56.28	4.64
Feb	9.71	1.40	16.36	3.64	13.08	2.27	14.69	1.46	8.54	1.96	58.19	3.60
Mar	9.64	0.97	16.67	2.70	12.76	1.90	14.79	1.46	7.52	1.89	57.55	3.34
Apr	8.98	1.31	15.48	3.75	10.48	2.03	13.07	0.01	7.86	1.99	54.64	3.44
May	8.70	1.60	13.46	3.68	9.82	2.83	11.85	1.23	8.46	1.83	47.47	4.58
Jun	9.29	2.70	12.55	5.20	10.34	3.23	11.76	2.44	9.83	2.80	42.19	5.73
Jul	9.09	2.31	12.20	4.93	10.13	3.33	11.01	2.33	9.56	3.16	41.40	5.66
Aug	10.08	2.48	13.39	4.67	11.49	3.25	12.68	1.24	9.84	3.51	47.95	5.38
Sep	8.89	1.92	12.50	4.93	9.56	2.82	12.10	2.36	9.38	2.92	42.38	5.73
Oct	9.49	2.05	13.27	5.71	11.49	3.52	12.96	1.29	10.41	3.44	45.85	5.55
Nov	9.93	2.40	12.88	5.30	11.03	3.69	12.50	1.24	10.22	3.38	43.88	5.96
Dec	9.91	1.70	14.36	3.90	10.53	2.36	12.77	1.72	9.29	1.93	52.69	4.83

5.0 Conclusions

There was no change in the predicted downstream concentrations and time of arrivals for all cases when the input was changed to four-digit years.

The downstream concentrations using V7 were generally on the same order of magnitude as V6 with slightly lower concentrations and quicker arrival times when all onsite stream flows are contributing to the Savannah River flow. The downstream arrival time at the Savannah River Water Plant ranges from no change to an increase of 8.77%, with minimum changes typically in March/April and maximum changes typically in October/November. The percent decrease in concentration is generally less than 15%, with the exception being releases from the mouth of Lower Three Runs (ML). Releases from ML have a much higher decrease in concentration, up to 60%, and this is due to the increase of mixing associated with the increase of flow at the mouth of the convergence with the Savannah River. The downstream concentrations generally have maximum percent change in January through April and minimum changes in June/July.

6.0 Recommendations, Path Forward or Future Work

The stream and river flow is much more variable than what is shown with monthly averages. This deviation from the actual flow may result in extremely inaccurate predictions in downstream peak concentrations and arrival times. It is recommended that the STREAM II model be updated to use current stream flows when possible, and only use the monthly average flow if no data is available. The site currently has a small network of active flow gauges, which would provide accurate current stream flows to the model. Exploration of alternate data sources (e.g. NWS modeled data sets) is also warranted.

7.0 References

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Appendix A. STREAM II Input Manual

DATA GROUP A: MODEL IDENTIFICATION AND SIMULATION CONTROL

Basic simulation information is provided in Data Group A, beginning with titles and descriptions in Records 1 and 2. The number of systems (state variables) and segments are specified in Record 4. Calculation time steps are provided in Records 6 and 7, and print intervals in Records 8 and 9. System bypass options are set in Record 10.

RECORD FORMATS

Record 1--Title of Simulation (A80)

TITLE1 = descriptive title of simulation. (A80)

Record 2--Description of Simulation (A80)

TITLE2 = description of simulation. (A80)

Record 3--Record 4 Names (A80)

HEADER = names of Record 4 variables, positioned properly; for user convenience only. (A80)

Record 4--Simulation Control Parameters (7I5, 2F5.0, F3.0, F2.0)

NOSEG = number of segments in model network. (I5)

NOSYS* = 2 (I5)

ICFL* = flag controlling use of restart file; 0 = neither read from nor write to restart file (initial conditions located in input file)

MFLAG = flag controlling messages printed in XX.dmp file; 0 = yes messages printed; 1 = no. (I5)

JMASS = 0 = no mass balance table generated; or
2 = generate mass balance table. (I5)

NEGSLN = negative solution option; 0 = prevents negative solutions; 1 = allows negative solutions. (I5)

INTYP = time step option; 0 = user inputs time step history; 1=model calculates time step. (I5)

ADFAC = advection factor; 0 = backward difference; 0.5 = central difference; 0-0.4 recommended. (F5.0)

ZDAY = day at beginning of simulation; 1 is first day. (F5.0)

ZHR = hour at the beginning of simulation. (F3.0)

ZMIN = minute at the beginning of simulation. (F2.0)

TFLG = switch controlling generation of transport file; 0 = generate file; 1 = do not generate file. (I5)

Record 5-- Print Segments (6I5)

ISEGOUT = six segment numbers for which the calculated peak concentration will be displayed on the screen. (I5)

Record 6--Number of Time Intervals (I5)

NOBRK = number of intervals into which the total simulation time is divided. time step size used in calculation over each time interval is defined in Record 7. (I5)

Record 7--Time Steps (4(F10.0, F10.0))

DTS(I)	=	maximum time step to be used until time T(I), days. (F10.0)
T(I)	=	time up to when time step DTS(I) will be used, days. (F10.0)

Record 8--Number of Print Intervals (I5)

NPRINT	=	number of print intervals. (I5)

Record 9--Print Intervals (4(F10.0, F10.0))

PRINT(I)	=	print interval to be used until time TPRINT(I), days. (F10.0)
TPRINT(I)	=	time up to when print interval PRINT(I) will be used, days. (F10.0)

Record 10--System Bypass Options (16I5)

SYSBY(K)*	=	SYSBY(1) is 1 and SYSBY(2) is 0. (I5)

* A specific value is assigned to the variable.

DATA GROUP B: EXCHANGE COEFFICIENTS

Exchange coefficients for surface water are computed from input dispersion coefficients, cross-sectional areas, and characteristic lengths. Dispersion coefficients may vary in time according to piecewise-linear time functions, with groups of segment pairs having the same dispersion time function.

RECORD FORMATS

Record 1--Number of Exchange Fields (I5, 75X)

NRFLD*	=	number of exchange fields. NRFLD =1. (I5)
TITLE	=	name of data group. (75X)

Record 2--Exchange Time Functions for Surface Water Field (I5, 2F10.0)

NTEX(1)	=	number of exchange time functions for field 1. (I5)
SCALR	=	scale factor for exchange coefficients. All exchange coefficients for field 1 will be multiplied by this factor. (F10.0)
CONVR	=	conversion factor for exchanges in field 1. (F10.0)

Records 3-6 are input as a group NTEX(1) times:

Record 3--Exchange Data (I5)

NORS(1,NT)	=	number of exchanges for field 1, time function NT. (I5)

Record 4--Areas, Characteristic Lengths (2F10.0, 2I5)

A(K)	=	area in square meters for exchange pair K. (F10.0)
EL(K)	=	characteristic length in meters for exchange pair K. (F10.0)
IR(K),JR(K)	=	segments between which exchange occurs. The order of the segments is unimportant. (2I5)

Record 4 is repeated NORS(1,NT) times.

Record 5--Number of Breaks in Time Function (I5)

NBRKR(1,NT) = number of values and times used to describe dispersion coefficient piecewise-linear time function. (I5)

Record 6--Piecewise Linear Dispersion Time Function (4(F10.0, F10.0))

RT(K) = value of dispersion coefficient in m^2/sec at time TR(K). (F10.0)

TR(K) = time in days. (F10.0)

Record 6 is repeated NBRKR(1,NT)/4 times.

Record 7--Exchange Bypass Options (16I5)

RBY(K)* = RBY(1)=1 and RBY(2)=0. (I5)

Record 1 is entered once for Data Group B. Records 2 through 6 are input for the surface water exchange field, with Records 3, 4, 5, and 6 being repeated for each time function in this exchange field. Record 4 uses as many lines as necessary to input NORS sets of A(K), EL(K), IR(K), and JR(K), with 1 set on each line. Record 6 uses as many lines as needed to input NBRKR pairs of RT(K) and TR(K), with 4 pairs occupying each line.

After data for all exchange fields are entered, Record 7 is input on the following line with NOSYS entries. For STREAM II, NOSYS is 2.

DATA GROUP C: VOLUMES

Initial segment volumes are provided in Data Group C. In addition, segment type and underlying segment numbers are specified.

RECORD FORMATS

Record 1--Preliminary Data (2I5, F10.0, 60X)

IVOPT = water column volume option -- 1 = constant water column volumes; 2, 3 = volumes adjusted to maintain flow continuity. (I5)

IBEDV* = benthic volume option -- 0 = constant bed volumes. (I5)

TDINTS = benthic time step in days for recomputing porosity (if IBEDV = 0) or for sediment bed compaction (if IBEDV = 1). (F10.0)

TITLE = name of data group. (60X)

Record 2--Scale Factors (2F10.0)

SCALV = scale factor for volumes. All volumes will be multiplied by this factor. (F10.0)

CONVV = conversion factor for volumes. (F10.0)

Record 3 is repeated NOSEG times:

Record 3--Segment Types and Volumes (5I6,5F10.0)

ISEG = segment number. (I6)

IBOTSG = segment immediately below ISEG. (I6)

ITYPE(ISEG)* = segment types: 1 = surface water segment. (I6)

ITY = segment's stream type used to associate with the function to perform segment volume adjustment according to flow: (I6)
1 = Savannah River
2 = Upper Three Runs
3 = McQueen Branch
4 = Tims Branch
5 = Beaver Dam Creek
6 = Fourmile Branch
7 = Pen Branch
8 = Steel Creek
9 = Lower Three Runs

IRR = number of tributaries upstream of the channel segment. IRR is used to determine the total flow through the segment and then the flow is used to adjust the segment volume accordingly. If IRR is 9999 then no volume adjustment will be performed for that segment. It is used for the segment representing the tributary to provide means to input flow to the main stream; this segment has nothing to do with the pollutant transport calculation. (I6)

BVOL(ISEG) = volume of segment ISEG in cubic meters. (F10.0)

VMULT(ISEG) = hydraulic coefficient "a" for velocity in ISEG as a function of flow:

$v = a Q^b$

If b = 0, VMULT is a constant velocity in m/sec. (F10.0)

VEXP(ISEG) = hydraulic exponent "b" for velocity in ISEG as a function of flow (0-1). A value of 0.4 represents rectangular channels. (F10.0)

DMULT(ISEG) = hydraulic coefficient "c" for depth of ISEG as a function of flow:

$d = c Q^d$

If d = 0, DMULT is a constant depth in m. (F10.0)

DXP(ISEG) = hydraulic exponent "d" for depth of ISEG as a function of flow (0-1). A value of 0.6 represents rectangular channels. (F10.0)

Note that the four hydraulic geometry parameters are used to calculate segment velocity and depth, which are not used by WASP5 in transport calculations. These are used to calculate reaeration or volatilization from segments. Records 1 and 2 are entered once for Data Group C. Record 3 is repeated NOSEG times. Figure A-2.1 in Appendix 2 shows the input example for variables ITY and IRR.

DATA GROUP D: FLOWS

RECORD FORMATS

Data Group D provides for the advective transport flows that are used in the model. The input format for Data Group D is rewritten for the STREAM II code. A constant flow as a function of the month in which the release is taking place is used for the transport calculation in STREAM II.

Record 1--Data Input Options: Number of Flow Fields (2I5, A12)

IQOPT* = 1
NFIELD* = 1 (I5)
HYDFIL = name of hydrodynamic file to be read by WASP5 during the simulation (for example, RIVER1.HYD). (A12)

DATA BLOCK D1: Direct Input of Field One Flows

Record 2--Number of Flow Time Functions (I5, 2F10.0)

NINQ(1) = number of time functions. (I5)
SCALQ = scaling factor. All flows in Field one are multiplied by SCALQ. (F10.0)
CONVQ = units conversion factor. (F10.0)

Records 3 - 6 are input as a group NINQ(1) times:

Record 3--Number of Flows (I5)

NOQS(1,NI) = number of unit flow responses in field one, time function NI; each unit flow is defined for a single segment pair. (I5)

Record 4--Flow Routing for Field One (4(F10.0, 2I15))

BQ(1,NI,K) = portion of flow for field one, time function NI that flows between segment pair K. (F10.0)
JQ(1,NI,K) = upstream segment. (I5)
IQ(1,NI,K) = downstream segment. (I5)

Record 4 is repeated NOQS(1,NI)/4 times.

Record 5—Flows from January to December (4F10.0))

QFLW(I) = advective flow in m^3/s. (F10.0)

Record 5, I =1 to 12, four entries per line.

Record 2 is input once for Data Block D1. Records 3, 4, and 5 are input once for each flow time function. Record 4 uses as many lines as needed to input NOQS sets of BQ, JQ, and IQ, with four sets per line. Record 5 uses three lines with four entries on each line. The sequence of flow time functions input starts with tributaries from upstream to downstream and ends with followed by the Savannah River.

END OF DATA BLOCKS FOR D

Record 6--Flow Bypass Options (16I5)
QBY(ISYS) = flow bypass option -- 0 = flow transport occurs in system ISYS; 1 = flow transport is bypassed for system ISYS. (I5)

ISYS = 1, NOSYS. For STREAM II, NOSYS is 2.

The flow bypass option allows flow transport to be set to zero in one or more systems. The bypass option applies to all transport fields. The input values for STREAM II are 1 and 0.

DATA GROUP E: BOUNDARY CONCENTRATIONS

Data Group E supplies concentrations for each system at the model network boundaries. Model boundaries consist of those segments that import, export, or exchange water with locations outside the network, as specified in Data Groups B and D. All system concentrations from 1 to NOSEG must be supplied for each boundary. Boundary concentrations vary with time following a piecewise linear time function specified by the user in Records 3 and 4.

RECORD FORMATS

Data Group E is repeated, in its entirety, NOSYS times.

Record 1--Data Input Option--Number of Boundary Conditions (I10, 70X)
NOBC(K) = number of boundary conditions used for system K. (I10)
TITLE = name of data group. (70X)

If no boundary conditions are to be input for system K, set NOBC(K) equal to zero and either continue with the next system or go to Data Group F if K is the last system.

Record 2--Scale Factor for Boundary Conditions (2F10.0)
SCALB = scale factor for boundary conditions. All boundary conditions will be multiplied by this factor. (F10.0)
CONVB = unit conversion factor for boundary conditions. Boundary conditions are expected to be in mg/L (i.e. - g/m^3), in which case CONVB will be 1.0. (F10.0)

Records 3-4 are input as a unit NOBC(K) times:

Record 3--Boundary Location (2I5)
IBC(K) = boundary segment number. (I5)
NOBRK(K) = number of values and times used to describe the broken line approximation. The number of breaks must be equal for all boundary conditions within a system. (I5)

Record 4--Boundary Concentrations (4(2F10.0))

BCT(K) = value of the boundary concentration at time T(K) in mg/L. (F10.0)
T(K) = time in days. If the length of the simulation exceeds T(NOBRK), the broken line approximation is repeated, starting at T(1), i.e., the approximation is assumed to be periodic, with period equation to T(NOBRK). All break times must agree for all segments, i.e., T(1) must be the same for all boundaries, T(2) must be the same for all boundaries, etc. (F10.0)

Record 4 is repeated NOBRK(K)/4 times.

Records 1 and 2 are entered once. Records 3 and 4 are a set and are repeated NOBC times. Within each NOBC set, Record 3 is entered once and Record 4 is repeated until NOBRK entries are input. Four entries (four BCT(K)-T(K) pairs) will fit on each 80-space line. The whole group (Records 1 - 4) is repeated NOSYS times, once for each model system. For STREAM II, NOSYS is 2.

DATA GROUP F: WASTE LOADS

The pollutant loading for STREAM II is defined by the user at the pre-processor module and the loading is passed to WASP5 from sub-routine TRACE

RECORD FORMATS

Data Block F1 (records 1) is repeated in its entirety NOSYS times:

Record 1--Number of Point Sources (I5)
IWK = segment number that has point source loading BWK. (I5)
Record 1 is repeated NOSYS times, once for each system. For STREAM II, NOSYS is 2.

Data Block F2, record 2, is input once:

Record 2—Instantaneous Release (I10)
NPSFIL = To conform with the WASP5 logic, NPSFIL is an external file used by WASP5 to input instantaneous release. This file name should include the directory name in which the NPSFIL resides. This file and its contents are described below. (A12)

EXTERNAL NONPOINT SOURCE FILE

This file contains information on which WASP5 systems and segments receive instantaneous releases.

Six records comprise the instantaneous release file.

Record 1--Data Options (A15, 3I5)
NPSMOD = Name or description of loading source model or method of generation; this is echoed to the output file for the record. (A15)
NUMSEG = Number of segments receiving loads. (I5)
INTOPT = Interpolation option; 1 = step function (only one in code now). (I5)
NUMSYS = Number of WASP systems receiving loads. (I5)

Record 2--Loading Segments (I5)
LSEG(I) = segment number receiving loads. (I5)

Record 2 is repeated NUMSEG times.

Record 3--Loading Systems (20I5)
LSYS(I) = WASP system numbers receiving loads. (I5)

Record 4--System Descriptors (A15)
NAMESY(I) = Name or description of WASP systems receiving loads. (A15)

Record 4 is repeated NUMSYS times.

Records 5 and 6 are repeated as a unit for the number of days that nonzero loads occur:

Record 5--Loading Days (F10.0)
LDAY = Time in days for the following nonzero load. (F10.0)

Record 6--Nonpoint Source Loads (A15, 20F10.0)
NAMESY(I) = System name or description (not read in by WASP). (A15)
NPSWK(I,J)* = 0.0; this is the loading that will be assigned by user at the pre-processor module and passed to WASP5 by subroutine TRACE (20F10.0)

Record 6 is repeated NUMSYS times.

Record 1 is input once. Record 2 is repeated NUMSEG times. Record 3 is then input once. Record 4 is repeated NUMSYS times. Records 5 and 6 are a set and are repeated (as a set) NUMSYS times. Within each set, Record 5 is entered once and Record 6 is repeated NUMSYS times.

DATA GROUP G: PARAMETERS

Parameters are not used by STREAM II.

RECORD FORMATS

Record 1--Number of Parameters (I10, 70X)
NOPAM* = 0 number of parameters required by the model. If no parameters are to be input, set NOPAM to zero and go to Data Group H. (I10)
TITLE = name of data group. (70X)

DATA GROUP H: CONSTANTS

STREAM II does not use this data group.

RECORD FORMATS

Record 1--Header (80X)
TITLE = name of data group. (80X)

Records 2-4 are input as a group NOSYS+1 times:

Record 2--Data Fields in Group ISYS (A10, I10)

CHNAME(ISYS) = a ten-character descriptive name for System (ISYS). (A10)
NFLD* = 0 number of fields of constants for this group; 0 = no constants for this group; the user may subdivide the constants into any number of arbitrary fields. (I10)

Record 1 is entered once in Data Group H. Record 2 is entered as NOSYS + 1 groups. For STREAM II, NOSYS is 2.

DATA GROUP I: KINETIC TIME FUNCTIONS

Note: STREAM II does not use kinetic time functions.

RECORD FORMATS

Record 1--Number of Time Functions (I10, 70X)
NFUNC = 0 number of time functions required by the model. If no time functions are to be input, set NFUNC equal to zero and go to Data Group J. (I10)
TITLE = name of data group. (70X)

DATA GROUP J: INITIAL CONDITIONS

RECORD FORMATS

The initial conditions are the segment concentrations and densities for the state variables at time zero (the start of the simulation).

Records 1-2 are input as a group NOSYS times:

Record 1--System Information (A40, I5, F5.0, F10.0, 20X)
CHEML = chemical or system name (A40).
IFIELD = solids field (3, 4, or 5) that transports this system in its pure or sorbed form (I5).
DSED = density of system; 0.0 for chemical, 0.5-2.5 for solids, kg/L. (F5.0).
CMAX = maximum concentration allowed, mg/L. (F10.0)
TITLE = name of data group. (20X)

Record 2--Initial Conditions (3(A5, 2F10.0))
ANAME(K) = an optional one to five alphanumeric character descriptive name or number identifying segment K. (A5)
C(ISYS,K) = initial concentration in segment K of system ISYS in the appropriate units, mg/L. (F10.0)
DISSF = dissolved fraction of chemical in segment K. (F10.0)

Record 2 is repeated NOSEG/3 times.

Records 1 and 2 are a set and will be repeated NOSYS times. Within each NOSYS set, Record 2 will use as many 80-space lines as needed to input NOSEG entries. Three entries (ANAME-C-DISSF) will fit on one line. After NOSEG entries have been entered in a NOSYS set, begin the next NOSYS set on the following line. For STREAM II, NOSYS is 2.

Appendix B. Input file for release from Upper Three Runs (H8.INP)

```
RELEASE from HWY 278 to the Upper Three Runs Creek
Using ArcView GIS to set the segments   Flows are function of month
 NSEG NSYS ICRD MFLG JMAS NSLN INTY ADFC   DD HHMM              A:MODEL OPTIONS
 624    2    0    1    2    0    1 0.0    0 0000    1
 576  589  608  619  221  400
  1
  0.0025      10.0
  3
    0.01      0.00      0.01       3.0      0.02      20.0
  1    0    1    1    1    1
  1                  *    +    *    +    *    +    *    +   B:EXCHANGES
  4      1.00      1.000
 551
 277.966     250.0    0    1
 277.966     500.0    1    2
                                                        •
                                                        •
                                                        •
 277.966     500.0  549  550
 277.966     250.0  550    0
  2
    15.0        0.      15.0     365.0
 20
 11.0369     250.0    0  553
 11.0369     500.0  553  554
                                                        •
                                                        •
                                                        •
 11.0369     500.0  570  571
 11.0369     500.0  571  572
  2
    0.0         0.       0.0      20.0
 48
 30.0000     500.0  572  573
 30.0000     500.0  573  574
                                                        •
                                                        •
                                                        •
 30.0000     500.0  618  619
 30.0000     500.0  619   98
  2
    1.5         0.       1.5      20.0
 14
```

```
11.0369    250.0    0  620
11.0369    500.0  620  573
277.966    250.0    0  551
277.966    500.0  551  214
277.966    250.0    0  552
277.966    500.0  552  391
3.00000    250.0    0  621
3.00000    500.0  621  114
5.50000    250.0    0  622
5.50000    500.0  622  120
197.140    250.0    0  623
197.140    500.0  623  149
17.2800    250.0    0  624
17.2800    500.0  624  188
 2
   0.0       0.      0.0     20.0
 1   0
 2   0     1.20       *   +   *   +   *   +   *   +   * C:VOLUMES
  1.000     1.00
  1    0    1    1    1 138983.00    0.054     0.43    0.4497     0.45
  2    0    1    1    1 138983.00    0.054     0.43    0.4497     0.45
  3    0    1    1    1 138983.00    0.054     0.43    0.4497     0.45
```

•

•

•

```
549    0    1    1    5 138983.00    0.054     0.43    0.4497     0.45
550    0    1    1    5 138983.00    0.054     0.43    0.4497     0.45
551    0    1    1 9999 138983.00    0.054     0.43    0.4497     0.45
552    0    1    1 9999 138983.00    0.054     0.43    0.4497     0.45
553    0    1    2    1 5518.4406    0.054     0.43    0.4497     0.45
```

•

•

•

```
618    0    1    2    2 15000.000    0.054     0.43    0.4497     0.45
619    0    1    2    2 15000.000    0.054     0.43    0.4497     0.45
620    0    1    2 9999 5518.4406    0.054     0.43    0.4497     0.45
621    0    1    1 9999 1500.0000    0.054     0.43    0.4497     0.45
622    0    1    1 9999 2750.0000    0.054     0.43    0.4497     0.45
623    0    1    1 9999 98570.000    0.054     0.43    0.4497     0.45
624    0    1    1 9999 8640.0000    0.054     0.43    0.4497     0.45
 1   1                    *D:FLOWS depend on month
 9     1.0     1.00
521
  1.00   0  553     1.00  553  554     1.00  554  555     1.00  555  556
  1.00  556  557     1.00  557  558     1.00  558  559     1.00  559  560
```

•
•
•

1.00 546 547 1.00 547 548 1.00 548 549 1.00 549 550
1.00 550 0
3.301653 3.207846 3.266333 2.888318
2.751149 2.924501 2.915570 3.157024
2.936142 3.283993 3.174319 3.186102
502
1.00 0 620 1.00 620 573 1.00 573 574 1.00 574 575

•
•
•

1.00 545 546 1.00 546 547 1.00 547 548 1.00 548 549
1.00 549 550 1.00 550 0
4.960624 4.457306 4.708665 3.624399
2.812807 3.260056 3.265267 4.043524
3.033206 4.414079 3.901904 3.990848
551
1.00 0 1 1.00 1 2 1.00 2 3 1.00 3 4
1.00 4 5 1.00 5 6 1.00 6 7 1.00 7 8

•
•
•

1.00 544 545 1.00 545 546 1.00 546 547 1.00 547 548
1.00 548 549 1.00 549 550 1.00 550 0
295.5323 374.5016 408.4568 292.2135
230.5022 199.2946 198.1960 243.3081
197.4634 226.3935 219.2800 270.5142
339
1.00 0 551 1.00 551 214 1.00 214 215 1.00 215 216
1.00 216 217 1.00 217 218 1.00 218 219 1.00 219 220

•
•
•

1.00 544 545 1.00 545 546 1.00 546 547 1.00 547 548
1.00 548 549 1.00 549 550 1.00 550 0
37.55606 36.74445 77.58755 60.91205
34.53681 21.32636 21.07870 22.07861
21.31566 23.17719 13.30829 36.78693
162

```
   1.00   0  552    1.00  552  391    1.00  391  392    1.00  392  393
   1.00  393  394    1.00  394  395    1.00  395  396    1.00  396  397

                                                •

                                                •

                                                •
   1.00  541  542    1.00  542  543    1.00  543  544    1.00  544  545
   1.00  545  546    1.00  546  547    1.00  547  548    1.00  548  549
   1.00  549  550    1.00  550   0
47.07052  38.84818  65.45759  58.57749
30.58463  22.45337  17.90599  18.90408
31.08435  19.16107  20.29185  31.29286
439
   1.00   0  621    1.00  621  114    1.00  114  115    1.00  115  116
   1.00  116  117    1.00  117  118    1.00  118  119    1.00  119  120

                                                •

                                                •

                                                •
   1.00  540  541    1.00  541  542    1.00  542  543    1.00  543  544
   1.00  544  545    1.00  545  546    1.00  546  547    1.00  547  548
   1.00  548  549    1.00  549  550    1.00  550   0
2.056473  1.946658  1.992379  1.924602
2.002427  2.251976  2.498277  2.450168
2.251504  2.130614  2.096862  2.048709
433
   1.00   0  622    1.00  622  120    1.00  120  121    1.00  121  122
   1.00  122  123    1.00  123  124    1.00  124  125    1.00  125  126

                                                •

                                                •

                                                •
   1.00  542  543    1.00  543  544    1.00  544  545    1.00  545  546
   1.00  546  547    1.00  547  548    1.00  548  549    1.00  549  550
   1.00  550   0
1.384937  1.533299  1.703730  1.022710
0.677472  0.947041  1.206633  1.546465
0.877933  1.346481  0.988259  1.018798
404
   1.00   0  623    1.00  623  149    1.00  149  150    1.00  150  151
   1.00  151  152    1.00  152  153    1.00  153  154    1.00  154  155

                                                •

                                                •

                                                •
```

```
   1.00  543  544     1.00  544  545     1.00  545  546     1.00  546  547
   1.00  547  548     1.00  548  549     1.00  549  550     1.00  550    0
4.738962  4.356244  4.266710  3.590576
3.326316  3.731688  3.319466  3.475208
3.346579  3.961162  3.811447  4.155269
365
   1.00    0  624     1.00  624  188     1.00  188  189     1.00  189  190
   1.00  190  191     1.00  191  192     1.00  192  193     1.00  193  194

                                                    •

                                                    •

                                                    •
   1.00  542  543     1.00  543  544     1.00  544  545     1.00  545  546
   1.00  546  547     1.00  547  548     1.00  548  549     1.00  549  550
   1.00  550    0
3.534430  3.362835  3.369553  2.140911
1.944576  2.238604  1.740116  3.108459
2.515323  2.667417  2.463094  2.243729
 1   0   1   1   1   1
    10                  *   +   *   +   *   +  E:BOUNDARIES
   1.00     1.00            *   +   *   +   *   +   *   Chem 1
 1   2
   0.00     0.00     0.00    20.00
550   2
   0.00     0.00     0.00    20.00
551   2
   0.00     0.00     0.00    20.00
552   2
   0.00     0.00     0.00    20.00
553   2
   0.00     0.00     0.00    20.00
620   2
   0.00     0.00     0.00    20.00
621   2
   0.00     0.00     0.00    20.00
622   2
   0.00     0.00     0.00    20.00
623   2
   0.00     0.00     0.00    20.00
624   2
   0.00     0.00     0.00    20.00
    10                  *   +   *   +   *   +  E:BOUNDARIES
   1.00     1.00            *   +   *   +   *   +   *  Solids 1
 1   2
   0.00     0.00     0.00    20.00
550   2
   0.00     0.00     0.00    20.00
551   2
   0.00     0.00     0.00    20.00
```

```
 552    2
    0.00      0.00      0.00     20.00
 553    2
    0.00      0.00      0.00     20.00
 620    2
    0.00      0.00      0.00     20.00
 621    2
    0.00      0.00      0.00     20.00
 622    2
    0.00      0.00      0.00     20.00
 623    2
    0.00      0.00      0.00     20.00
 624    2
    0.00      0.00      0.00     20.00
 556                        *    +    *    +    * (Chem 1)    F:LOADS
 556                        *    +    *    +    * (Solids 1)  F:LOADS
.\INP\H8.NPS                     *    +    *    +    *  (NPS)     F:LOADS
       0                       *    +    *    +    *    +   G:PARAMETERS
                              *    +    *    +    *    +    H:CONSTANTS
GLOBALS           0
Chem1             0
Solids1           0
       0                       *    +    *    +    *    I:TIME FUNCTIONS
    Chem 1                           3 1.00    1.0E+4    + j: initial con
  1:      0.00      0.00   2:      0.00      0.00   3:      0.00      0.00
  4:      0.00      0.00   5:      0.00      0.00   6:      0.00      0.00
```

•

•

•

```
619:      0.00      0.00 620:      0.00      0.00 621:      0.00      0.00
622:      0.00      0.00 623:      0.00      0.00 624:      0.00      0.00
 Solids 1                        0 1.00   1.0E+04
  1:      0.00      0.00   2:      0.00      0.00   3:      0.00      0.00
  4:      0.00      0.00   5:      0.00      0.00   6:      0.00      0.00
```

•

•

•

```
619:      0.00      0.00 620:      0.00      0.00 621:      0.00      0.00
622:      0.00      0.00 623:      0.00      0.00 624:      0.00      0.00
```

Distribution:

C.H. Hunter, 773-A
R.L. Buckley, 773-A
S.R. Chiswell, 773-A
R.J. Kurzeja, 773-A
M.J. Parker, 773-A
B.J. Viner, 773-A
S.W. Weinbeck, 773-A
D.W. Werth, 773-A
L.M. Chandler, 773-A
D.S. Foutch, 703-45A
B.L. Blue, 703-45A
D. Delmore, 730-2B