A Toxic Spill Model for the Potomac River Basin

by

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CHAPTER ONE

INTRODUCTION

The Potomac River basin system is a source of water for the Washington, D.C. Metropolitan area (WMA) and numerous smaller municipalities located on the main stem of the Potomac River and on the many tributaries. In particular, the Potomac River provides an increasing portion of the water supply for the WMA. The drainage area upstream of the intakes for the water supply utilities in the WMA is substantial: 11,000 sq. miles (28,490 km^2). Numerous opportunities exist for accidental spills of toxic materials to enter the Potomac system on the main stem or one of the tributaries and temporarily threaten the potability of the water. The risk of an accident is real -- at least one potentially dangerous spill has reached the Potomac River in recent years. In this instance a toxic substance was introduced into the Potomac river upstream of Shepherdstown, W. Va. in June 1981. The spill was small in quantity and of a volatile compound, aniline. Although downstream concentrations were not threatening, the event underscored the need for the effective management of toxic spills.

One component of a successful management system is a means by which to estimate the fate of spilled material so that downstream industrial and water supply utilities may be notified in time to take appropriate action, which may include closing the intakes while the contaminant passes by. This report describes the development of a model which accomplishes this function. A toxic spill model has been developed based on time of travel studies performed on selected river reaches in the Potomac basin. The model assumes a perfectly soluble, conservative substance has entered the system at a user specified location, and once supplied with a description of the magnitude and timing of the spill, the model may be used to provide the following information:

1. Time of arrival of leading edge of contaminant cloud at a point.
2. Time of arrival of maximum concentration of contaminant cloud at a point.
3. Time of arrival of trailing edge of contaminant cloud at a point.
4. Maximum concentration of contaminant cloud at a point.
5. Time of passage of contaminant cloud at a point.

This information may be obtained for any site located within the calibrated portions of the basin. These reaches are displayed on a map of the Potomac River basin in Figure 1.1. In addition to showing the calibrated river reaches, the map indicates the locations of the major water intake structures and the major transportation routes where spills are likely to occur. A list of the water intake facilities is provided in Table 1.1. The list includes the operating utility, the name of the river or tributary on which the intake is located , and the number of miles upstream from the mouth of the tributary if the

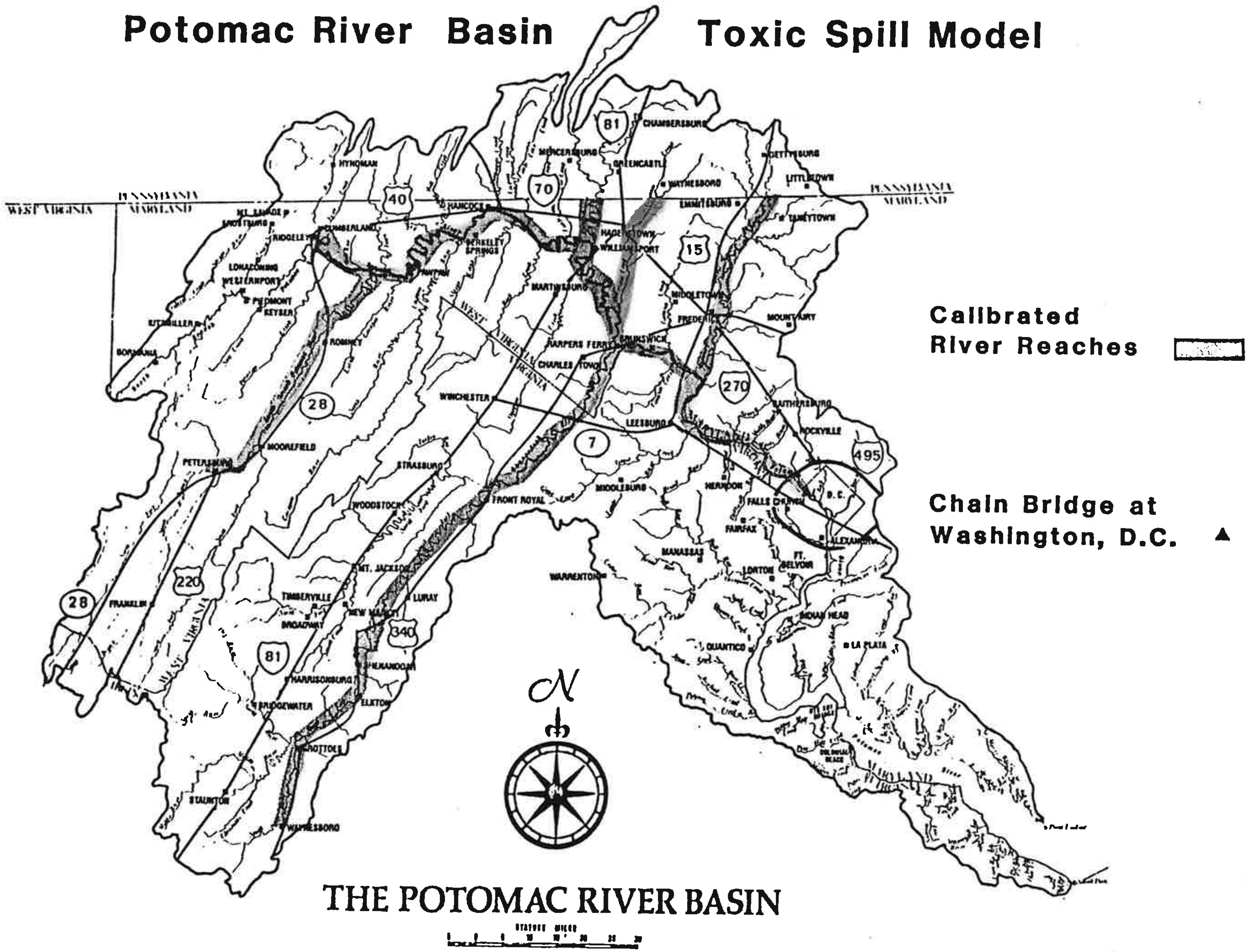

Figure 1.1 Map of the Potomac River basin

Table 1.1 Water Supply Intakes on Calibrated Reaches in the Potomac River Basin

Location	Utility	River/ Tributary	Miles Above: Trib. Mouth	Miles Above: Chain Bridge
Petersburg, W. Va.	Petersburg Municipal Water System Grant County PSD	South Branch	69	169
Moorefield, W. Va.	City	South Branch	57.3	169
Romney, W. Va.	City	South Branch	31.8	169
Hancock, Md.	City	Potomac	-	123
Hagerstown, Md.	City Sharpsburg-Washington Co. Sanitation Comm.	Potomac	-	95
Shepherdstown, W. Va.	City	Potomac	-	68
Shenandoah, Va.	City	Shenandoah	129.1	56
Front Royal, Va.	City Potomac Edisons Riverton Sta.	Shenandoah	57.7	56
Brunswick, Md.	City	Potomac		50
Frederick, Md.	City Fort Dietrick	Monocacy	21.2	38
Leesburg, Va.	City	Potomac		32
Seneca Pool	Fairfax County Water Authority	Potomac		18
Near Watkins Island	Washington Suburban Sanitary Comm.	Potomac		14
Rockville, Md.	City	Potomac		12
Great Falls	Washington Aqueduct Division	Potomac		10
Little Falls	Washington Aqueduct Division	Potomac		1

intake is on a tributary or the river mile above Chain Bridge if the intake is on the main stem. In addition, if the intake is located on a tributary, the river mile above Chain Bridge of the confluence with the Potomac River is provided.

The purposes of this report are threefold. First this report is to generally describe the method by which the data from various travel time studies are transformed into predictive parameters which estimate travel times for a range of discharges. Secondly, the derivation of these parameters for the main stem of the Potomac River and five tributaries is discussed. Finally, this report is to serve as an operational manual for the spill model.

CHAPTER TWO

METHODOLOGY

The generalized method for predicting travel times and concentrations of a soluble substance used in the spill model requires a minimum of two travel time studies. These studies provide sufficient information for the interpolation and extrapolation to travel times corresponding to a wide range of flows and over lengthy stretches of river.

One dye study yields a time-concentration curve which describes the passage of a soluble substance past a fixed point on the river, Figure 2.1. Comparison of several time-concentration curves representing a sequence of sampling sites describes both the passage of the substance past each point and the longitudinal dispersion observed with the existing flow regime, see Figure 2.2.

The information provided in these curves forms the basis for interpolation and extrapolation for a general case, that is for a spill occurring at any flow within the calibrated range and at any point along the reach of the study. The information is generalized through the use of the following equation which defines the inverse relationship observed between discharge and travel time:

$$\log Q = a * \log T + b$$

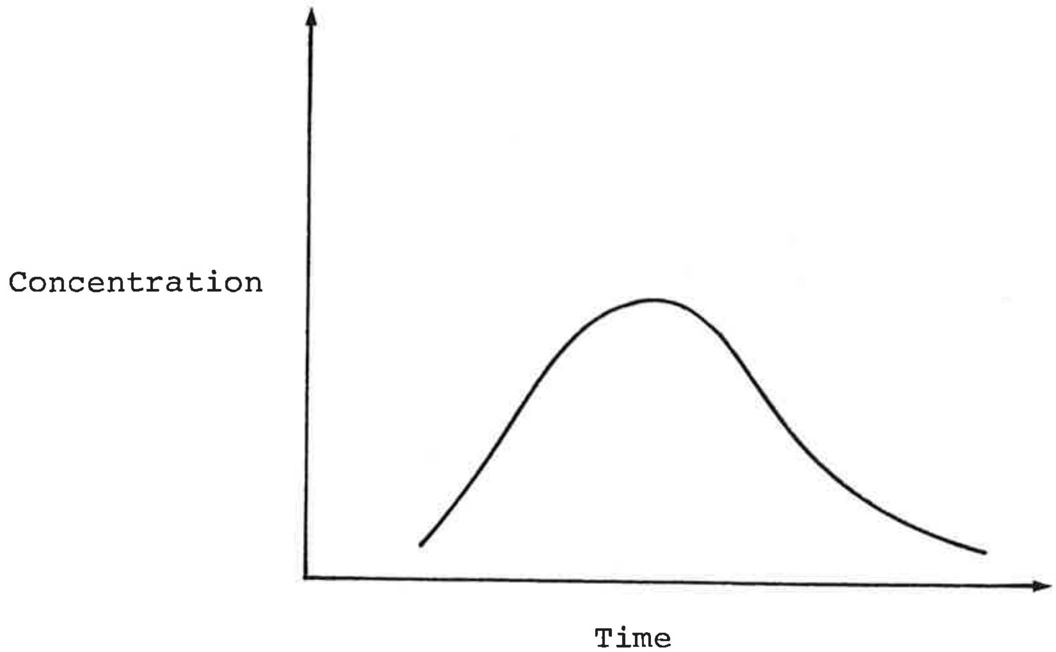

Figure 2.1 Time-concentration curve

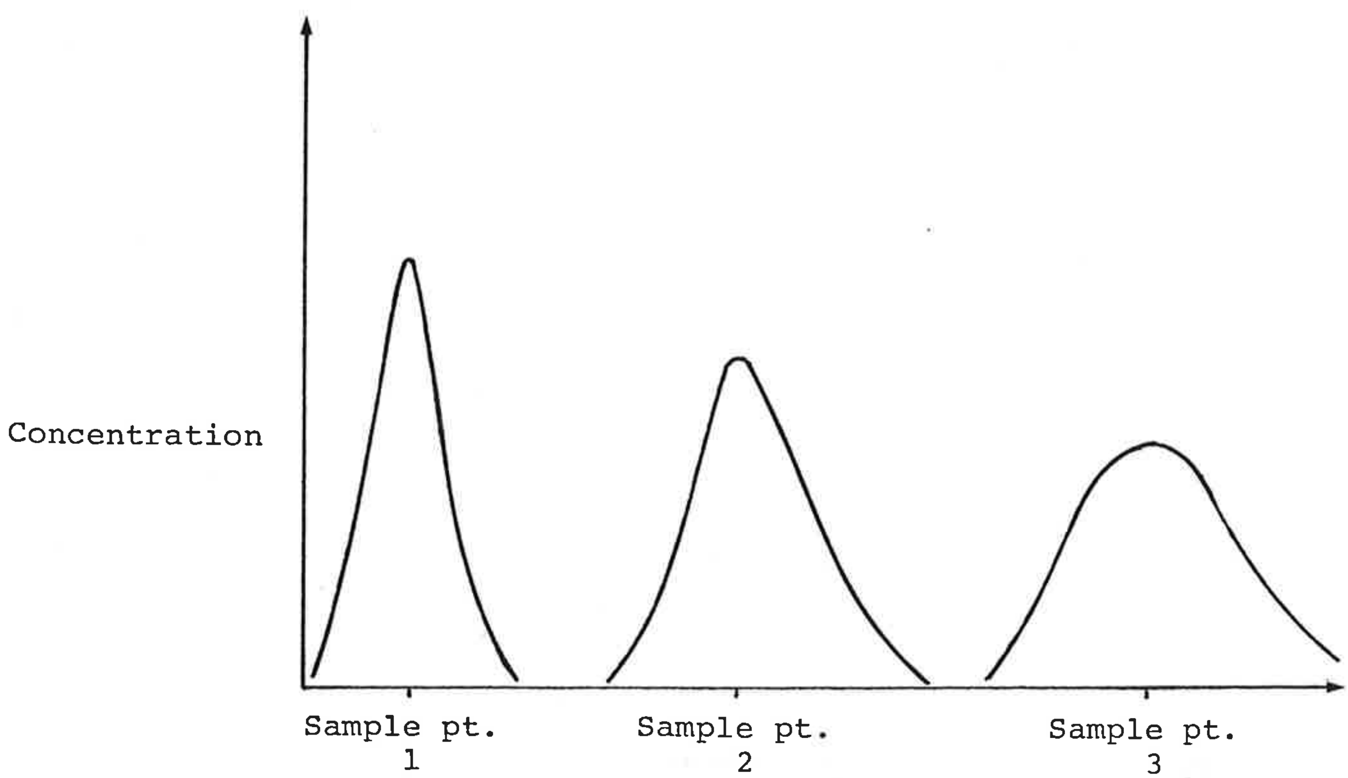

Figure 2.2 Time-concentration curves at sequential sampling points

where:

Q = an observed discharge

T = a measured travel time

a, b = regression coefficients

The parameters of this equation are estimated for each subreach within the study as defined by the sampling points. Therefore, the travel time through a reach may be calculated, once a discharge has been specified, with the following equation:

T = 10 ** (1/a (log Q - b))

When a point within the reach is of interest, the travel time to that point is obtained by scaling the total travel time by the ratio of the distances travelled.

Three particular travel times are defined, obtained from the time-concentration curves, and analyzed. These travel times correspond to the leading edge, the peak concentration, and the trailing edge of the dye cloud. The trailing edge is defined as the point on the curve where the concentration falls to 10 percent of the peak concentration. Using the regression coefficients resulting from the analysis of each set of travel times, travel times may be estimated for a wide range of discharges. The location of the discharge, which is to be specified, is determined to coincide with a gage at which the information is readily available so as to facilitate operation of the spill model in critical situations.

Identifying and incorporating useful and consistent measures of the flow regime requires further analysis. Basing travel time predictions on one gage is not sufficient for long stretches of river because although stream discharge generally increases in the downstream direction as the drainage area increases, these increases do not occur uniformly with distance along the river. At the points where tributaries enter the river, stream discharge increases abruptly. Depending on the drainage area of the tributary, these increases can be substantial. Usually, however, the river channel has adjusted to these increases in flow, and an increase in velocity commensurate with the increase in flow does not occur. For this reason, absolute discharge in the river is not an ideal parameter for the relationship between traveltime and discharge over long distances.

Alternatively, flow duration is an index of river discharge that is fairly constant throughout a reach of a stream, provided there is no flood wave moving through the system. This characteristic makes flow duration a useful index of stream discharge. Flow duration is defined as the percentage of time the historic mean-daily discharges exceeded a specified discharge. Therefore, in long rivers where several gages are maintained and flow duration curves, see Figure 2.3, are available the regression coefficients are based on the flow of the gage which is most representative of its hydrologic regime.

The discharge at the additional gages is either obtained from real-time information or through interpolation from a flow duration curve for that gage once the duration has been

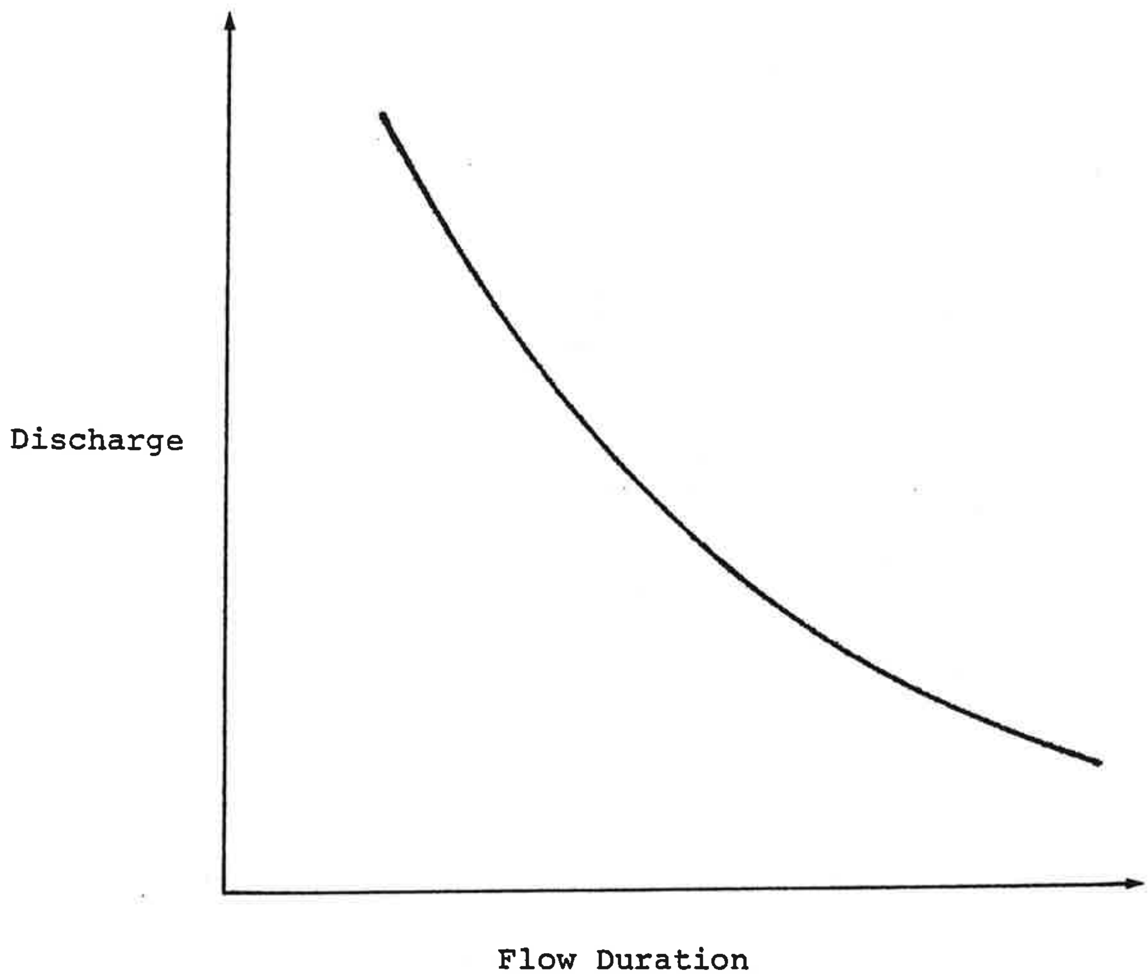

Figure 2.3 Flow duration curve

determined for a primary gage.

The regression coefficients resulting from the discharge - travel time relationship for the three travel times also provide sufficient information with which to estimate the concentrations of the passing substance over time. The estimation procedure is based on the relationship between a time-concentration curve and a scalene triangle, see Figure 2.4. As shown in the figure, the peak concentration relative to the area under the time-concentration curve is similar to the height of the scalene triangle relative to the area of the triangle.

The scalene triangle, appealing due to the simpler shape and fewer data requirements, was tested to determine how accurately it represented a simplified time-concentration curve. The rationale and the results of this test are outlined here. The first advantage of the scalene triangle is that the ratio of the height of the triangle to the area of the triangle can be expressed entirely in terms of the length of the base of the triangle; if unit peak concentration is expressable in terms of values generated with the regression coefficients, it would reduce the problems with incomplete lateral mixing often encountered in the field and the associated problem of defining discharge-weighted concentrations. Second, it would allow calculation of peak concentrations for long travel times without the need for observed time-concentration curves for those traveltimes. Testing the relationship yielded the following equation:

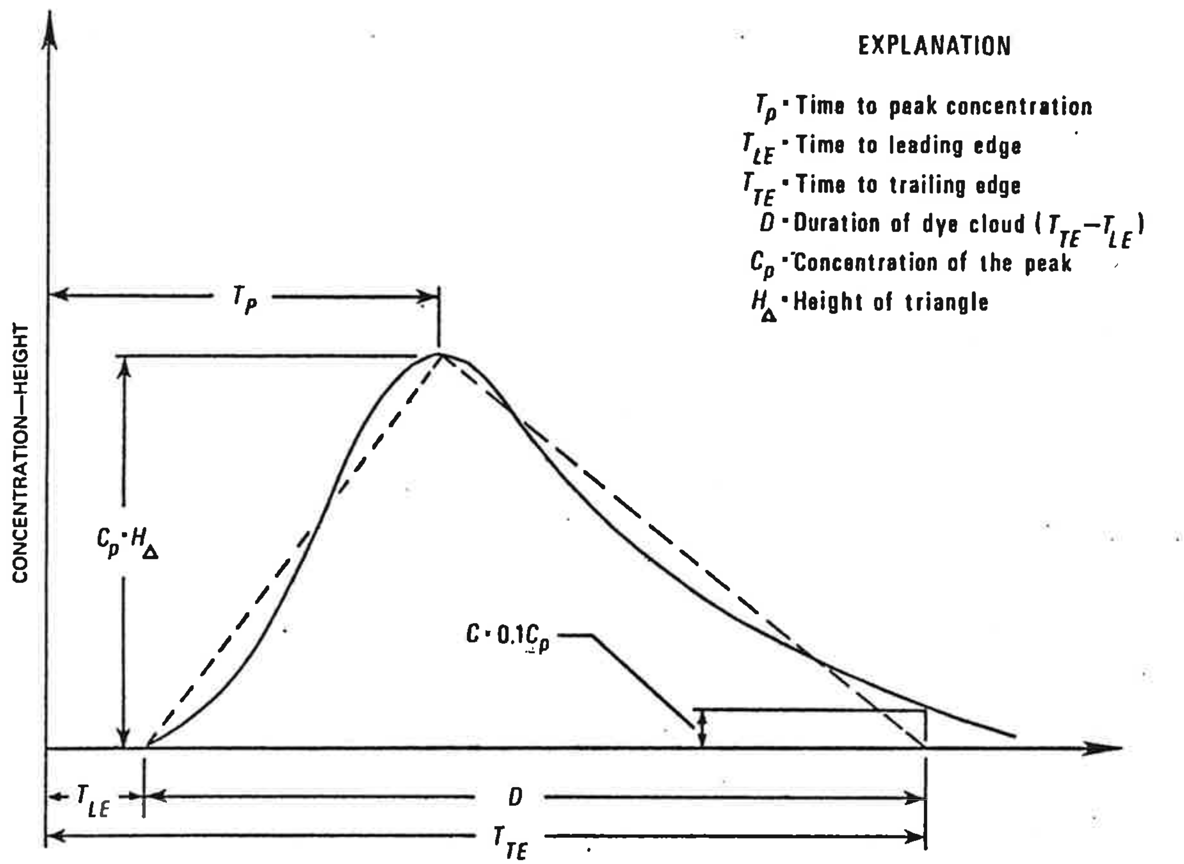

Figure 2.4 Relation between time-concentration curve and scale triangle.

$$As = 1.042 * At^{1.002}$$

where:

As = the area under the scalene triangle calculated as 1/2 the base times the observed peak concentration

At = the area under the time-concentration curve

A graph of this relationship is shown in Figure 2.5, as provided by Taylor et al. (1985). The value 1.002 is assumed to be unity and suggests that the relationship between the two areas is valid throughout the range of the analyzed areas. This equation may be arranged as follows:

$$At = As / 1.042$$

By substituting this value in an equation which relates the unit peak concentration (Cup) with the observed peak concentration (Cp) and the observed area under the time-concentration curve (At), namely:

$$Cup = 4440 * Cp / At$$

yields the following equation:

$$Cup = 4440 * 1.042 * Cp / As$$

As can be replaced with the formula for the area of a triangle where the base is expressed in terms of the difference between the travel times of the leading edge and the trailing edge or the cloud duration, D. This formula may be written as:

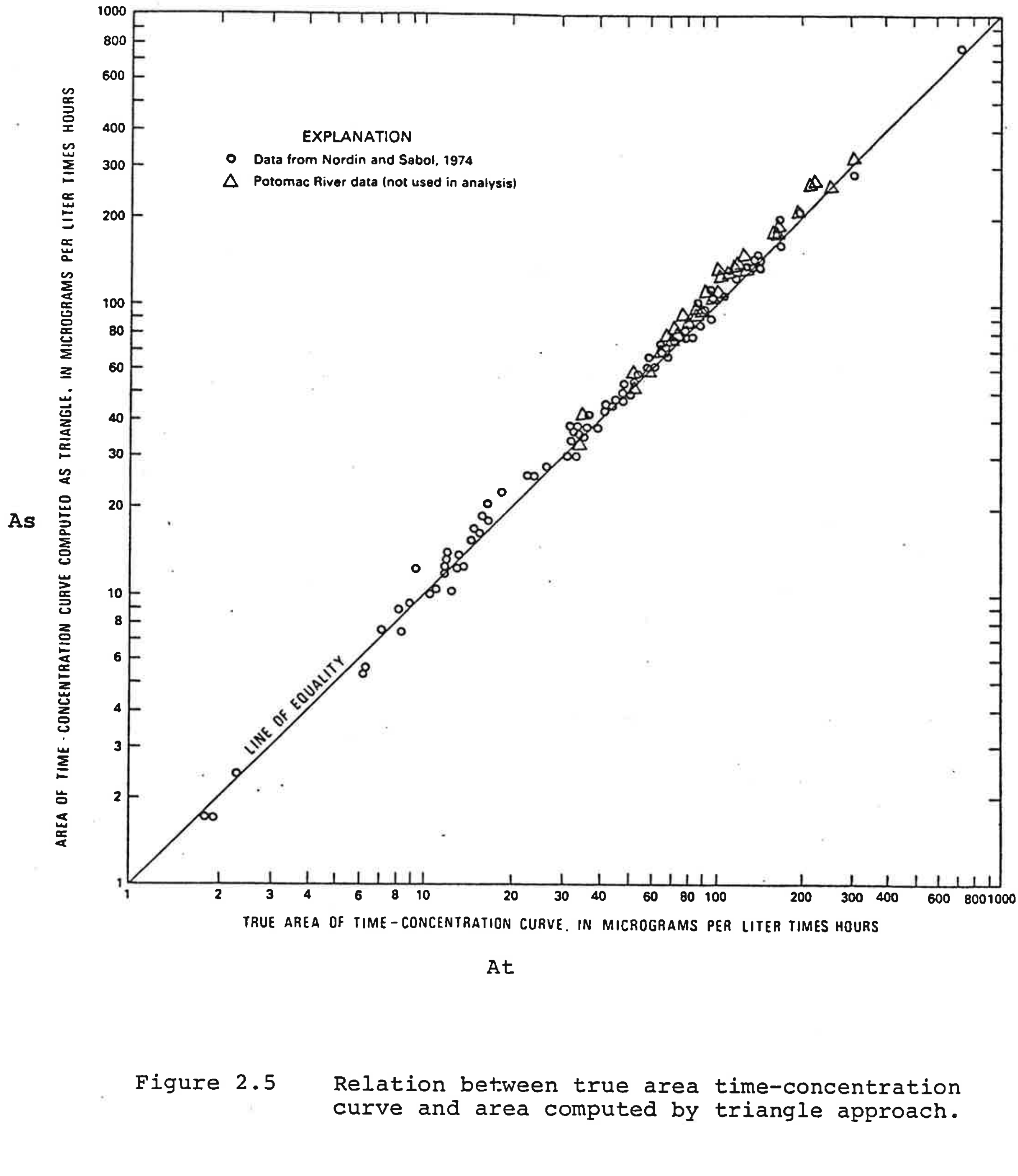

Figure 2.5 Relation between true area time-concentration curve and area computed by triangle approach.

$$As = 0.5 * D * Cp$$

and changes the expression for Cup to the following:

$$Cup = 4440 * 1.042 * Cp / 0.5 * D * Cp$$

or:

$$Cup = 9250 / D$$

Dimensional analysis shows that the unit peak concentration is an inverse function of time, as is expected.

With information describing the timing of the arrival of the leading edge, the trailing edge, and the peak concentration in addition to describing the magnitude of the peak concentration, concentrations at any point on the time concentration curve may be estimated. This results from interpolation using the scalene triangle analogy. These estimates may be performed for any point along the calibrated reaches. How this information is derived and incorporated into the computer code is discussed in the next section.

CHAPTER THREE

COMPUTER APPLICATION OF THE METHODOLOGY

traveltime parameters were derived for 189 miles of the Potomac River and for the following portions of tributaries of the Potomac River:

Antietam Creek	40.5 miles
Conococheague Creek	21.2 miles
Monocacy River	57.1 miles
Shenandoah River	178.5 miles
South Branch Potomac River	69.0 miles

A spill that occurs on a tributary is routed down the length of the tributary with the flow specified for the appropriate index gage, mixed with the Potomac River at the confluence, and routed down the Potomac River with the flows specified for main stem gages. The loadings into the Potomac are calculated to maintain the degree of longitudinal dispersion which developed during travel down the tributary.

The derivation of the traveltime parameters for the main stem of the Potomac River is discussed below. This is followed by the derivation of the traveltime parameters for the tributaries.

Characterization of the Main Stem

The main stem of the Potomac River was calibrated between Cumberland, Maryland and Chain Bridge at Washington D.C., a distance of 189 miles. The location of this reach is shown in Figure 3.1. The calibration is a result of a multiple step procedure which translates the data provided by two traveltime studies, one in May 1964 and one in Fall 1981, into general time of travel coefficients. A complete description of the sampling and analysis techniques is provided by Taylor et al. (1985). Below is a brief account of the method for deriving the traveltime coefficients with an emphasis placed how the data from the studies is incorporated into the toxic spill model.

For purposes of the traveltime studies the 189 miles were divided into 16 subreaches as defined by 17 sampling sites. Time-concentration curves were developed for each site corresponding to the existing flow durations of approximately 60 percent in 1964 and 90 percent in 1981. Curves for a subreach in the latter study are shown in Figure 3.2.

From these curves, the traveltimes for the leading edge, the peak concentration, and the trailing edge of a dye cloud were obtained. Average velocities were calculated for each reach and each study by dividing the traveltime through the reach by the length of the reach. This yields two points consisting of velocity discharge pairs. A discharge-velocity line was then derived for each set of points. The linear relationship was used to transform discharges corresponding to particular flow

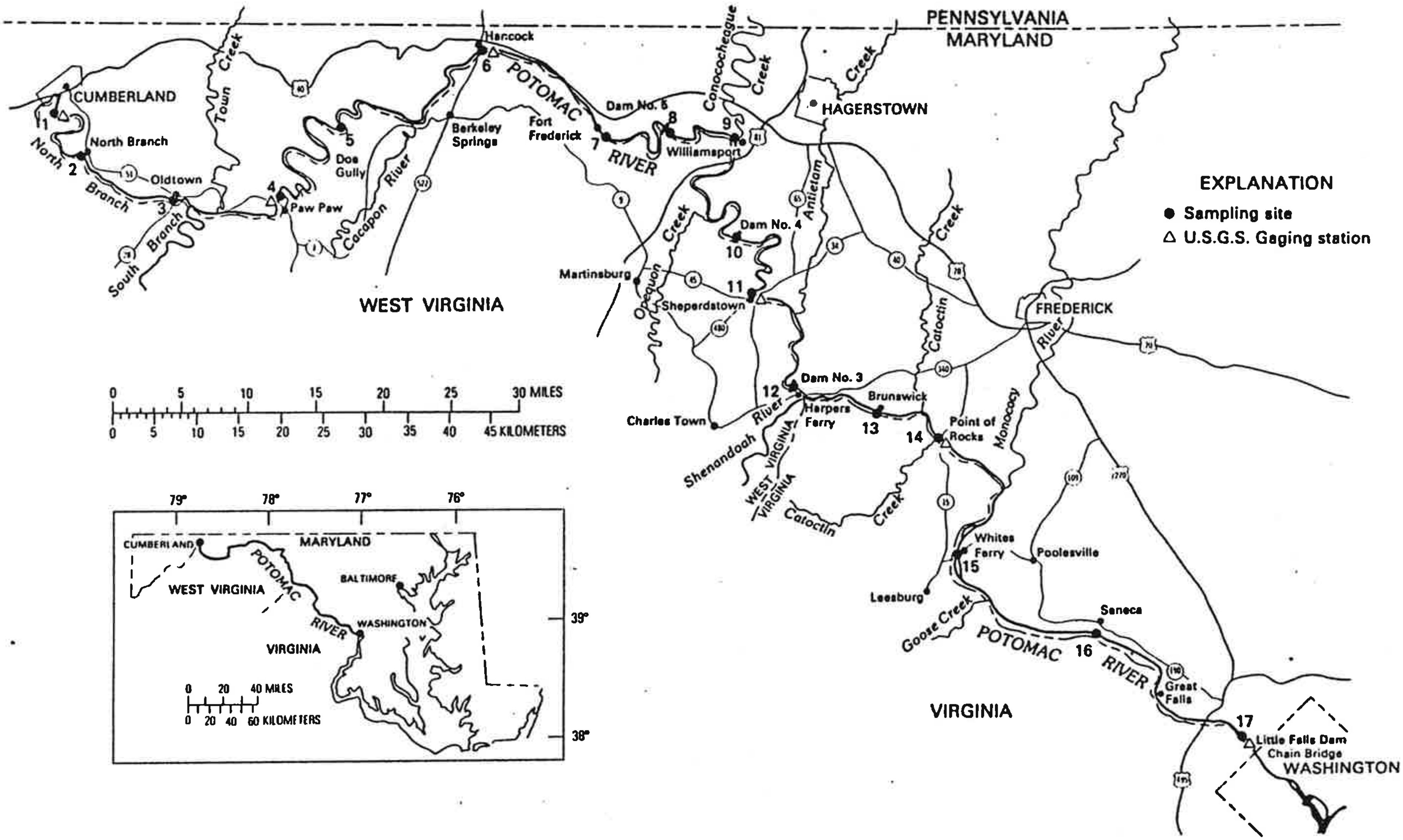

Figure 3.1 Location of calibrated reach of the Potomac River

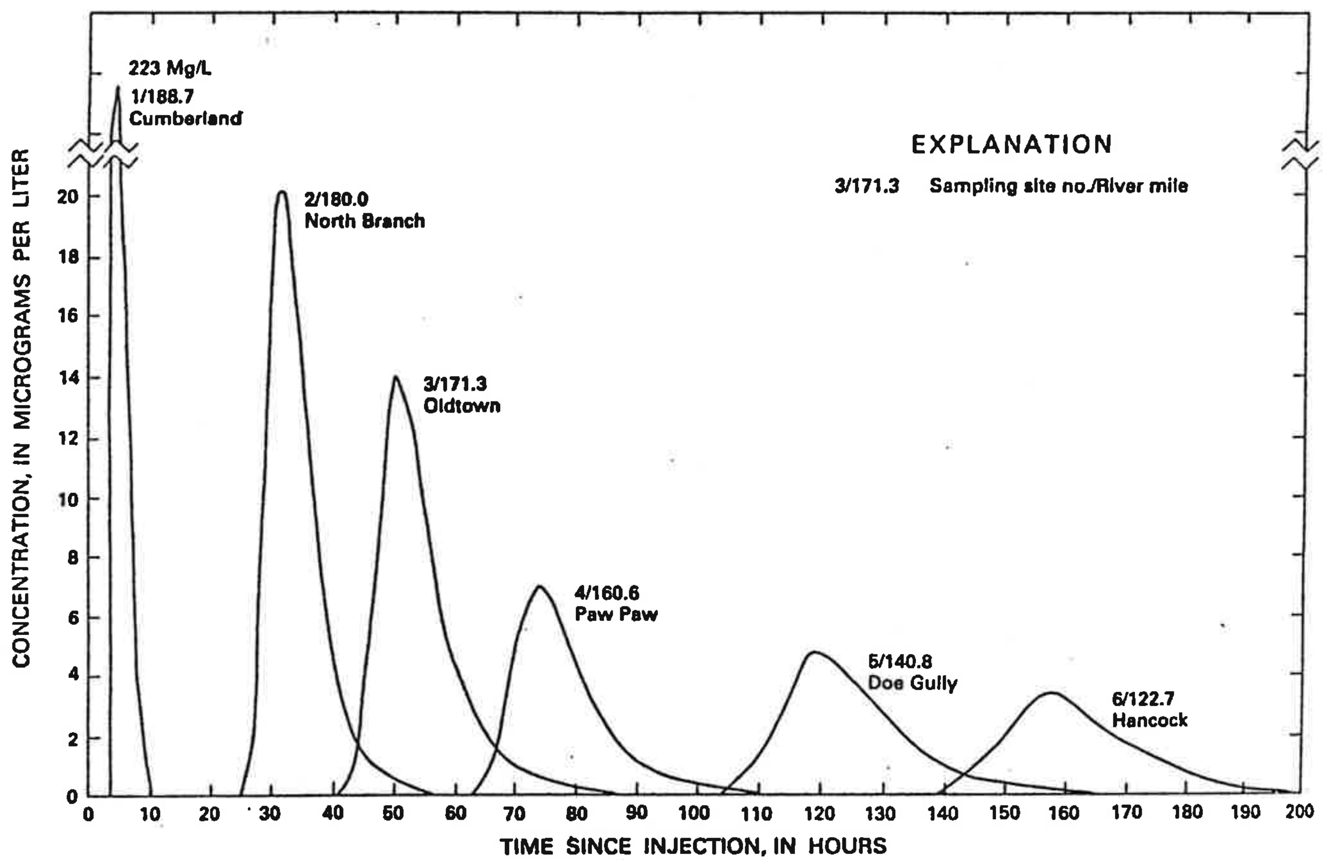

Figure 3.2 Observed time-concentration curves for Cumberland to Hannock subreach for the October 1981 study.

durations into velocities. The velocities were then transformed back into traveltimes by dividing the reach length by the velocity. This sequence of calculations was performed for incremental flow durations. Once the traveltimes are summed down the length of the river, total traveltimes for a number of flow durations are provided, as shown in Figure 3.3. The information provided in this graph is sufficient for the interpolation of the traveltimes of the trailing edge for any flow duration, any point of origin, and any downstream point of interest. Additional graphs provide the same information for the traveltimes of the leading edge and the peak concentration.

The interpolation process is automated within the Toxic Spill Model. That is, the information provided in the traveltime-distance graphs is used to derive the traveltime parameters ultimately stored and employed within the model. Specifically, traveltimes corresponding to the flow durations of 50, 70, 80, 90, and 95 were selected from the graph and paired with the discharge at the index gage best representing the flow regime of the reach. This information (data for the regression models) is provided in Table 3.1. The length of each reach and the gaging station coupled with the reach are also indicated; the number of reaches has been reduced to eleven for the model. The coefficients resulting from the regression analysis are provided in Table 3.2.

A link between the flow at the index gages must be established to allow the summation of traveltimes down the

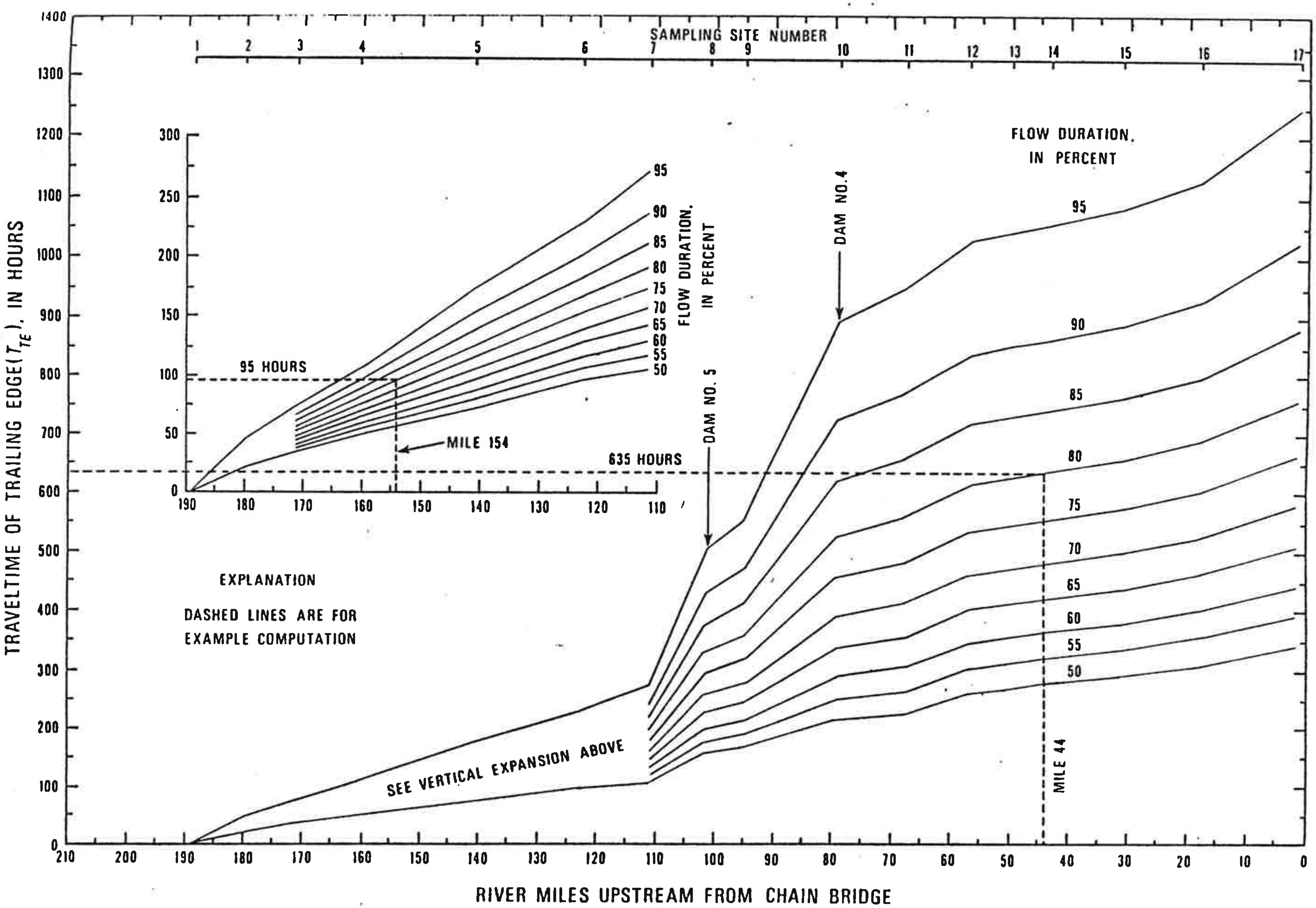

Figure 3.3 Travel time-distance relation for trailing edge of dye cloud at selected durations.

Table 3.1 Study Information for the Potomac River

Reach (gage)	Length of Reach (mi)	Flow (cfs)	Travel Times (hrs) Leading Edge	Peak Conc.	Trailing Edge
1 (PP)	28.1	1500	33	39	49
		720	46	54	68
		510	54	63	80
		370	64	75	94
		290	71	83	104
2 (PP)	37.9	1500	32	36	47
		720	50	57	71
		510	62	70	87
		370	78	87	108
		290	90	100	123
3 (H)	11.5	1900	8	10	10
		920	15	16	19
		640	19	22	25
		460	25	29	35
		370	30	34	43
4 (H)	9.7	1900	20	27	49
		920	40	56	97
		640	57	78	135
		460	82	110	190
		370	102	137	231
5 (H)	6.6	1900	6	8	10
		920	14	16	22
		640	19	22	30
		460	28	33	43
		370	102	137	231
6 (Sh)	15.5	2900	24	33	49
		1600	50	72	112
		1100	74	107	169
		780	108	158	255
		600	138	201	337
7 (Sh)	11.7	2900	8	9	11
		1600	17	20	24
		1100	23	26	33
		780	33	39	46
		600	41	49	58

Table 3.1 (continued)

Reach (gage)	Length of Reach (mi)	Flow (cfs)	Travel Times (hrs) Leading Edge	Peak Conc.	Trailing Edge
8 (Sh)	10.5	2900	23	27	34
		1600	32	37	47
		1100	38	44	55
		780	47	53	67
		600	54	61	78
9 (Pt)	13.6	5200	14	16	19
		3000	17	19	22
		2200	18	20	23
		1600	19	22	25
		1260	20	23	26
10 (Pt)	25.6	5200	25	29	31
		3000	37	41	44
		2200	44	47	53
		1600	55	58	65
		1260	63	67	75
11 (Pt)	16.8	5200	22	24	34
		3000	35	40	56
		2200	46	53	73
		1600	61	70	99
		1260	76	86	122

PP - Paw Paw, West Virginia
H - Hancock, Maryland
Sh - Shepherdstown, West Virginia
Pt - Point of Rocks, Maryland

Table 3.2 Travel Time Coefficients for the Main Stem of the Potomac River

	Leading Edge		Peak Concen.		Trailing Edge	
Reach	a	b	a	b	a	b
1	-2.1278	6.4012	-2.1571	6.6007	-2.1640	6.8290
2	-1.5792	5.5468	-1.6007	5.6665	-1.6930	5.9999
3	-1.2502	4.4145	-1.3141	4.5749	-1.1281	4.4025
4	-1.0019	4.5756	-1.0112	4.7266	-1.0526	5.0558
5	-0.9331	4.0119	-0.9993	4.1713	-1.0000	4.2694
6	-0.8977	4.7130	-0.8681	4.7956	-0.8178	4.8588
7	-0.9644	4.3534	-0.9333	4.3732	-0.9506	4.4761
8	-0.9625	4.3514	-1.9450	6.2471	-1.9201	6.4020
9	-3.9596	8.2864	-3.8886	8.4137	-4.4997	9.4839
10	-1.5345	5.8688	-1.7075	6.2150	-0.9541	4.9540
11	-1.1437	5.2469	-1.1782	5.3550	-1.1083	5.4129

length of the river. Four gages were used to represent the the main stem. These are located at:

Paw Paw, West Virginia	(PP)
Hancock, Maryland	(H)
Shepherdstown, West Virginia	(Sh)
Point of Rocks, Maryland	(Pt)

Only the flow (stage) at Point of Rocks must be entered into the model; estimates of the flow at the other gages are based on correlations with the Point of Rocks information. This is performed by first transforming the stage (available by phone, (703) 260-0305) at Point of Rocks into a discharge, Qpt, using the stage-discharge curve for Point of Rocks:

$$Qpt = 10 ** (1.4119 * \log(stage) + 3.2191)$$

Discharge at the upstream gages are determined by the following equations:

$$Qpp = 0.3191 * Qpt - 182.26$$

$$Qh = 0.4065 * Qpt - 239.35$$

$$Qsh = 0.5925 * Qpt - 182.42$$

Otherwise, if the stages at the upstream gages are specified, equations representing the stage-discharge curves for these gages are used.

The elements of the model which represent the Potomac River between Cumberland and Chain Bridge have been described. The necessary inputs are contaminant loadings from a spill and the stage at the Point of Rocks gage. Loadings may also result from spills on any of the five calibrated tributaries. The method of calibration for the tributaries is discussed below followed by a detailed discussion of the inputs required by the model and the products generated.

Characterization of the Tributaries

Five tributaries have been calibrated for inclusion in the model. Depending upon the data made available in the traveltime studies for each tributary, the exact manner in which the traveltime coefficients were derived varies.

As discussed above, the determination of the parameters which estimate the time of travel of pollutants revolves around the following equation:

$$\log Q = a * \log T + b$$

where Q is an easily obtainable measure of flow within the tributary sub-basin and T is a measure of the traveltime of the pollutant. Values for a and b are obtained through regression after two or more traveltime studies have been performed. The traveltime studies were performed at discharges such that the range of expected flows is represented.

The derivation of useful coefficients requires that the values of a and b be related to information available almost instantaneously. Therefore, the flow, Q, used in the regression model is one measured at an index gage on the tributary. How this flow information is obtained and used in the derivation of a and b differs for the various tributaries based on the information collected and made available in each dye study.

For the Antietam Creek and the Conococheague Creek (1) and the Monocacy River (2), the flows were measured at the sampling points. These discharge values were transformed into index gage flows by a scaling factor determined from the drainage area ratio:

$$Qindex = Qsample * (DAindex/DAsample)$$

where:

Qindex = the flow at the index gage (estimated)

Qsample = the flow at the sample point (measured)

DAindex = the drainage area at the index gage

DAsample = the drainage area at the sample site

The data and the resulting traveltime coefficients are provided in tables 3.3 - 3.8 for these three tributaries. Specifically, The information required for the derivation of the traveltime parameters for Antietam Creek are provided in Table 3.3. Descriptors of each reach, the reaches shown in Figure 3.4, comprise the first three columns. These are reach number, drainage area ratio, and length of reach. The drainage area ratio is the ratio between the drainage area defined by the bottom of the reach and the drainage area defined by the index

Table 3.3 Antietam Creek Study Information

Reach	D.A. Ratio	Length of Reach (mi)	Study1	Flow at Site (cfs)	Flow at Gage (cfs)	Travel Times (hrs) Leading Edge	Peak Conc.	Trailing Edge
1	.33	1.60	1	41	124	2.4	3.4	5.1
			2	85	258	2.0	2.6	4.2
			3	180	545	1.0	1.4	1.9
2	.35	4.35	1	42	120	8.1	9.4	12.9
			2	86	246	5.9	6.9	8.6
			3	185	529	3.7	4.1	4.8
3	.59	7.40	1	58	98	26.5	30.4	39.0
			2	120	203	16.1	17.9	22.2
			3	260	441	9.3	10.4	11.5
4	.64	5.05	1	63	98	20.5	23.8	29.0
			2	140	219	12.4	12.8	13.6
			3	275	430	7.0	7.5	8.8
5	.70	7.85	1	72	103	19.8	25.0	43.8
			2	160	229	11.8	13.8	19.2
			3	300	429	9.0	9.8	11.5
6	.83	4.30	1	101	121	11.7	12.2	21.2
			2	188	227	6.7	7.3	9.4
			3	360	434	4.2	4.8	5.5
7	1.00	6.25	1	112	112	10.1	12.8	17.6
			2	225	225	7.5	7.9	8.9
			3	430	430	5.1	5.3	7.0
82	1.04	4.85	1	114	110	7.9	8.8	10.8
			2	230	221	5.2	5.4	6.8
			3	450	433	4.2	4.4	5.7

1 Study 1 was performed on 5-27-69 at an approximate flow duration of 75%
Study 2 was performed on 8-18-70 at an approximate flow duration of 40%
Study 3 was performed on 3-24-70 at an approximate flow duration of 12%

2 extrapolated to the mouth of the creek

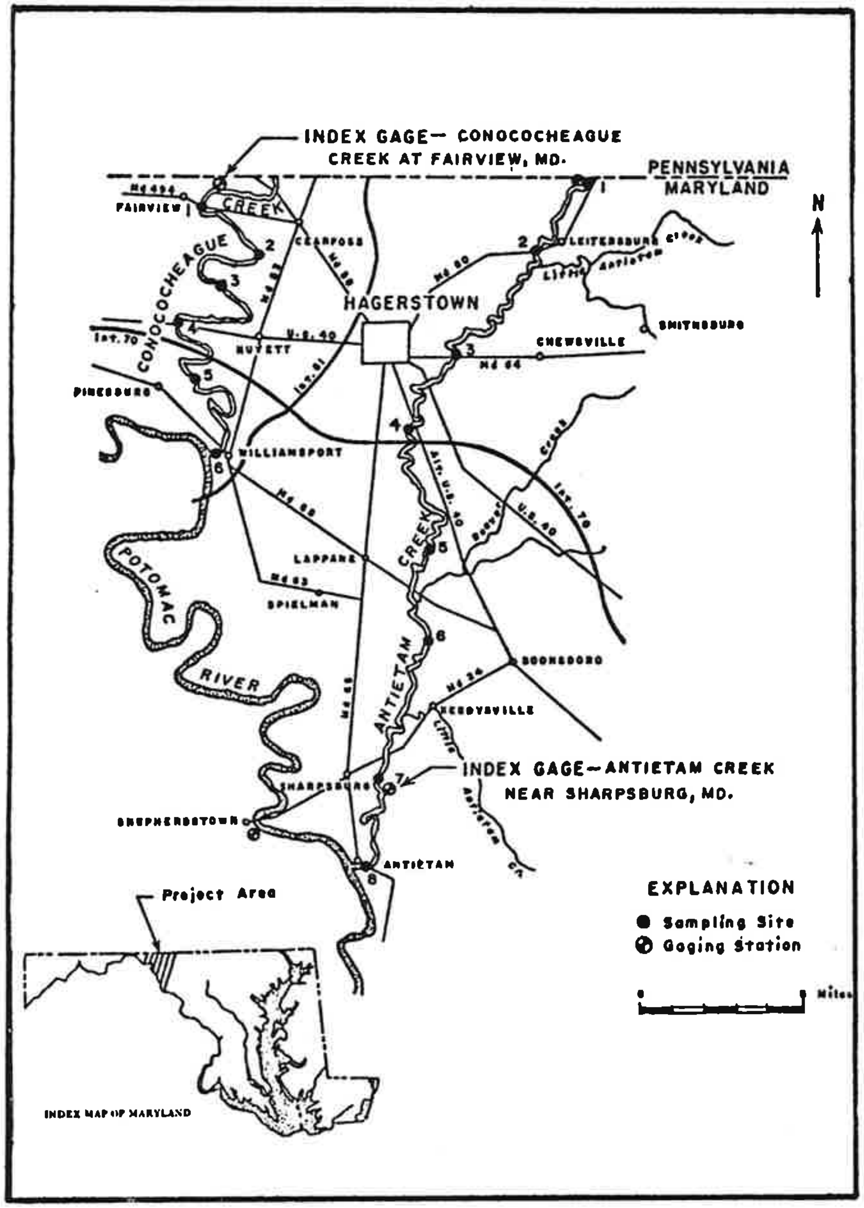

Figure 3.4 Location of calibrated reaches of Antietam Creek and Conococheague Creek

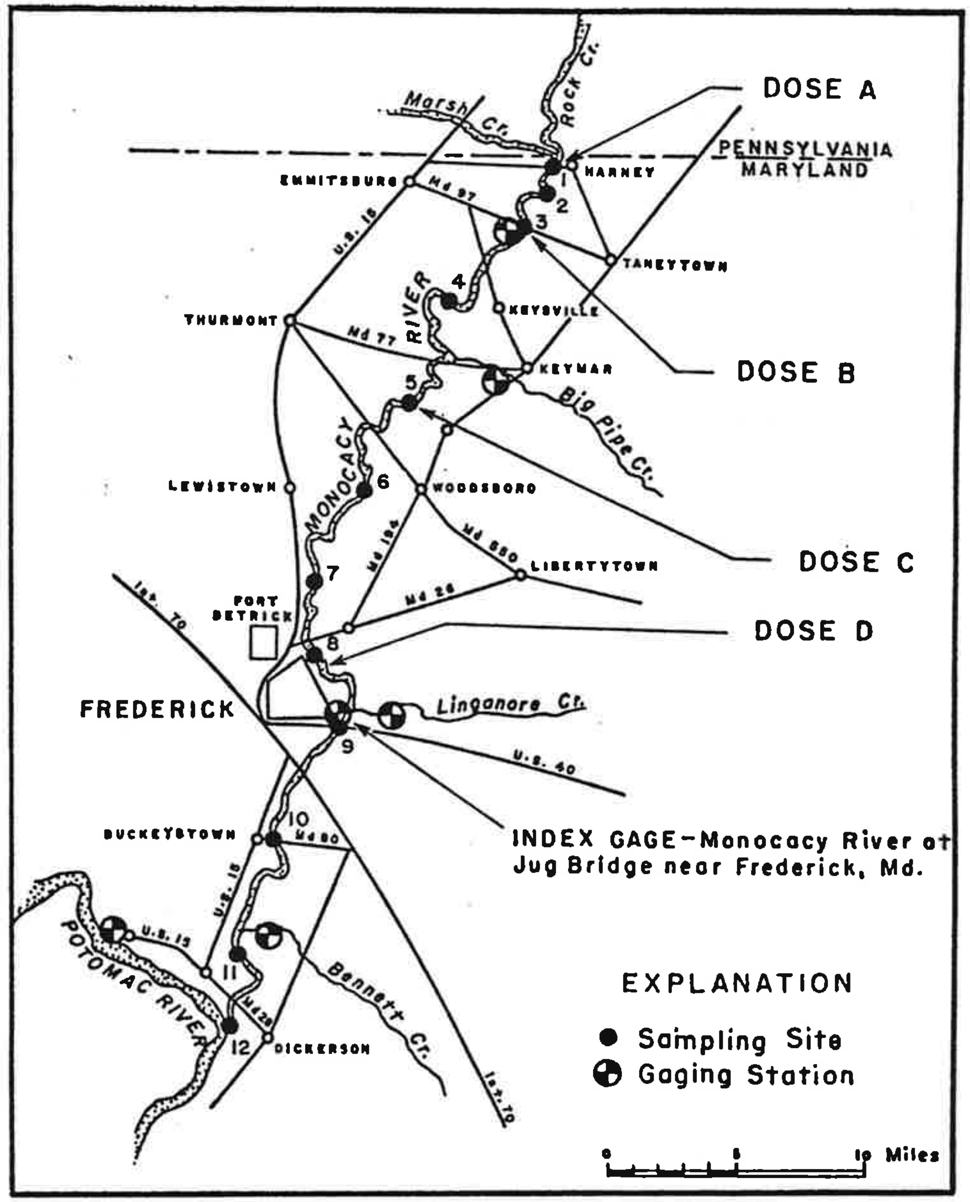

Figure 3.5 Location of calibrated reach of the Monocacy River

gage for the tributary. In addition, for each dye study performed on the creek, the following data is provided: the flow measured for the reach (sampling site at the bottom of the reach), the estimated flow at the index gage, and the observed traveltimes for the leading edge of a dye cloud, the peak concentration of the dye cloud and the trailing edge of the dye cloud. The traveltime coefficients in Table 3.4 were derived by linear regression. Analogous information is provided for Conococheage Creek in Table 3.5 and Table 3.6. Figure 3.4, a map of the sub-basin, shows the designation of the reaches. The Monocacy River is pictured in Figure 3.5 with the corresponding traveltime information displayed in Table 3.7 and Table 3.8.

For the Shenandoah River(3) and the South Branch Potomac River(4), the daily discharges at the basin gages were provided for the duration of each dye study. The daily values were averaged over the period and a mean daily discharge was obtained for each gage and study period. The flow values and the cumulative traveltimes for the South Branch are provided in Table 3.9. The sub-basin is shown in Figure 3.6. The results of the regression for the South Branch are shown in Table 3.10. The Shenandoah required further examination.

The Shenandoah River was characterized by four gages as opposed to the one used to represent each of the other tributaries. The main channel of the Shenandoah River is 178 miles long (see Figure 3.7) in contrast to 22 miles for Antietam Creek, 40.5 miles for Conococheague Creek, 57.1 miles for the

Table 3.4 Travel Time Coefficients for Antietam Creek

	Leading Edge		Peak Concen.		Trailing Edge	
Reach	a	b	a	b	a	b
1	-1.5218	2.7596	-1.5877	2.9922	-1.3384	3.1321
2	-1.8735	3.8012	-1.7541	3.8153	-1.4867	3.7487
3	-1.4323	4.0331	-1.3988	4.0647	-0.5789	2.9766
4	-1.3671	3.8032	-1.2764	3.7512	-1.2155	3.7565
5	-1.7747	4.3000	-1.5040	4.1036	-1.0579	3.7398
6	-1.2366	3.3969	-1.3569	3.5491	-0.9275	3.2990
7	-1.9549	4.0307	-1.5230	3.7304	-.9693	3.7266
8	-2.0806	3.8914	-1.8571	3.7786	-2.0113	4.1002

Table 3.5 Conococheague Creek Study Information

Reach	D.A. Ratio	Length of Reach (mi)	Study[1]	Flow at Site (cfs)	Flow at Gage (cfs)	Travel Times (hrs) Leading Edge	Peak Conc.	Trailing Edge
1	1.00	2.75	1	1040	1040	1.3	1.4	1.8
			2	241	241	2.6	3.0	3.8
			3	91	91	4.7	5.4	8.4
2	1.04	2.65	1	1040	1000	1.6	1.8	2.6
			2	242	233	3.4	3.6	5.1
			3	100	96	6.7	8.6	12.8
3	1.04	2.95	1	1050	1000	1.8	1.9	2.4
			2	243	238	3.6	3.7	5.3
			3	102	96	7.6	10.6	16.8
4	1.08	4.00	1	1060	981	2.4	2.6	3.1
			2	245	226	5.0	5.2	6.6
			3	102	94	12.3	12.9	17.0
5	1.08	3.80	1	1070	991	2.5	2.8	3.6
			2	245	221	5.2	5.8	7.8
			3	105	97	12.2	17.0	20.0
6[2]	1.14	5.00	1		947	3.9	4.5	6.1
			2		219	10.5	12.8	17.2
			3		92	23.3	25.5	33.2

[1] Study 1 was performed on 4-30-70 at an approximate flow duration of 90%
Study 2 was performed on 5-06-69 at an approximate flow duration of 60%
Study 3 was performed on 9-30-69 at an approximate flow duration of 15%

[2] extrapolated to the mouth of the creek

Table 3.6 Travel Time Coefficients for Conococheague Creek

	Leading Edge		Peak Concen.		Trailing Edge	
Reach	a	b	a	b	a	b
1	-1.8455	3.1810	-1.7616	3.2394	-1.5778	3.3780
2	-1.6065	3.2788	-1.4471	3.3096	-1.4254	3.5053
3	-1.6200	3.3638	-1.3005	3.2565	-1.1811	3.3707
4	-1.4155	3.4644	-1.4502	3.5285	-1.3571	3.5905
5	-1.4517	3.5112	-1.2402	3.4524	-1.3375	3.6723
6	-1.3079	3.7251	-1.3464	3.8475	-1.3826	4.0606

Table 3.7 Monocacy River Study Information

Reach	D.A. Ratio	Length of Reach (mi)	Study1	Flow at Site (cfs)	Flow at Gage (cfs)	Travel Times (hrs) Leading Edge	Peak Conc.	Trailing Edge
1	1.75	.21	1	38	181	26.5	35.5	57.0
			2	94	448	8.6	10.9	25.0
2	2.95	.21	1	42	200	12.5	15.5	24.0
			2	92	438	6.2	8.1	8.0
3	5.80	.38	1	88	232	21.8	27.2	45.0
			2	195	513	10.4	13.3	19.0
4	8.35	.63	1	140	222	26.4	29.8	37.0
			2	405	643	13.6	15.2	10.0
5	6.45	.75	1	165	220	14.0	15.5	16.0
			2	445	593	8.0	8.7	11.0
			3	71	95	22.0	27.0	41.0
6	5.00	.78	1	200	256	9.4	10.4	15.0
			2	535	686	5.5	6.4	7.5
			3	71	91	23.5	27.0	39.0
7	5.25	.86	1	225	262	8.4	10.5	13.0
			2	560	651	5.2	6.1	7.0
			3	80	93	19.0	22.0	35.0
8	4.65	1.00	1	270	270	8.6	10.3	15.0
			2	655	655	5.0	6.0	9.0
			3	108	108	13.5	17.5	32.0
9	7.15	1.05	1	295	281	18.3	20.4	28.0
			2	720	686	9.2	10.6	13.3
			3	113	108	38.5	45.5	71.0
10	5.45	1.16	1	330	285	9.5	11.5	13.0
			2	780	672	5.9	6.3	8.0
			3	122	105	18.5	22.0	32.0

Table 3.7 Monocacy River Study Information (continued)

Reach	D.A. Ratio	Length of Reach (mi)	Study1	Flow at Site (cfs)	Flow at Gage (cfs)	Travel Times (hrs) Leading Edge	Peak Conc.	Trailing Edge
112	3.95	1.19	1		282	7.7	8.5	11.3
			2		655	5.1	5.8	7.2
			3		104	12.8	15.4	20.5

1 Study 1 was performed in November 1967 at an approximate flow duration of 70%
Study 2 was performed in June 1968 at an approximate flow duration of 35%
Study 3 was performed in September 1968 at an approximate flow duration of 95%

2 extrapolated to the mouth of the river

Table 3.8 Travel Time Coefficients for the Monocacy River

	Leading Edge		Peak Concen.		Trailing Edge	
Reach	a	b	a	b	a	b
1	-0.8048	3.4030	-0.7671	3.4467	-1.0989	4.1872
2	-1.1180	3.5273	-1.2079	3.7388	-0.7135	3.2859
3	-1.0752	3.8038	-1.1122	3.9603	-0.9228	3.8904
4	-1.6016	4.6236	-1.5780	4.6731	-0.8120	3.6201
5	-1.8133	4.4139	-1.6212	4.2885	-1.2985	4.0340
6	-1.3626	3.8024	-1.3588	3.8756	-1.2164	3.8782
7	-1.4769	3.8370	-1.5103	3.9852	-1.1939	3.7941
8	-1.8087	4.0933	-1.6837	4.1299	-1.4048	4.1293
9	-1.2937	4.0826	-1.2684	4.1271	-1.1026	4.0643
10	-1.6148	4.0579	-1.4841	4.0188	-1.3087	3.9710
11	-2.0045	4.2349	-1.8809	4.2364	-1.7471	4.3037

Table 3.9 Study Information for the South Branch Potomac River

		Travel Times (hrs)					
		November 1970 (Q=1230)			September 1982 (Q=110)		
Reach	Reach Length	Leading Edge	Peak Conc.	Trailing Edge	Leading Edge	Peak Conc.	Trailing Edge
1	2.8	1.6	1.9	3.3	7.1	8.8	18.3
2	7.6	6.0	7.2	9.5	27.7	32.5	34.0
3	4.6	3.2	4.0	5.3	13.5	16.2	18.0
4	11.8	10.3	11.3	12.1	36.6	43.3	57.0
5	10.4	11.3	11.5	17.6	41.7	44.5	54.8
6	4.7	3.4	4.9	5.6	13.3	17.1	31.8
7	3.7	3.8	4.0	5.6	22.7	26.5	34.0
8	10.0	8.0	9.0	12.0	34.6	38.8	35.0
9[1]	13.4	11.7	14.7	18.8	78.8	86.9	108.9

[1] extrapolated to the tributary mouth, an additional 0.6 miles

Table 3.10 Travel Time Coefficients for the South Branch

	Leading Edge		Peak Concen.		Trailing Edge	
Reach	a	b	a	b	a	b
1	-1.6202	3.4206	-1.5750	3.5289	-1.4094	3.8207
2	-1.5783	4.3181	-1.6019	4.4632	-1.8935	4.9412
3	-1.6771	3.9371	-1.7261	4.1291	-1.9746	4.5201
4	-1.9042	5.0185	-1.7972	4.9825	-1.5578	4.7766
5	-1.8490	5.0371	-1.7842	4.9824	-2.1256	5.7374
6	-1.7700	4.0306	-1.9317	4.4231	-1.3902	4.1300
7	-1.3508	3.8731	-1.2768	3.8586	-1.3386	4.0914
8	-1.6486	4.5788	-1.6523	4.6666	-2.2554	5.5239
9	-1.2658	4.4420	-1.3587	4.6759	-1.3744	4.8411

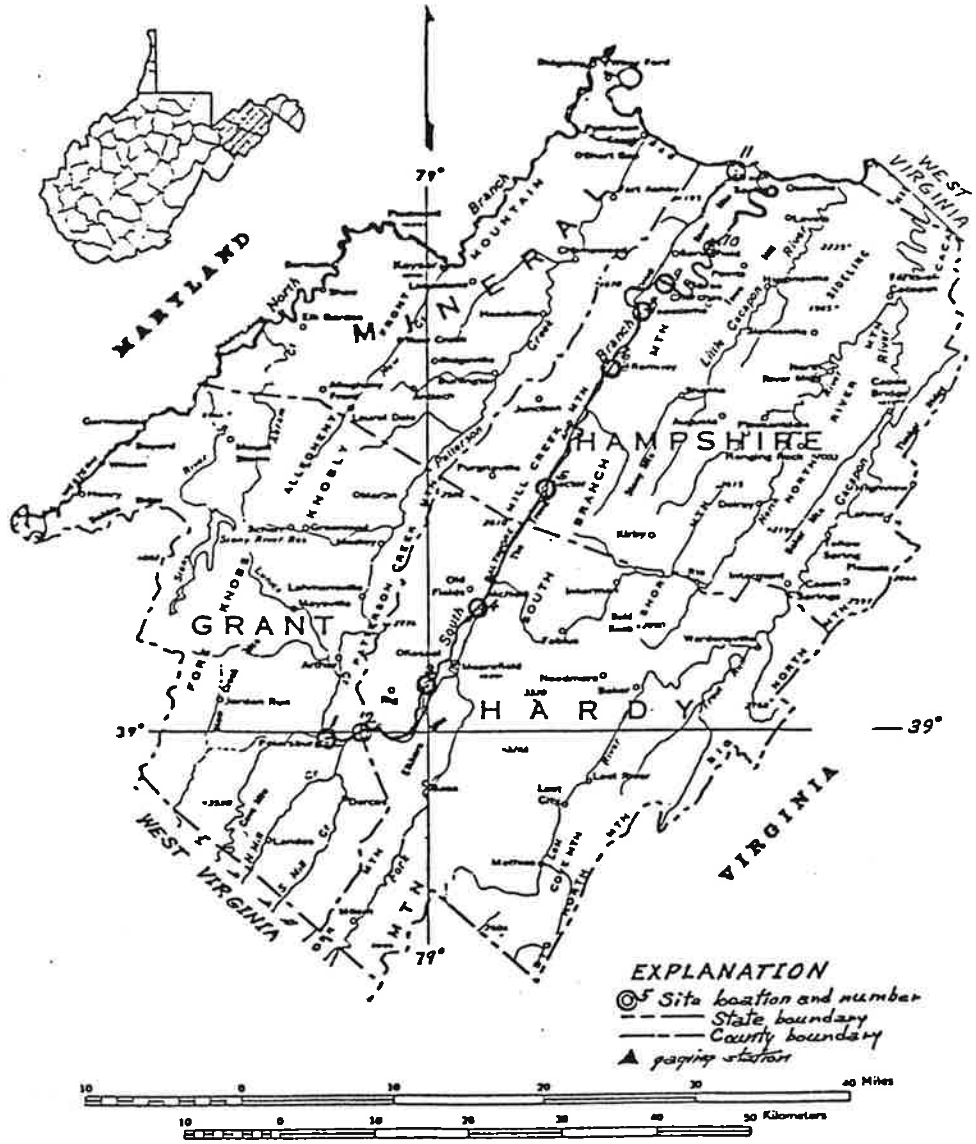

Figure 3.6 Location of calibrated reach of the South Branch Potomac River

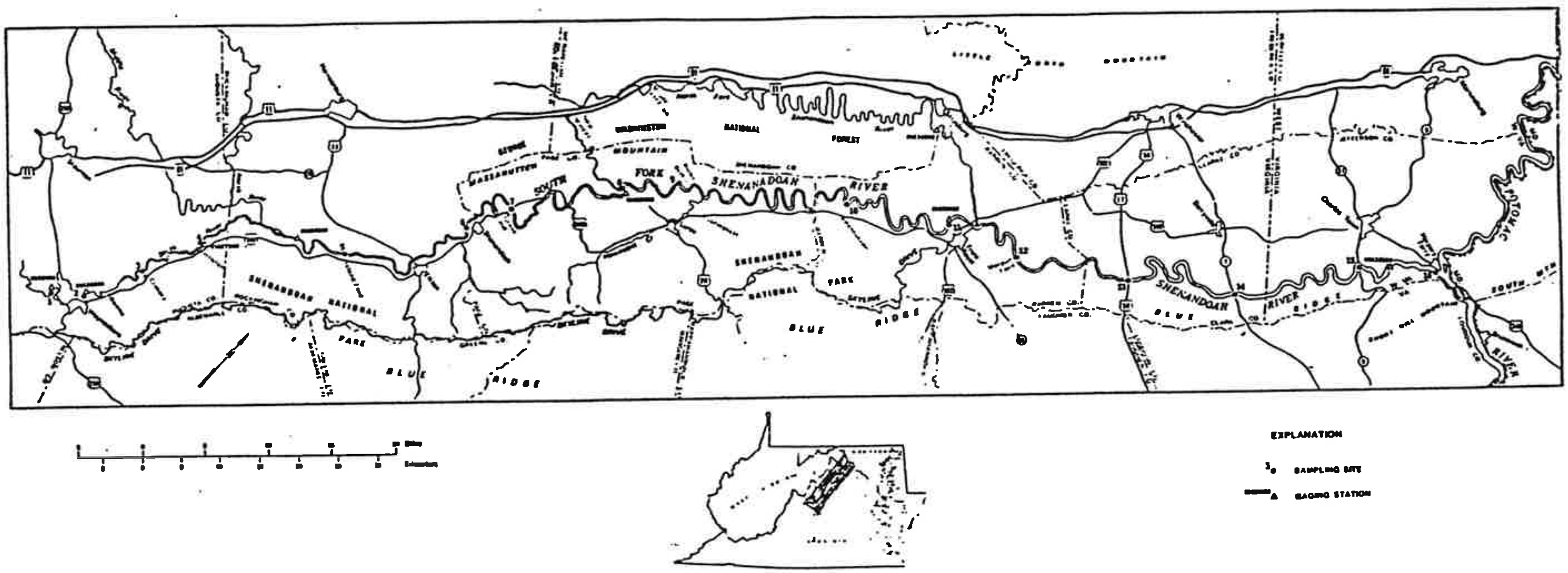

Figure 3.7 Location of calibrated reach of the Shenandoah River

Monocacy River, and 69.0 miles for the South Branch Potomac River.

The discharges for two of the four gages, Millville and Front Royal, may be obtained by phone (703) 260-0305. The flows for the second two gages are calculated based on the flow duration obtained from the values of the first two gages. Flow duration curves for the four gages were provided in the dye study. The discharge values gleaned from these graphs are provided in Table 3.11. The curves for each gage were extended linearly on the log probability graphs beyond the flow duration range of the study (30-95). The additional points resulting from linear extrapolation are shown in parentheses. If flows which are specified during operation of the spill model are determined to be infeasible given these linearizations, the user is asked to enter more reasonable information. Although the traveltime estimates are much less accurate when outside the range of the study, only extremely unlikely flows have been excluded in this step.

The Shenandoah River was divided into four regions and the regression models employed the flow corresponding to the appropriate region. The division is shown in Table 3.12. The average daily discharge for each gage is provided in Table 3.13. The flow values and the cumulative traveltimes are shown in Table 3.14. The regression coefficients for each reach are provided in Table 3.15.

Table 3.11 Flow Duration Data for Index Gages on the Shenandoah River

Flow Duration	Flow (cfs) Harriston	Lynwood	Front Royal	Millville
5	(640)	(2800)	(4200)	
10				
15				
20				(6000)
25				
30	239	944	1520	3210
35	215	844	1320	2570
40	193	740	1190	2000
45	174	658	1042	1730
50	156	581	929	1480
55	139	517	822	1290
60	125	460	728	1140
65	112	412	651	941
70	102	368	579	842
75	91	329	520	789
80	82	291	468	741
85	75	259	421	683
90	68	227	376	635
95	58	194	318	585
100	(26)	(80)	(130)	(350)

Note: the ( ) values result from linear extensions of the flow duration curves and therefore are not supported by existing flow data; the model is calibrated most accurately for flow durations between 30 and 95.

Table 3.12 Reach Information for the Shenandoah River

Reach	Length of Reach (mi)	River Mile at End of Reach	Drainage Area Ratio (Base Gage)
1	5.3	173.2	.70 (H)
2	7.4	165.8	.87 (H)
3	6.4	159.4	1.00 (H)
4	16.8	142.6	1.06 (L)
5	13.5	129.1	1.18 (L)
6	7.9	121.2	1.19 (L)
7	15.0	106.2	1.27 (L)
8	7.0	99.2	1.29 (L)
9	26.1	73.1	.96 (F)
10	15.4	57.7	1.00 (F)
11	10.2	47.5	.91 (M)
12	10.9	36.6	.92 (M)
13	14.5	22.1	.97 (M)
14	13.7	8.4	.99 (M)
15	7.6	0.8	1.01 (M)

H - Harriston
L - Lynwood
F - Front Royal
M - Millville

Table 3.13 Study Discharges at the Index Gages on the Shenandoah River

Gage	River Mile	Mean Study Discharge (cfs) September 1983	June 1984
Harriston	159.2	76	173
Lynwood	148.6	282	656
Front Royal	57.2	426	1038
Millville	4.8	597	1798

Table 3.14 Study Information for the Shenandoah River

Reach (Gage)	Travel Times (hrs) September 1983 Leading Edge	Peak Conc.	Trailing Edge	June 1984 Leading Edge	Peak Conc.	Trailing Edge
1 (H)	18.0	22.0	26.0	8.7	11.2	15.4
2 (H)	23.0	26.0	32.0	12.2	14.3	15.7
3 (H)	20.0	23.0	25.0	10.3	11.5	13.3
4 (L)	52.0	56.0	67.0	25.5	27.5	33.0
5 (L)	40.0	42.0	52.0	21.5	24.0	25.5
6 (L)	18.0	20.0	26.0	8.7	10.2	12.0
7 (L)	36.0	46.0	63.0	19.5	21.5	25.2
8 (L)	34.0	52.0	76.0	16.0	17.5	25.3
9 (F)	78.0	81.0	85.0	32.0	38.5	47.0
10 (F)	46.0	50.0	57.0	21.0	22.5	25.0
11 (M)	48.0	46.0	73.0	20.5	20.5	22.0
12 (M)	23.0	35.0	32.0	12.5	14.0	16.0
13 (M)	28.0	31.0	33.0	14.1	15.0	17.8
14 (M)	35.0	38.0	43.0	15.4	18.0	22.0
15 (M)1	35.4	42.0	47.5	15.5	18.0	20.1

H - Harriston
L - Lynwood
F - Front Royal
M - Millville

1 extrapolated to the tributary mouth, an additional 0.8 miles

Table 3.15 Travel Time Coefficients for the Shenandoah

	Leading Edge		Peak Concen.		Trailing Edge	
Reach	a	b	a	b	a	b
1	-1.1365	3.3045	-1.2239	3.5209	-1.5777	4.1103
2	-1.3031	3.6525	-1.3821	3.8336	-1.1604	3.6245
3	-1.2451	3.4979	-1.1920	3.5012	-1.3092	3.7082
4	-1.1848	4.4834	-1.1871	4.5256	-1.1921	4.6272
5	-1.3599	4.6289	-1.5086	4.8991	-1.1848	4.4834
6	-1.1612	3.9079	-1.2538	4.0815	-1.0919	3.9953
7	-1.3770	4.5933	-1.1100	4.2959	-.9214	4.1081
8	-1.1200	4.1656	-.7752	3.7805	-.7676	3.8939
9	-.9996	4.5207	-1.1974	4.9146	-1.5031	5.5296
10	-1.1358	4.5180	-1.1153	4.5243	-1.0806	4.5268
11	-1.2959	4.9547	-1.3641	5.0442	-.9192	4.4888
12	-1.8081	5.2381	-1.2032	4.6339	-1.5906	5.1701
13	-1.6071	5.1017	-1.5187	5.0410	-1.7860	5.4880
14	-1.3429	4.8495	-1.4755	5.1069	-1.6452	5.4633
15	-1.3350	4.8439	-1.3025	4.8337	-1.2820	4.9255

CHAPTER FOUR

OPERATION OF THE MODEL

The toxic spill model routes a dissolved conservative substance from the point the substance enters the river network to points of particular concern downstream (e.g. municipal water intakes). Longitudinal dispersion is incorporated in the timing and concentration of the pollutant as described in the previous sections.

The model queries the user for the necessary information in an interactive manner. The descriptive data required to both characterize the spill and the state of the system it is entering may be divided into three sets. They are as follows:

1. the location of the spill
2. the extent of the spill
3. the streamflow for the main stem and/or tributaries

The location of the spill is identified by specifying the river mile either from the mouth of a tributary or above Chain Bridge for the main stem, as appropriate. To characterize the extent of the spill, the user is asked to provide the amount (in lbs) of contaminant entering the river each hour for the duration of the spill.

Once the user has specified the downstream points of concern, the model begins the necessary computations. The sequencing of specifying the data, performing the computations, and producing the output is shown in a flow chart of the model, Figure 4.1. Specifically, after the descriptive data is obtained, the model is directed to the appropriate tributary or main stem subroutine and the initial concentrations are translated to arrival times and concentrations at the downstream points of concern. All of this is maintained in an output file entitled "travel."

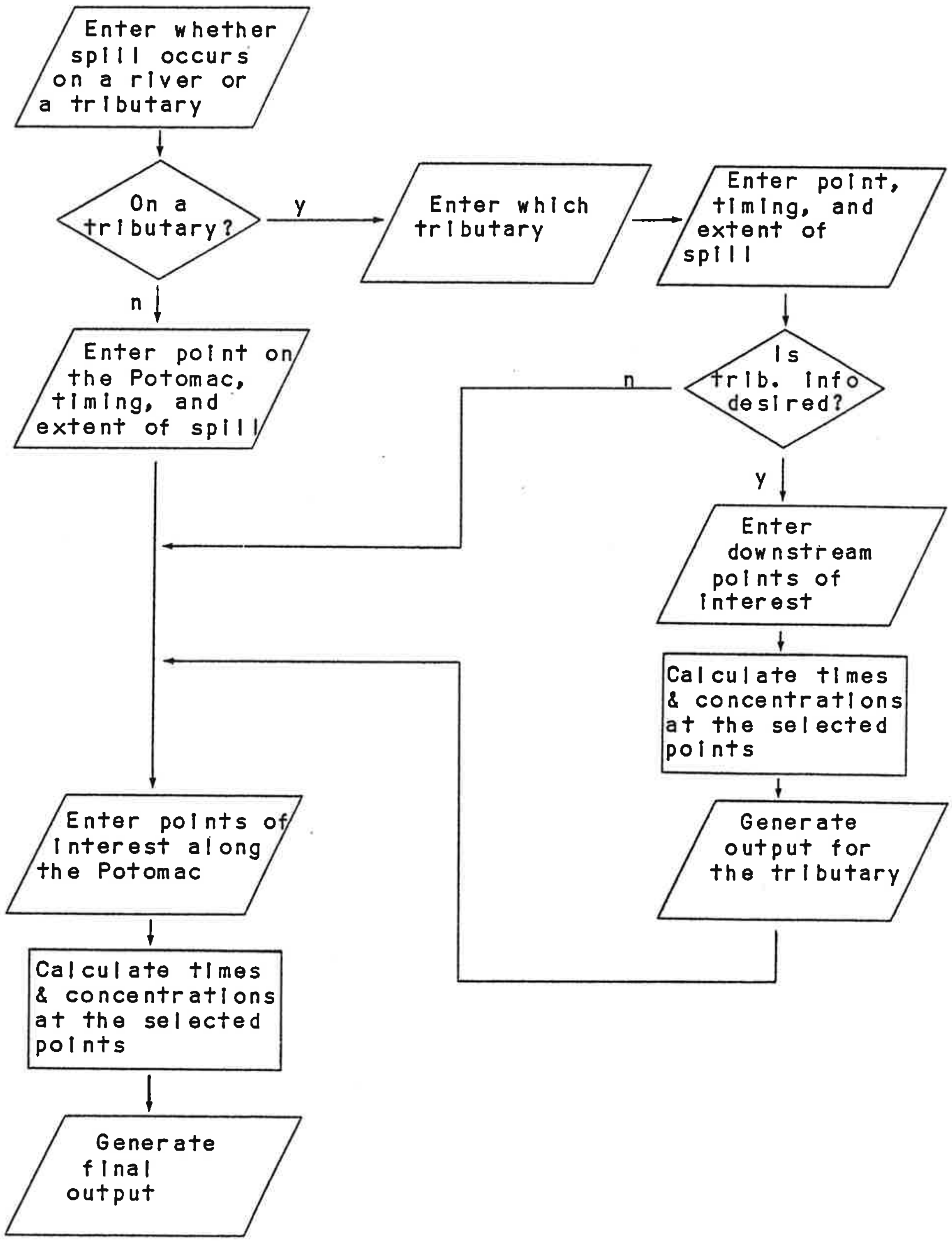

Figure 4.1 Flow chart for the Toxic Spill Model

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Taylor, K.R., R.W. James, Jr., and B.M. Helinsky. 1986. "Traveltime and Dispersion on the Shenandoah River and its Tributaries, Waynesboro, Virginia, to Harper's Ferry, West Virginia." U.S. Geological Survey Water Resources Investigations Report 86-4065.

Taylor, K.R., and W.B. Solley. 1971. "Traveltime and Concentration Attenuation of a Soluble Dye in Antietam and Conococheague Creeks, Maryland." U.S. Geological Survey Information Circular 12.

APPENDIX A

FORTRAN CODE FOR THE TOXIC SPILL MODEL

```
c     TRAVEL TIME STUDY PROGRAM
c
c     Program written by Interstate Commission on the Potomac River
c     Basin staff in three stages:
c
c      1.  Main stem and three tributaries  -- Competed August 1983
c      2.  Shenandoah and South Branch      -- Added Fall 1985
c      3.  Program was verified and input/output formats were revised
c          --February 1991
c
      real XSPILL,XXSPILL,por
      integer ihr,ida,imo,ihrr,idaa,imoo,iyr
      integer J,IPT,iz
      integer ilocal,irver,path,before
      character y
      common/try/por
      common /dest/XFINAL(11),J
      common /tim/WT(2000),ihr,ihrr,ida,idaa,imo,imoo,iz,iyr
      common /poto/ X(60),A(60),B(60),C(60),E(60),F(60),
     *P(60),QP(60),QQ(60),XSPILL,XXSPILL,ifs,jfs
      common /loop/path,qdur
      common /where/ilocal,irver,before
      open(2,file='travel',status='unknown')
      rewind 2
   94 format (a1)
      ifs=1
      before=0
c
c the initial part of the program determines river, location of spill
c  and  discharge values
c
      write(2,1300)
      print 1300
 1300 format(//,' *** ICPRB Toxic Spill Model for the Potomac River',
     * ' Basin***')
      write(2,1301)
 1301 format(//,' Spill Location',/,' --------------')
      print 80
  80  format(//,' If the spill occurred on the Potomac River, type "1"',
     * ' followed by a',/,' carriage return.  If the spill occurred on',
     * ' a tributary (Monocacy, ',/,' Antietam, Conococheaque, ',
     * 'Shenandoah, or the South Branch of the Potomac',/,' River)',
     * ', type "2" followed by a carriage return.',/)
      read (5,*) ilocal
      if (ilocal.eq.1) then
      before=1
      call potomac
      call time
      go to 8000
      endif
      print*,' '
      print 81
  81  format(' Indicate the tributary that the spill occurred on',
     * ' by typing in the',/,' appropriate integer followed by a',
     * ' carriage return.',//,
     *      '         1-Monocacy River',/,
     *      '         2-Antietam Creek',/,
     *      '         3-Conococheaque Creek',/,
     *      '         4-Shenandoah River',/,
     *      '         5-South Branch Potomac River',/,
     *      ' ')
```

```
      read(5,*)irver
      if (irver.eq.1) then
      call monocacy
      write(2,1311)XSPILL
 1311 format(/,' The spill occurred on the Monocacy River',f5.1,
     * ' miles above its',/,' confluence with the Potomac River.',/)
      write(2,1317)
 1317 format(/,' Tributary Flows',/,' ---------------',/)
      write(2,1321)qq(18)
 1321 format(' The flow at USGS gaging station:  Monocacy River',
     * ' at Jug Bridge,',/,' near Frederick, MD. was',f7.1,
     * ' cfs, at the time of the spill.',/)
      go to 6000
      endif
      if (irver.eq.2) then
      call antietam
      write(2,1312)XSPILL
      write(2,1317)
      write(2,1322) qq(29)
 1322 format(' The flow at USGS gaging station:  Antietam Creek',
     * ' near Sharpsburg,',/,' MD. was',f7.1,' cfs, at the',
     * ' time of the spill.',/)
 1312 format(/,' The spill occurred on Antietam Creek',f5.1,
     * ' miles above its',/,' confluence with the Potomac River.',/)
      go to 6000
      endif
      if (irver.eq.3) then
      call conococh
      write(2,1313)XSPILL
      write(2,1317)
      write(2,1323) qq(12)
 1323 format(' The flow at USGS gaging station:  Conococheaque',
     * ' Creek at Fairview,',/,' MD. was',f7.1,' cfs, at the',
     * ' time of the spill.',/)
 1313 format(/,' The spill occurred on Conococheaque Creek',f5.1,
     * ' miles above its',/,' confluence with the Potomac River.',/)
      go to 6000
      endif
      if (irver.eq.4) then
      call shenan
      write(2,1314)XSPILL
      write(2,1317)
      write(2,1401) qq(47)
 1401 format(' The flow at USGS gaging station:  Shenandoah',
     * ' River at Millville',/,' WV. was',f8.1,' cfs, at the time',
     * ' of the spill.',/)
      if (path.eq.5) then
      write(2,1402) qq(45)
 1402 format(' The flow at USGS gaging station:  South Fork',
     * ' Shenandoah River at Front',/,' Royal VA. was',f7.1,' cfs,',
     * ' at the time of the spill.',/)
      endif
      write(2,1403) qdur
 1403  format(' The flows at the following USGS gaing stations',
     * ' were calculated',/,' based on a flow duration value of',
     * f6.1,' at Shenandoah River',/,' at Millville, WV. at the',
     * ' time of the spill:',/)
      if(path.eq.3) then
      write(2,1404) qq(45)
 1404 format('      The flow at South Fork Shenandoah River at Front',/,
     * '      Royal VA. was calculated to be',f7.1,' cfs.',/)
```

```
      endif
      write(2,1405) qq(40)
1405 format('       The flow at South Fork Shenandoah River near',/,
     * '       Lynnwood, VA. was calculated to be',f7.1,' cfs',/)
      write(2,1406) qq(37)
1406 format('       The flow at South River at Harriston, VA. was',/,
     * '       calculated to be',f6.1,' cfs.',/)
1314 format(/,' The spill occurred on the Shenandoah River',f6.1,
     * ' miles above its',/,' confluence with the Potomac River.',/)
      go to 6000
      else
      call sbranch
      write(2,1315)XSPILL
      write(2,1317)
      write(2,1325) qq(52)
1325 format(' The flow at UGSG gaging station:  South Branch',
     * ' Potomac River near',/,' Springfield, WV. was',f7.1,
     * ' cfs, at the time of the spill.',/)
1315 format(/,' The spill occurred on the South Branch Potomac',
     * ' River',f5.1,/,' miles above its confluence with the Potomac',
     * ' River.',/)
      endif
6000 call time
      J=0
      if (irver.eq.1) then
      print 1150
1150 format(/,' The program produces contaminant concentration',
     * ' tables which show',/,' the concentration as a function of',
     * ' time for selected downstream points.',/,' The program',
     * ' automatically produces contaminant concentration',
     * ' tables',/,' at the confluence of the Monocacy and Potomac',
     * ' Rivers.  If you would',/,' like contaminant concentration',
     * ' tables at other points on the Monocacy',/,' River, type "Y"',
     * ' followed by a carriage return.  Otherwise type "N"',/
     * ' followed by a carriage return.',/)
      read 94,y
      if (y.eq.'N'.or.y.eq.'n') goto 7000
      else if (irver.eq.2) then
      print 1151
1151 format(/,' The program produces contaminant concentration',
     * ' tables which show',/,' the concentration as a function of',
     * ' time for selected downstream points.',/,' The program',
     * ' automatically produces contaminant concentration',
     * ' tables',/,' at the confluence of Antietam Creek and the',
     * ' Potomac River.  If you',/,' would like contaminant',
     * ' concentration',
     * ' tables at other points on Antietam',/,' Creek, type "Y"',
     * ' followed by a carriage return.  Otherwise type "N"',/
     * ' followed by a carriage return.',/)
      read 94,y
      if (y.eq.'N'.or.y.eq.'n') goto 7000
      else if (irver.eq.3) then
      print 1153
1153 format(/,' The program produces contaminant concentration',
     * ' tables which show',/,' the concentration as a function of',
     * ' time for selected downstream points.',/,' The program',
     * ' automatically produces contaminant concentration',
     * ' tables',/,' at the confluence of Conococheaque Creek and the',
     * ' Potomac River.',/,' if you would like contaminant',
     * ' concentration',
     * ' tables at other points on',/,
```

```
     * ' Conococheaque Creek, type "Y"',
     * ' followed by a carriage return.  Otherwise',/,' type "N"',
     * ' followed by a carriage return.',/)
      read 94,y
      if (y.eq.'N'.or.y.eq.'n') goto 7000
      else if (irver.eq.4) then
      print 1154
 1154 format(/,' The program produces contaminant concentration',
     * ' tables which show',/,' the concentration as a function of',
     * ' time for selected downstream points.',/,' The program',
     * ' automatically produces contaminant concentration',
     * ' tables',/,' at the confluence of the Shenandoah and Potomac',
     * ' Rivers.  If you would',/,' like contaminant concentration',
     * ' tables at other points on the Shenandoah',/,' River, type "Y"',
     * ' followed by a carriage return.  Otherwise type "N"',/
     * ' followed by a carriage return.',/)
      read 94,y
      if (y.eq.'N'.or.y.eq.'n') goto 7000
      else
      print 1155
 1155 format(/,' The program produces contaminant concentration',
     * ' tables which show',/,' the concentration as a function of',
     * ' time for selected downstream points.',/,' The program',
     * ' automatically produces contaminant concentration',
     * ' tables',/,' at the confluence of the South Branch Potomac',
     * ' River and the',
     * ' Potomac',/,' River  If you would like contaminant',
     * ' concentration',
     * ' tables at other',/,' points on the South Branch Potomac',
     * ' River, type "Y"',
     * ' followed by a',/,' carriage return.  Otherwise type "N"',
     * ' followed by a carriage return.',/)
      read 94,y
      if (y.eq.'N'.or.y.eq.'n') go to 7000
      endif
      if(irver.eq.1) then
 1181 print 1161
 1161 format(//,' Type in an integer to indicate the number of',
     * ' downstream',
     * ' locations',/,' along the Monocacy River (not including the',
     * ' confluence) at which you',/,' want contaminant concentration',
     * ' tables, followed by a carriage return.',/)
      read(5,*)J
      if (J.gt.5) then
      print 1171
 1171 format(//,' The number of downstream locations cannot exceed',
     * ' five.  Type in a',/,' carriage return to repeat the'
     * ' previous step.',/)
      read(5,*)
      go to 1181
      endif
      else if(irver.eq.2) then
 1182 print 1162
 1162 format(//,' Type in an integer to indicate the number of',
     * ' downstream',
     * ' locations',/,' along Antietam Creek (not including the',
     * ' confluence) at which you',/,' want contaminant concentration',
     * ' tables, followed by a carriage return.',/)
      read(5,*)J
      if (J.gt.5) then
      print 1172
```

```
 1172 format(//,' The number of downstream locations cannot exceed',
     * ' five.  Type in a',/,' carriage return to repeat the'
     * ' previous step.',/)
      read(5,*)
      go to 1182
      endif
      else if(irver.eq.3) then
 1183 print 1163
 1163 format(//,' Type in an integer to indicate the number of',
     * ' downstream locations',
     * /,' along Conococheaque Creek (not including the',
     * ' confluence) at which you',/,' want contaminant concentration',
     * ' tables, followed by a carriage return.',/)
      read(5,*)J
      if (J.gt.5) then
      print 1173
 1173 format(//,' The number of downstream locations cannot exceed',
     * ' five.  Type in a',/,' carriage return to repeat the'
     * ' previous step.',/)
      read(5,*)
      go to 1183
      endif
      else if(irver.eq.4) then
 1184 print 1164
 1164 format(//,' Type in an integer to indicate the number of',
     * ' downstream locations',
     * /,' along the Shenandoah River  (not including the',
     * ' confluence) at which you',/,' want contaminant concentration',
     * ' tables, followed by a carriage return.',/)
      read(5,*)J
      if (J.gt.5) then
      print 1174
 1174 format(//,' The number of downstream locations cannot exceed',
     * ' five.  Type in a',/,' carriage return to repeat the'
     * ' previous step.',/)
      read(5,*)
      go to 1184
      endif
      else
 1185 print 1165
 1165 format(//,' Type in an integer to indicate the number of',
     * ' downstream locations',
     * /,' along the South Branch Potomac River (not including',
     * ' the confluence)',/,' at which you want contaminant',
     * ' concentration tables, followed by a',/,' carriage',
     * ' return.',/)
      read(5,*)J
      if (J.gt.5) then
      print 1175
 1175 format(//,' The number of downstream locations cannot exceed',
     * ' five.  Type in a',/,' carriage return to repeat the'
     * ' previous step.',/)
      read(5,*)
      go to 1185
      endif
      endif
c
      if (irver.eq.1) then
      print 1201
 1201 format (//,' Type in the downstream locations along the',
     * ' Monocacy River',/,' at which you want contaminant',
```

```
     * ' concentration tables.  These point',/,' locations',
     * ' should be expressed in terms of miles upstream from the',/,
     * ' confluence of the Monocacy and Potomac Rivers.  Input',
     * ' the locations',/,' as real values on the same line,',
     * ' seperated by blank spaces, and',/,' followed by a carriage',
     * ' return.  The following table provides some',/,' reference',
     * ' points from which to calculate the river mileages:',/)
      print*,' '
      print*,' River                         ',
     * 'River'
      print*,' Mile      Landmark            ',
     * 'Mile      Landmark'
      print*,' 57.1  Md.-Pa. State Line   ',
     * ' 21.2  Filtration Plant'
      print*,' 56.7  Harney Bridge        ',
     * ' 19.7  Sewage Disposal'
      print*,' 46.2  Sixes Bridge         ',
     * ' 16.6  U.S. Route 40 Bridge'
      print*,' 43.2  Mumma Ford Bridge    ',
     * ' 13.8  B&O Railroad'
      print*,' 37.8  Legore Bridge        ',
     * '  9.4  State Route 80'
      print*,' 34.9  State Route 550      ',
     * '  6.2  Lilypons Bridge'
      print*,' 29.5  Devilbiss Bridge     ',
     * '  2.0  State Route 28'
      print*,' 25.2  Pennsylvania Railroad',
     * '  0.5  B&O Railroad'
      print*,' '
      else if (irver.eq.2) then
      print 1202
1202 format (//' Type in the downstream locations along Antietam',
     * ' Creek at which',/,' you want contaminant concentration',
     * ' tables.  These point locations',/,' should be expressed in',
     * ' terms of miles upstream from the confluence',/,' of Antietam',
     * ' Creek and the Potomac River.  Input the locations as real',/,
     * ' values on the same line, seperated by blank spaces, and',
     * ' followed',/,' by a carriage return.  The following table',
     * ' provides some reference',/,' points from which to calculate',
     * ' the river mileages:',/)
      print*,' '
      print*,' River                         ',
     * 'River'
      print*,' Mile      Landmark            ',
     * 'Mile      Landmark'
      print*,' 40.5  Md.-Pa. State Line   ',
     * ' 13.3  State Highway 68'
      print*,' 35.7  State Highway 60     ',
     * ' 11.1  Monroe Road'
      print*,' 33.0  Old Forge Road Bridge',
     * '  9.5  B&O Railroad'
      print*,' 28.3  State Highway 64     ',
     * '  8.2  Hicks Bridge'
      print*,' 26.6  U.S. Highway 40      ',
     * '  5.7  State Highway 34'
      print*,' 24.4  Sewage Disposal Plant',
     * '  4.5  USGS Gage'
      print*,' 23.2  West Baltimore Street',
     * "  0.2  Harper's Ferry Road"
      print*,' '
      else if (irver.eq.3) then
```

```
      print 1203
 1203 format (//' Type in the downstream locations along',
     * ' Conococheaque Creek at which',/,' you want contaminant',
     * ' concentration tables.  These point locations',/,' should be',
     * ' expressed in terms of miles upstream from the',
     * ' confluence',/,' of Conococheaque Creek and the Potomac River.',
     * ' Input the locations',/,' as real values on the same line,',
     * ' seperated by blank spaces, and',/,' followed by a',
     * ' carriage return.  The following table provides some',/,
     * ' reference points from which to calculate the river',
     * ' mileages:',/)
      print*,' '
      print*,' River                         ',
     * 'River'
      print*,' Mile      Landmark            ',
     * 'Mile      Landmark'
      print*,' 21.2  State Highway 58      ',
     * '  5.0  Kemps Mill Road'
      print*,' 19.1  USGS Gage             ',
     * '  3.8  Kemps Mill Dam'
      print*,' 18.4  State Highway 494     ',
     * '  0.9  Western Maryland Railway'
      print*,' 15.8  Broadfording Road     ',
     * '  0.2  W.D. Byron & Son Water Intake'
      print*,' 12.8  Mouth of Roush Run    ',
     * '  0.1  C & O Canal Aqueduct'
      print*,'  8.8  U.S. Highway 40'
      print*,' '
       else if (irver.eq.4) then
       print 1204
 1204 format (//' Type a in the downstream locations along the',
     * ' Shenandoah River at which',/,' you want contaminant',
     * ' concentration tables.  These point locations',/,' should be',
     * ' expressed in terms of miles upstream from the',
     * ' confluence',/,' of the Shenandoah and Potomac Rivers.  Input',
     * ' the locations as real',/,' values on the same line,',
     * ' seperated by blank spaces, and followed',/,' by a carriage',
     * ' return.  The following table provides some reference',/,
     * ' points from which to calculate the river mileages:',/)
      print*,' '
      print*,'River                          ',
     * 'River'
      print*,'Mile      Landmark             ',
     * 'Mile      Landmark'
      print*,'178.5  Waynesboro            ',
     * ' 99.2  Bixler Bridge'
      print*,'173.2  Hopeman Parkway       ',
     * ' 73.1  Bentonville'
      print*,'165.8  Crimora               ',
     * ' 57.5  Front Royal'
      print*,'159.4  Harriston             ',
     * ' 47.5  Morgan Ford'
      print*,'142.6  Island Ford           ',
     * ' 36.6  U.S. Highway 17 and 50'
      print*,'129.1  Shenandoah            ',
     * ' 22.1  State Highway 7'
      print*,'121.2  Grove Hill            ',
     * '  8.4  State Highway 9'
      print*,'106.2  U.S. Highway 211      ',
     * "  0.8  Harper's Ferry"
      print*,' '
```

```
      else
      print 1205
 1205 format (//,' Type in the downstream locations along the',
     * ' South Branch Potomac River',/,' at which you want',
     * ' contaminant concentration tables.  These point',/,
     * ' locations should be expressed in terms of miles upstream',
     * ' from the',/,' confluence of the South Fork Potomac River',
     * ' and the Potomac River.',/,' The following table provides',
     * ' some reference points from which to',/,' calculate',
     * ' the river mileages:',/)
      print*,' '
      print*,' River                          ',
     * 'River'
      print*,' Mile      Landmark             ',
     * 'Mile        Landmark'
      print*,' 69.0  Petersburg               ',
     * ' 31.8  U.S. Rt 50 bridge - Romney'
      print*,' 66.2  U.S. Rt 220 Bridge       ',
     * ' 27.1  Wapocomo'
      print*,' 57.3  South Fork - Moorefield',
     * ' 23.4  W.V. Rt 28 Bridge - Grace'
      print*,' 48.9  Sycamore, B&O RR Bridge',
     * ' 13.4  Springfield, W.V.'
      print*,' 40.9  Stony Run                '
      print*,' '
      endif
      read (5,*) (XFINAL(IPT), IPT=1,J)
 7000 XFINAL(J+1)=0
      J=J+1
      print 1206
 1206 format(//,' The program is running please wait.',/)
      call travel
c
      print 1212
 1212 format(//,' If you want the program to produce contaminant',
     * ' concentration tables',/,' which show the concentration as',
     * ' a function of time for selected points',/,' on the',
     * ' mainstem of the Potomac River type "Y", followed by',
     * ' a carriage',/,' return, otherwise type "N", followed',
     * ' by a carriage return.',/)
      read 94,y
      if (y.eq.'N'.or.y.eq.'n') goto 9000
c XSPILL (spill location) must be changed to give location where
c tributary enters Potomac
      XSPILL=XXSPILL
      iz=1440
      before=1
      call potomac
 8000 call destination
      print 1206
      call travel
 9000 continue
      print 83
   83 format(//,' The program is finished.  The results are',
     * ' contained in file "travel".',/)
      write(2,3300)
 3300 format(/,' Comments',/,' --------')
      write(2,3301)
 3301 format(/,' The results of this model simulation assumes',
     * ' that the contaminant is',/,' conservative and 100%',
     * ' soluble.',/)
```

```
      write(2,3302)
 3302 format(/,' Contaminant concentrations less than 1 ug/l have',
     * ' been deleted from',/,' the contaminant concentration tables',
     * ' in order to save space.',/)
      if (ilocal.ne.1) then
      write(2,3303)
 3303 format(/,' Contaminant inflow rates of less than 1 lb/hour',
     * ' into the Potomac',/,' River have been eliminated from the',
     * ' table in order to save space.',/)
      endif
c
      if(before.eq.1)then
      if(por.lt.1260.or.por.gt.5200) then
      write(2,3310)por
 3310 format(/,' The model results were calculated based on a flow',
     * ' of',f7.1,' cfs at USGS',/,' gaging station:  Potomac River',
     * ' at Point of Rocks, MD.  The model was',/,' calibrated based',
     * ' on a flow at this station of between 1260 and 5200 cfs.',/,
     * ' Since the input flow value is outside this range, the model',
     * ' results',/,' should be used with caution.',/)
      endif
      endif
c
      if(irver.eq.1) then
      if(qq(18).lt.100.or.qq(18).gt.1000) then
      write(2,3311) qq(18)
 3311 format(/,' The model results were calculated based on a flow',
     * ' of',f6.1,' cfs at USGS',/,' gaging station: Monocacy River',
     * ' at Jug Bridge, near Frederick, MD.  The',/,' model was',
     * ' calibrated based on a flow at this station of between 100',/,
     * ' and 1000 cfs.  Since the input flow value is outside this',
     * ' range, the',/,' model results should be used with caution.',/)
      endif
      endif

      if(irver.eq.2) then
      if(qq(29).lt.90.or.qq(29).gt.500) then
      write(2,3312) qq(29)
 3312 format(/,' The model results were calculated based on a flow',
     * ' of',f6.1,' cfs at USGS',/,' gaging station:  Antietam Creek',
     * ' near Sharpsburg, MD.  The model was',/,' calibrated based on',
     * ' a flow at this station of between 90 and 500 cfs.',/,' Since',
     * ' the',
     * ' input flow value is outside this range, the model results',
     * /,' should be used with caution.',/)
      endif
      endif

      if(irver.eq.3) then
      if(qq(12).lt.90.or.qq(12).gt.1000) then
      write(2,3313) qq(12)
 3313 format(/,' The model results were calculated based on a flow',
     * ' of',f6.1,' cfs at USGS',/,' gaging station:  Conococheaque',
     * ' Creek at Fairview, MD.  The model was',/,' calibrated based',
     * ' on a flow at this station of between 90 and 1000',/,' cfs.',
     * '  Since the input flow value is outside this range, the model',
     * ' should',/,' be used with caution.',/)
      endif
      endif

      if(irver.eq.4) then
```

```
      if(qq(47).lt.683.or.qq(47).gt.1730) then
      write(2,3314) qq(47)
 3314 format(/,' The model results were calculated based on a flow',
     * ' of',f6.1,' cfs at USGS',/,' gaging station:  Shenandoah River',
     * ' at Millville, WV.  The model was',/,' calibrated based on a',
     * ' flow at this station of between 683 and 1730',/,' cfs.',
     * '  Since the input flow value is outside this range, the model',
     * ' should',/,' be used with caution.',/)
      endif
      endif

      if(irver.eq.5) then
      if(qq(52).lt.110.or.qq(52).gt.1230) then
      write(2,3315) qq(52)
 3315 format(/,' The model results were calculated based on a flow',
     * ' of',f7.1,' cfs at USGS',/,' gaging station:  South Branch',
     * ' Potomac River near Springfield, WV. The',/,' model was',
     * ' calibrated based on a flow at this station of between 110',/,
     * ' and 1230 cfs.  Since the input flow value is outside this',
     * ' range, the',/,' model should be used with caution.',/)
      endif
      endif

      end
c
c
c
cSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSS
c
      subroutine destination
c This part of the program establishes final destination points along
c the Potomac River
c
c XFINAL=final destination point on the potomac river
c J=# of destination points
c
      integer IPT,J
      common /dest/XFINAL(11),J
c
  100 continue
      print 10
   10 format(//,' Type in an integer to indicate the number of',
     * ' downstream locations',/,' along the Potomac River at which',
     * ' you want contaminant concentration',/,' tables followed',
     * ' by a carriage return.',/)
      read (5,*) J
      if (j .gt. 3) then
      print 11
   11 format(//,' The number of downstream locations cannot exceed',
     * ' three.  Type in a',/,' carriage return to repeat the',
     * ' previous step.',/)
      read (5,*)
      go to 100
      endif
c
c
      print 20
   20 format(//,' Type in the downstream locations along the',
     * ' Potomac River at which you',/,' want contaminant',
     * ' concentration tables.  These point locations should',
     * /,' be expressed in terms of miles upstream from Chain',
```

```
     * ' Bridge.  Input the',/,' locations as real values on the',
     * ' same line, seperated by blank spaces',/,' and followed',
     * ' by a carriage return.  The following table provides',/,
     * ' some reference points from which to calculate the river',
     * ' mileages:',/)
      call table
      read (5,*) (XFINAL(IPT), IPT=1,J)
      return
      end
c
c sssssssssssssssssssssssssssssssssssssssssssssssssssssssssssssss
c
      subroutine time
c this part of the program sets time parameter, weight injection, and
c duration of injection
c
c imo=month the spill occurred
c ida=day the spill occurred
c ihr=hour(1-24) the spill occurred
c iyr=year the spill occurred
c WT=pounds of soluable solution entering water per hour
c iz=duration of spill (hours)
c
      integer ihr,ida,imo,z,iz,iyr,before,bhr,bda,bmo,byr
      common /tim/WT(2000),ihr,ihrr,ida,idaa,imo,imoo,iz,iyr
c
      common /where/ilocal,irver,before
      print 20
   20 format(//,' Type in the time at which the spill occurred.  On',
     * ' the same line',/,' seperated by blank spaces, type in a two',
     * ' digit integer representing',/,' the hour of the day based on',
     * ' a 24-hour clock, a one or two digit',/,' integer',
     * ' representing the day of the month, a one or two digit',
     * ' integer',/,' representing the month, and a four digit',
     * ' integer representing the year,',/,' followed by a',
     * ' carriage return.',/)
      read(5,*) ihr,ida,imo,iyr
      ihrr=ihr
      idaa=ida
      imoo=imo
      bhr=ihr
      bda=ida
      bmo=imo
      byr=iyr
      print 30
   30 format (///,' Type in an integer indicating the duration in',
     * ' hours of the contaminant',/,' inflow, followed by a',
     * ' carriage return.',/)
      read(5,*) iz
      print 40
   40 format(//,' For each hour, type in a real value with up to two',
     * ' decimal places',/,' indicating the number of pounds of',
     * ' contaminant that entered the river',/,' during that hour,',
     * ' followed by a carriage return.  The minimum input',/,' value',
     *   ' is one pound of contaminant per hour.',//)
      write(2,1406)
 1406 format(/,' Spill Rate',/,' ----------',/)
      if(ilocal.eq.1)then
         write(2,1410)
 1410 format(' The following table shows the rate at which the',
     * ' spill entered the',/,' Potomac River:',/)
```

```
      else
         if(irver.eq.1)then
            write(2,1411)
 1411 format(' The following table shows the rate at which the',
     * ' spill entered the',/,' Monocacy River:',/)
         else if(irver.eq.2)then
            write(2,1412)
 1412 format(' The following table shows the rate at which the',
     * ' spill entered Antietam',/,' Creek:',/)
         else if(irver.eq.3)then
            write(2,1413)
 1413 format(' The following table shows the rate at which the',
     * ' spill entered',/,' Conococheaque Creek:',/)
         else if(irver.eq.4)then
            write(2,1414)
 1414 format(' The following table shows the rate at which the',
     * ' spill entered the',/,' Shenandoah River:',/)
         else
            write(2,1415)
 1415 format(' The following table shows the rate at which the',
     * ' spill entered the',/,' South Branch Potomac River:',/)
         endif
      endif
      write(2,7700)
 7700 format(47x,'Pounds of',/,15x,'Time',12x,'Hours After',4x,
     * 'Contaminant',/,5x,'Year',2x,'Month',2x,'Day',3x,'Hour',4x,
     * 'the Spill',6x,'per Hour')
      write(2,7701)
 7701 format(5x,'----------------------',3x,'-----------',3x,
     * ' ------------')
      do 400 z=1,iz
      print 1140, z
 1140 format(' Number of pounds of contaminant entering the river in',
     * ' hour ', I5,':')
      print*,' '
      read(5,*) WT(z)
      print*,' '
      write(2,7702)byr,bmo,bda,bhr,z,WT(z)
 7702 format(5x,i4,4x,i2,4x,i2,4x,i2,7x,i4,10x,f6.1)
      bhr=bhr+1
      if(bhr.ge.24)then
      bhr=0
      bda=bda+1
      endif
      if(bda.gt.28)then
      call month(bda,bmo,byr)
      endif
  400 continue
      return
      end
c
c
c
cSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSS
c
      subroutine potomac
c
c DATA FOR POTOMAC RIVER
c
c this part of the program sets the time variables for the potomac and
c determines location of spill
```

```
c
c XSPILL=location of spill, measured miles upstream from Chain Bridge
c XXSPILL=location of mouth of tributary where spill enters
c
      integer ifs,jfs,dummy
      real XSPILL,XXSPILL
c
      common /poto/ X(60),A(60),B(60),C(60),E(60),F(60),
     *P(60),QP(60),QQ(60),XSPILL,XXSPILL,ifs,jfs
c
      DATA (x(I),i=1,11)/160.6,122.7,111.2,101.5,94.9,79.4,
     *67.7,57.2,43.6,18.0,1.0/
      DATA (A(I), I=1,11)/6.4012,5.5468,4.4145,4.5756,4.0119,
     *4.713,4.3534,4.3514,8.2864,5.8688,5.2469/
      DATA (B(I), I=1,11)/2.1278,1.5792,1.2502,1.0019,.9331,
     *.8977,.9644,.9625,3.9596,1.5345,1.1437/
      DATA (C(I), I=1,11)/28.1,37.9,11.5,9.7,6.6,15.5,11.7,10.5,
     *13.6,25.6,16.8/
      DATA (E(I), I=1,11)/6.6007,5.6665,4.5749,4.7266,4.1713,
     *4.7956,4.3732,6.2471,8.4137,6.2150,5.3550/
      DATA (F(I), I=1,11)/2.1571,1.6007,1.3141,1.0112,.9993,
     *.8681,.9333,1.9450,3.8886,1.7075,1.1782/
      DATA (P(I), I=1,11)/6.829,5.999,4.4025,5.0558,4.2694,
     *4.8588,4.4761,6.4020,9.4839,6.1092,5.4129/
      DATA (QP(I), I=1,11)/2.1640,1.6930,1.1281,1.0526,1.000,
     *.8178,.9506,1.9201,4.4997,1.6036,1.1083/
c
c*****************************************************************
c
      dummy=i
      if(ifs.gt.1) then
      go to 101
      endif
      print*,' '
      print*,' '
  100 print 99
   99 format(//,' Indicate the point at which the spill entered the',
     * ' Potomac River by',/,' typing in a real number followed by a',
     * ' carriage return.  This value',/,' represents the number of',
     * ' miles upstream from Chain Bridge, Washington D.C.',/,' The',
     * ' mileage value must be greater than zero and may not exceed',
     * /,' 188.  The following table provides some reference points',
     * ' from which to',/,' calculate the river mileage.  However,',
     * ' the model is not limited to',/,' calculating the impacts of',
     * ' spills at just these locations.',/)
      call table
      read (5,*)XSPILL
      if (XSPILL.le.0) then
      print 98
   98 format (/,' Mileage value must be greater than zero.  Type in a',
     * ' carriage return',/,' to repeat this step.',/)
      read (5,*)
      go to 100
      endif
      if (XSPILL.gt.188.7) then
      print 97
   97 format (/,' Mileage value must be less than 188.7.  Type in a',
     * ' carriage return',/,' to repeat this step.',/)
      read (5,*)
      go to 100
      endif
```

```
      write(2,1302) XSPILL
 1302 format(/,' The spill occurred on the Potomac River',f6.1,' miles',
     * ' above Chain Bridge.',/)
      XXSPILL=XSPILL
  101 ifs=1
      jfs=11
      call flow(QQ)
      return
      end
c
cSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSS
c
      subroutine conococh
c
c DATA FOR CONONCHEAGUE CREEK
c
c This part of the model sets intial data for Cononcheague Creek, and
c determines location of spill
c
c XSPILL=location of spill measured miles upstream from mouth of creek
c XXSPILL=location where Cononcheague Creek enters the Potomac. Measured
c         miles upstream from Chain Bridge.
c
      integer ifs,jfs
      real Q,XSPILL,XXSPILL
      common /poto/ X(60),A(60),B(60),C(60),E(60),F(60),
     *P(60),QP(60),QQ(60),XSPILL,XXSPILL,ifs,jfs
c
      data (X(I), I=12,17)/18.4,15.75,12.8,8.8,5.,0./
      data (A(I), I=12,17)/3.1810,3.2788,3.3638,3.4644,3.5112,
     *3.7251/
      data (B(I), I=12,17)/1.8455,1.6065,1.6200,1.4155,1.4517,
     *1.3079/
      data (C(I), I=12,17)/2.75,2.65,2.95,4.,3.8,5./
      data (E(I), I=12,17)/3.2394,3.3096,3.2565,3.5285,3.4524,
     *3.8475/
      data (F(I), I=12,17)/1.7616,1.4771,1.3005,1.4502,1.2402,
     *1.3464/
      data (P(I), I=12,17)/3.3780,3.5053,3.3707,3.5905,3.6723,
     *4.0606/
      data (QP(I), I=12,17)/1.5778,1.4254,1.1811,1.3571,1.3375,
     *1.3826/
      ifs=12
      jfs=17
      XXSPILL=95.
c *************************************************************

  100 print 1105
 1105 format(///, ' Type in a real number followed by a carriage',
     * ' return to indicate the',/,
     * ' point at which the spill entered',
     * ' Conococheaque Creek.  The value',/,' represents the number',
     * ' of miles upstream from the confluence of',/,' Conococheaque',
     * ' Creek and the Potomac River.  The mileage value must',/,
     * ' be greater than zero and it may not exceed 21.2.  The',
     * ' following table',/,' provides some reference points from',
     * ' which to calculate the river',/, ' mileage.  However, the',
     * ' model is not limited to ','calculating the',/,' impact',
     * ' of spills at just these locations.')
      print*,' '
      print*,' '
```

```
      print*,' River                            ',
     * 'River'
      print*,' Mile      Landmark               ',
     * 'Mile      Landmark'
      print*,' 21.2  State Highway 58       ',
     * '   5.0  Kemps Mill Road'
      print*,' 19.1  USGS Gage                ',
     * '   3.8  Kemps Mill Dam'
      print*,' 18.4  State Highway 494      ',
     * '   0.9  Western Maryland Railway'
      print*,' 15.8  Broadfording Road      ',
     * '   0.2  W.D. Byron & Son Water Intake'
      print*,' 12.8  Mouth of Roush Run     ',
     * '   0.1  C & O Canal Aqueduct'
      print*,'  8.8  U.S. Highway 40'
      print*,' '
      read(5,*) XSPILL
      if (XSPILL.gt.21.2) then
      print 1106
 1106 format (/' The model does not simulate spills occurring more',
     * ' than 21.2 miles',/,' upstream from the confluence of',
     * ' Conococheaque Creek and the Potomac',/,' River. Type',
     * ' in a carriage return to return to the previous menu.',/)
      read (5,*)
      go to 100
      endif
      if (XSPILL.le.0.) then
      print 1107
 1107 format (/,' The mileage value must be greater than zero.  Type',
     * ' in a carriage',/,' return to return to the previous menu.',/)
      read (5,*)
      go to 100
      endif
      print 1122
 1122 format (//,' Type in a real discharge value followed by a',
     * ' carriage return to ',/,' indicate the flow in cfs at',
     * ' USGS gaging station:  Conococheaque Creek',/,
     * ' at Fairview, MD, at the time of the spill.  The stage height',
     * ' may be',/,' obtained by calling (703) 260-0305.  The',
     * ' operations guide contains ',/,' tables for converting stage',
     * ' height to discharge.',/)
      read(5,*) Q
      do 101 I=12,17
      QQ(I)=Q
  101 continue
      return
      end
c
cSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSS
c
      subroutine monocacy
c
c DATA FOR MONOCACY RIVER
c
c This part of the model sets intial data for the Monocacy River and
c determines location of spill
c
c XSPILL=location of spill measured miles upstream from mouth of creek
c XXSPILL=location where Monocacy River enters the Potomac. Measured
c        miles upstream from Chain Bridge.
c
```

```
      integer ifs,jfs
      real Q,XSPILL,XXSPILL
      common /poto/ X(60),A(60),B(60),C(60),E(60),F(60),
     *P(60),QP(60),QQ(60),XSPILL,XXSPILL,ifs,jfs
c
      data (X(I), I=18,28)/54.95,52.,46.2,37.85,31.45,26.45,
     *21.2,16.55,9.4,3.95,0./
      data (A(I), I=18,28)/3.403,3.5273,3.8038,4.6236,4.4139,3.8024,
     *3.8370,4.0933,4.0826,4.0579,4.2349/
      data (B(I), I=18,28)/.8048,1.1180,1.0752,1.6016,1.8133,1.3626,
     *1.4769,1.8087,1.2937,1.6148,2.0045/
      data (C(I), I=18,28)/1.75,2.95,5.8,8.35,6.45,5.,5.25,4.65,
     *7.15,5.45,3.95/
      data (E(I), I=18,28)/3.4467,3.7388,3.9603,4.6731,4.2885,3.8756,
     *3.9852,4.1299,4.1271,4.0188,4.2364/
      data (F(I), I=18,28)/.7671,1.2079,1.1122,1.578,1.6212,1.3588,
     *1.5103,1.6837,1.2684,1.4841,1.8809/
      data (P(I), I=18,28)/4.1872,3.2859,3.8904,3.6201,4.0340,3.8782,
     *3.7941,4.1293,4.0643,3.9710,4.3037/
      data (QP(I), I=18,28)/1.0989,.7135,.9229,.8120,1.2985,1.2164,
     *1.1939,1.4048,1.1026,1.3087,1.7471/
      ifs=18
      jfs=28
      XXSPILL=38.
c*********************************************************************
 110  print 801
 801  format(///, ' Type in a real number followed by a carriage',
     * ' return to indicate the',/,
     * ' point at which the spill entered',
     * ' the Monocacy River.  The value',/,' represents the number of',
     * ' miles upstream from the confluence of the',/,' Monocacy and',
     * ' Potomac Rivers.  The mileage value must be greater',/,
     * ' than zero and it may not exceed 57.0.  The following table',
     * ' provides ',/,' some reference points from which to calculate',
     * ' the river mileage.  ',/,' However, the model is not limited',
     * ' to calculating the impact of',/,
     * ' spills at just these locations.')
      print*,' '
      print*,' '
      print*,' River                        ',
     * 'River'
      print*,' Mile      Landmark           ',
     * 'Mile      Landmark'
      print*,' 57.1  Md.-Pa. State Line   ',
     * ' 21.2  Filtration Plant'
      print*,' 56.7  Harney Bridge        ',
     * ' 19.7  Sewage Disposal'
      print*,' 46.2  Sixes Bridge         ',
     * ' 16.6  U.S. Route 40 Bridge'
      print*,' 43.2  Mumma Ford Bridge    ',
     * ' 13.8  B&O Railroad'
      print*,' 37.8  Legore Bridge        ',
     * '  9.4  State Route 80'
      print*,' 34.9  State Route 550      ',
     * '  6.2  Lilypons Bridge'
      print*,' 29.5  Devilbiss Bridge     ',
     * '  2.0  State Route 28'
      print*,' 25.2  Pennsylvania Railroad',
     * '  0.5  B&O Railroad'
      print*,' '
      read(5,*)XSPILL
```

```
      if (XSPILL.gt.57.) then
      print 1100
 1100 format (/,' The model does not simulate spills occurring more',
     * ' than 57.0 miles',/,' upstream from the confluence of the',
     * ' Monocacy and Potomac Rivers.',/,' Type in a carriage',
     * ' return to return to the previous menu.',/)
      read (5,*)
      go to 110
      endif
      if (XSPILL.le.0.) then
      print 1101
 1101 format (/,' The mileage value must be greater than zero.  Type',
     * ' in a carriage',/,' return to return to the previous menu.',/)
      read (5,*)
      go to 110
      endif
      print 1120
 1120 format (//,' Type in a real discharge value followed by a',
     * ' carriage return to ',/,' indicate the flow in cfs at USGS',
     * ' gaging station:  Monocacy River',/,' at Jug',
     * ' Bridge near Frederick, MD., at the time of the spill.',
     * '  The',/,' stage height may be obtained by calling (703)',
     * ' 260-0305.  The operations',/,' guide contains tables for',
     * ' converting stage height to discharge.',/)
      read (5,*) Q
      do 111 I=18,28
      QQ(I)=Q
  111 continue
      return
      end
c
c
cSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSS
c
      subroutine antietam
c
c DATA FOR ANTIETAM CREEK
c
c This part of the model sets intial data for the Antietam River and
c determines location of spill
c
c XSPILL=location of spill measured miles upstream from mouth of creek
c XXSPILL=location where Antietam River enters the Potomac. Measured
c         miles upstream from Chain Bridge.
c
      integer ifs,jfs
      real Q,XSPILL,XXSPILL
      common /poto/ X(60),A(60),B(60),C(60),E(60),F(60),
     *P(60),QP(60),QQ(60),XSPILL,XXSPILL,ifs,jfs
c
      DATA (X(I), I=29,36)/40.05,35.7,28.3,23.25,15.4,11.1,
     *4.85,0./
      DATA (A(I), I=29,36)/2.7596,3.8012,4.0331,3.8032,4.3000,3.3969,
     *4.0304,3.8914/
      DATA (B(I), I=29,36)/1.5218,1.8735,1.4323,1.3671,1.7747,1.2366,
     *1.9549,2.0806/
      DATA (C(I), I=29,36)/1.6,4.35,7.4,5.05,7.85,4.3,6.25,4.85/
      DATA (E(I), I=29,36)/2.9922,3.8153,4.0647,3.7512,4.1036,3.5491,
     *3.7304,3.7786/
      DATA (F(I), I=29,36)/1.5877,1.7541,1.3988,1.2764,1.5040,1.3569,
     *1.5230,1.8571/
```

```
      DATA (P(I), I=29,36)/3.1321,3.7487,2.9766,3.7565,3.7398,3.2990,
     *3.7266,4.1002/
      DATA (QP(I), I=29,36)/1.3384,1.4867,.5789,1.2155,1.0579,.9275,
     *1.3634,2.0113/
      ifs=29
      jfs=36
      XXSPILL=64.
c*******************************************************************
  120 print 1102
 1102 format (///, ' Type in a real number followed by a carriage',
     * ' return to indicate the',/,
     * ' point at which the spill entered',
     * ' the Antietam Creek.  The value',/,' represents the number of',
     * ' miles upstream from the confluence of the',/,' Antietam',
     * ' Creek and the Potomac River.  The mileage value must',/,
     * ' be greater than zero and it may not exceed 42.0.  The',
     * ' following',/,' table provides some reference points from',
     * ' which to calculate',/,' the river mileage.  However, the',
     * ' model is not limited to calculating',/,
     * ' the impact of spills at just these locations.')
      print*,' '
      print*,' '
      print*,' River                        ',
     * 'River'
      print*,' Mile      Landmark           ',
     * 'Mile      Landmark'
      print*,' 40.5  Md.-Pa. State Line   ',
     * ' 13.3  State Highway 68'
      print*,' 35.7  State Highway 60     ',
     * ' 11.1  Monroe Road'
      print*,' 33.0  Old Forge Road Bridge',
     * '  9.5  B&O Railroad'
      print*,' 28.3  State Highway 64     ',
     * '  8.2  Hicks Bridge'
      print*,' 26.6  U.S. Highway 40      ',
     * '  5.7  State Highway 34'
      print*,' 24.4  Sewage Disposal Plant',
     * '  4.5  USGS Gage'
      print*,' 23.2  West Baltimore Street',
     * "  0.2  Harper's Ferry Road"
      print*,' '
      read(5,*) XSPILL
      if (XSPILL.gt.42.) then
      print 1103
 1103 format (/,' The model does not simulate spills occurring more',
     * ' than 42.0 miles',/,' upstream from the confluence of the',
     * ' Antietam Creek and the Potomac',/,' River.  Type in a',
     * ' carriage return to return to the previous menu.',/)
      read(5,*)
      go to 120
      endif
      if (XSPILL.le.0.) then
      print 1104
 1104 format (/,' The mileage value must be greater than zero.  Type',
     * ' in a carriage',/,' return to return to the previous menu.',/)
      read (5,*)
      go to 120
      endif
      print 1121
 1121 format (//,' Type in a real discharge value followed by a',
     * ' carriage return to ',/,' indicate the flow in cfs at USGS',
```

```
      * ' gaging station:  Antietam Creek',/,' near Sharpsburg, MD.',
      * ', at the time of the spill.  The stage height',/,
      * ' may be obtained by calling (703) 260-0305.  The',
      * ' operations guide ',/,' contains tables for converting',
      * ' stage height to discharge.',/)
        read(5,*) Q
        do 121 I=29,36
        QQ(I)=Q
  121   continue
        return
        end
c
cSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSS
c
      subroutine flow(QQ)
c
c This part of the program converts gage readings at Paw Paw, Hancock,
c Point of Rocks, and Shepherdstown to correct discharge values.
c If gage readings are not availble at Paw Paw, Shepherdstown, or
c Hancock, the program will automatically convert the discharge value
c from  Point of Rocks to an adjusted discharge, assuming similiar
c flow duration.
c
c xxpt=stage reading at Point of Rocks ----> q4=discharge value
c xxsh= "       "      "  Shepherdstown  ----> q3=    "        "
c xxh=  "       "      "  Hancock        ----> q2=    "        "
c xxpp= "       "      "  Paw Paw        ----> q1=    "        "
c
c
      real xxpt,xxsh,xxh,xxpp,por
      dimension QQ(60)
c
      common/try/por
   10 format(2x,f6.2,5x,f6.2,8x,f6.2,10x,f6.2)
   19 format(3x,f7.0,6x,f7.0,6x,f7.0,6x,f7.0)
      print*,' '
      print*,' '
 1411 print 1211
 1211 format(' Type in river stage values in feet for the following',
     * ' USGS gaging stations:',/,' Potomac River at Point of Rocks,',
     * ' MD., Potomac River at Shepherdstown, WV.,',/,' Potomac River',
     * ' at Hancock, MD., and Potomac River at Paw Paw, WV. These',/,
     * ' real values should be typed in on one line seperated by',
     * ' blank',
     * ' spaces,',/,' followed  by a carriage return.  These values',
     * ' may be obtained by calling',/,' (703) 260-0305.  If you',
     * ' would like the program to calculate the stages',/,' at',
     * ' Shepardstown, Hancock, or Paw Paw based on the stage at',
     * ' the gage',/,' at Point of Rocks, enter zero for these',
     * ' gages.  However, a stage reading',/,' of at least 0.49 feet',
     * ' must be typed in for Point of Rocks.  The',/,' program will',
     * ' automatically calculate river flows in cfs for these gages.',/)
      read(5,*) xxpt,xxsh,xxh,xxpp
      if(xxpt.lt.0.49) then
         print 1410
 1410 format(//,' The stage height at Point of Rocks must be at least',
     * ' 0.49 feet.  Type in',/,' a carriage return in order to',
     * ' to return to the previous menu.',/)
         read(5,*)
         go to 1411
      endif
```

```
      write(2,1420)
1420 format(/,' Potomac River Flows',/,' -------------------',/)
      write(2,1421)
1421 format(' Gage heights at the time of the spill were input for',
    * ' the following',/,' USGS gaging stations:',/)
      write(2,1426)xxpt
1426 format('      Potomac River at Point of Rocks, MD. was',f6.2,
    * '   feet.',/)
      if(xxsh.gt.0) then
         write(2,1422)xxsh
1422 format('      Potomac River at Shepherdstown, WV. was',f6.2,
    * '   feet.',/)
      endif
      if(xxh.gt.0)then
         write(2,1423)xxh
1423 format('      Potomac River at Hancock, MD. was',f6.2,'  feet.',
    * /)
      endif
      if(xxpp.gt.0)then
         write(2,1424)xxpp
1424 format('      Potomac River at Paw Paw, WV. was',f6.2,'  feet.',
    * /)
      endif
      write(2,1425)
1425 format(/,' River flows in cfs at the time of the spill were',
    * ' calculated for the',/,' following USGS gaging stations',
    * ' based on the gage height at the station:',/)
      q4=10**(1.4119*alog10(xxpt)+3.2191)
      por=q4
      if(xxpp.le.0.) then
      q1=.3191*q4-182.26
      else
      q1=10**(2.1078*alog10(xxpp)+1.7887)
      end if
      if(xxh.le.0) then
      q2=.4065*q4-239.35
      else
      q2=10** (1.8435*alog10(xxh)+2.2974)
      end if
      if(xxsh.le.0.) then
      q3=.5925*q4-182.42
      else
      q3=10**(1.6859*alog10(xxsh)+2.7638)
      end if
      write(2,1427)q4
1427 format('      Potomac River at Point of Rocks, MD. was',
    * f8.1,' cfs.',/)
      if(xxsh.gt.0)then
      write(2,1428)q3
1428 format('      Potomac River at Shepherdstown, WV. was',
    * f8.1,' cfs.',/)
      endif
      if(xxh.gt.0)then
      write(2,1429)q2
1429 format('      Potomac River at Hancock, MD. was',f8.1,' cfs.',/)
      endif
      if(xxpp.gt.0)then
      write(2,1430)q1
1430 format('      Potomac River at Paw Paw, WV. was',f8.1,' cfs.',/)
      endif
      if(xxsh.le.0.or.xxh.le.0.or.xxpp.le.0)then
```

```
      write(2,1431)
 1431 format(/,' River flows in cfs at the time of the spill were',
     * ' calculated for the',/,' following USGS gaging stations',
     * ' based on the gage height at Point of',/,' Rocks, MD.:',/)
      endif
      if(xxsh.le.0)then
      write(2,1432)q3
 1432 format('      Potomac River at Shepherdstown, WV. was',
     * f8.1,' cfs.',/)
      endif
      if(xxh.le.0)then
      write(2,1433)q2
 1433 format('      Potomac River at Hancock, MD. was',f8.1,' cfs.',/)
      endif
      if(xxpp.le.0)then
      write(2,1434)q1
 1434 format('      Potomac River at Paw Paw, WV. was',f8.1,' cfs.',/)
      endif
      QQ(1)=q1
      QQ(2)=q1
      QQ(3)=q2
      QQ(4)=q2
      QQ(5)=q2
      QQ(6)=q3
      QQ(7)=q3
      QQ(8)=q3
      QQ(9)=q4
      QQ(10)=q4
      QQ(11)=q4
      return
      end
c
cSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSS
c
      subroutine travel
c
      real GG,GH,CONPEK,XSPILL,XXSPILL,WT
      real LE(60),CE(60),QD(60),TE(60),TOTPEK(3500)
      real PEAK,Sc,St,ltt,wtt,LET,LEX,LETT
      integer LETOT,CETOT,TETOT,D
      integer HR,IR,J,IPT,iwt,iz
      integer ifs,jfs,ipt,before
      integer ihr,ihrr,ida,idaa,imo,imoo,iyr,count
      common /tim/WT(2000),ihr,ihrr,ida,idaa,imo,imoo,iz,iyr
      common /poto/ X(60),A(60),B(60),C(60),E(60),F(60),
     *P(60),QP(60),QQ(60),XSPILL,XXSPILL,ifs,jfs
      common /dest/XFINAL(11),J
      common /where/ilocal,irver,before
ccccccccccccccccccccccccccccccccccccccccccccc
      data (QD(I), I=1,60)/1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,1.,
     *1.00,1.04,1.04,1.08,1.08,1.14,
     *.21,.21,.38,.63,.75,.78,.86,1.00,1.05,1.16,1.19,
     *.33,.35,.59,.64,.70,.83,1.00,1.04,
     *.7,.87,1.,1.06,1.18,1.19,1.27,1.29,.96,1.,.91,.92,.97,.99,1.01,
     *.46,.50,.73,.81,.88,.91,.93,1.0,1.01/
      XXXSPILL=XSPILL
      count=1
C#########################################################################C
c
C  DO LOOP FOR EACH LOCATION
      DO 300 IPT=1,J
```

```
c  reset cummulative times
        LETT=0
        CETT=0
        TETT=0
c  reset time variables
        ihr=ihrr
        ida=idaa
        imo=imoo
c  XSPILL=location of the spill
c  reset location of spill
        XSPILL=XXXSPILL
c
c set, or reset value of cummulative concentration at each hour
cccccccccccccccccccccccccccccccccccccccccccccc
        do 15 I=1,3500
        TOTPEK(I)=0.
   15 continue
C*******************************************************************C
C  DO LOOP TO CALCULATE TRAVEL TIME FOR EACH WEIGHT INJECTION
c  jfs-ifs  represents the number of subreaches USGS did sampling
c  on for that particular river
            DO 301  I=ifs,jfs
c adjust flow for floater/sinker contaminant
            qfloat = qq(i)
c The first part of the do loop locates the subreach of the spill
            IF (XSPILL.GT.X(I)) then
            LET=10**((-alog10(Qfloat)+A(I))/B(I))
            LE(I)=(XSPILL-X(I))*LET/C(I)
c LETT represents the cummulative time for leading edge
            LETT=LE(I)+LETT
            CET=10**((-alog10(qfloat)+E(I))/F(I))
            CE(I)=(XSPILL-X(I))*CET/C(I)
c CETT represents the cummulative time for concentration edge
            CETT=CE(I)+CETT
            TET=10**((-alog10(qfloat)+P(I))/QP(I))
            TE(I)=(XSPILL-X(I))*TET/C(I)
c TETT represents the cummulative time for the trailing edge
            TETT=TE(I)+TETT
            XSPILL=X(I)
c       write(2,41) I,ifs,jfs,
c     1  XSPILL,X(I),LET,QQ(I),A(I),
c     1  B(I),LE(I),C(I),LETT,CET,
c     1  E(I),F(I),CE(I),CETT,TET,
c     1  P(I),QP(I),TE(I),TET,TETT
            endif
c The 'if statement'  checks to see if the contaminant has passed the
c desired final location
            IF  (XFINAL(IPT).GE.X(I))  THEN
            LEX=(XFINAL(IPT)-X(I))*LET/C(I)
c LETOT represents the corrected leading edge time
            LETOT=LETT-LEX
            CEX=(XFINAL(IPT)-X(I))*CET/C(I)
c CETOT represents the corrected concentration edge time
            CETOT=CETT-CEX
            TEX=(XFINAL(IPT)-X(I))*TET/C(I)
c TETOT represents the corrected trailing edge time
            TETOT=TETT-TEX
            D=TETOT-LETOT
            QQQ=QQ(I)*QD(I)
c        write(2,44)  XFINAL(IPT),X(I),LEX,LET,C(I),
c     1  LETOT,LETT,CEX,CET,C(I),
```

```
c     1  CETOT,CETT,TEX,TET,TETT,
c     1  TETOT,D,QQQ,QQ(I),QD(I)
        go to 302
        endif
  301      continue
  302  GG=CETOT-LETOT
       GH=TETOT-CETOT
       LLTOT=LETOT
       CCTOT=CETOT
       ltt=(XXXSPILL-XFINAL(IPT))/LLTOT
       ctt=(XXXSPILL-XFINAL(IPT))/CCTOT
       write(2,*)' '
C*********************************************************************C
C  DO LOOP TO CALCULATE EDGE TIMES AND PEAK CONC. FOR EACH INJECTION
          do 303 iwt=1,iz
          if(wt(iwt).lt.1) go to 310
c Peak concentration for each weight is calculated by multiplying the
c weight injected by a constant(9250)  and then dividing by the duration
c of the spill and the discharge value
          PEAK=9250.*WT(iwt)/(D*QQQ)
c Sc represents the slope on the left-handed side of the triangle
          Sc=PEAK/GG
c St represents the slope on the right-handed side of the triangle
          St=PEAK/GH
C*********************************************************************C
C  DO LOOP TO CALCULATE CONCENTRATION FOR EACH HOUR PER MASS
c
c The concentration for each hour is derived by multiplying the slope
c of the triangle and the time length of the base
                  do 304 IR=LETOT,TETOT
                  if (IR.le.CETOT) then
                  SLOPE=Sc
                  CONPEK=SLOPE*(IR-LETOT)
                  else
                  SLOPE=St
c CONPEK represents the conc.  at each hr for each weight injection
                  CONPEK=PEAK-SLOPE*(IR-CETOT)
                  endif
c TOTPEK represents the total concentration at each hour
                  TOTPEK(IR)=TOTPEK(IR)+CONPEK
c      WRITE(2,40) iwt,iz,IR,LETOT,TETOT,Sc,St,CONPEK,TOTPEK(IR),PEAK
  304             continue
  310     LETOT=LETOT+1
          CETOT=CETOT+1
          TETOT=TETOT+1
  303     continue
C*********************************************************************C
C*********************************************************************C
      if(ifs.eq.1.and.count.eq.1)then
      write(2,1520)
 1520 format(//,' Contaminant Concentration on the Potomac River',/,
     *            ' ----------------------------------------------',/)
      else if(ifs.ne.1.and.count.eq.1)then
      write(2,1521)
 1521 format(//,' Contaminant Concentration on the Tributary',/,
     *            ' ------------------------------------------',/)
      else
      write(2,1540)
 1540 format(/)
      endif
      count=2
```

```
      if (ifs.eq.1) then
      write(2,1500)XFINAL(IPT)
 1500 format(' The model has calculated the following contaminant',
     * ' concentrations',/,' on the Potomac River at a point',f6.1,
     * ' miles upstream from Chain Bridge,',/,' Washington, D.C.,',
     * ' following the spill:',/)
      else
      if (irver.eq.1) then
      write(2,1501)XFINAL(IPT)
 1501 format(' The model has calculated the following contaminant',
     * ' concentrations',/,' on the Monocacy River at a point',f5.1,
     * ' miles upstream from the',/,' confluence of the Monocacy and',
     * ' the Potomac Rivers, following the spill:',/)
      else if (irver.eq.2) then
      write(2,1502)XFINAL(IPT)
 1502 format(' The model has calculated the following contaminant',
     * ' concentrations',/,' on Antietam Creek at a point',f5.1,
     * ' miles upstream from the confluence',/,' of Antietam Creek',
     * ' and the Potomac River, following the spill:',/)
      else if (irver.eq.3) then
      write(2,1503)XFINAL(IPT)
 1503 format(' The model has calculated the following contaminant',
     * ' concentrations',/,' on Conococheaque Creek at a point',f5.1,
     * ' miles upstream from the',/,' confluence of Conococheaque',
     * ' Creek and the Potomac River, following',/,' the spill:',/)
      else if (irver.eq.4) then
      write(2,1504)XFINAL(IPT)
 1504 format(' The model has calculated the following contaminant',
     * ' concentrations',/,' on the Shenandoah River at a point',f6.1,
     * ' miles upstream from the',/,' confluence of the Shenandoah',
     * ' and Potomac Rivers, following',/,' the spill:',/)
      else
      write(2,1505)XFINAL(IPT)
 1505 format(' The model has calculated the following contaminant',
     * ' concentrations',/,' on the South Branch Potomac River at a',
     * ' point',f5.1,' miles upstream',/,' from the confluence of the',
     * ' South Branch Potomac River and the Potomac',/,' River',
     * ' following the spill:',/)
      endif
      endif

      write(2,1506)
 1506 format(15x,'Time',12x,'Hours After',3x,'Concentration')
      write(2,1507)
 1507 format(5x,'Year',2x,'Month',2x,'Day',3x,'Hour',4x,
     * 'the Spill',7x,' (ug/l)')
      write(2,1508)
 1508 format(5x,'-----------------------',3x,'-----------',3x,
     * '-------------')
 1522 format(5x,i4,4x,i2,4x,i2,4x,i2,7x,i4,10x,f7.1)
      wtt=0.
C  DO LOOP FOR PRINT STATEMENTS
                        do 305 HR=1,2000
                        if (XFINAL(IPT).eq.0.) then
c Weight (lbs)  per hour equals Concentration Peak times discharge times
c a conversion factor of .00021622
                        WT(HR)=TOTPEK(HR)*QQQ*.00021622
                        endif
                        if (TOTPEK(HR).lt.1.) then
                        go to 306
                        endif
```

```
                          write (2,1522)iyr,imo,ida,ihr,HR,TOTPEK(HR)
  306                     ihr=ihr+1
                          if (ihr.ge.24) then
                          ihr=0
                          ida=ida+1
                          endif
                          if (ida.gt.28) then
                          call month(ida,imo,iyr)
                          endif
  305                     continue
      if(ilocal.ne.1.and.before.eq.0)then
      write(2,1550) ctt
 1550 format(/,' The average velocity of the peak of the',
     * ' concentration plume from',/,' the point of the spill to',
     * ' the point of interest is',f6.3,' miles',/,' per hour.',/)
      else if(ilocal.ne.1.and.before.eq.1)then
      write(2,1551) ctt
 1551 format(/,' The average velocity of the peak of the',
     * ' concentration plume from',/,' the confluence of the',
     * ' tributary and the Potomac river is',f6.3,' miles',/,
     * ' per hour.',/)
      else if(ilocal.eq.1)then
      write(2,1550) ctt
      endif
      if (XFINAL(IPT).gt.0.) then
      go to 300
      endif
      write(2,1530)
 1530 format(/,' Contaminant Inflow to the Potomac River',)
      write(2,1531)
 1531 format(' ----------------------------------------',/)
      write(2,1532)
 1532 format(' The following table shows the rate at which the',
     * ' contaminant would enter',/,' the Potomac',
     * ' River:',/)
      write(2,1533)
 1533 format(5x,'Hours After',3x,'Inflow Rate')
      write(2,1534)
 1534 format(6x,'the Spill',5x,'(lbs/hr)')
      write(2,1535)
 1535 format('    --------------------------')
      do 307 i=1,2000
      if (WT(i).gt.1) then
      write(2,1536) i,WT(i)
 1536 format(8x,i4,9x,f6.2)
      endif
      wtt=wtt+WT(I)
  307 continue
      write(2,*)' '
      write(2,1537) wtt
 1537 format(' The total weight of the contaminant entering the',
     * ' Potomac River',/,' is',f6.0,' pounds.')
  300 continue
      write(2,*)' '
      return
      end

c
cSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSS
c
      subroutine month (ida,imo,iyr)
```

```
c
      dimension days(12)
      data days /31,28,31,30,31,30,31,31,30,31,30,31/
      temp=mod(iyr,4)
      if(ida.eq.29.and.imo.eq.2.and.mod(iyr,4).eq.0) then
      ida=29
      else if (ida.gt.days(imo)) then
      ida=1
      imo=imo+1
      endif
      if (imo.gt.12) then
      imo=1
      iyr=iyr+1
      endif
      return
      end
c
cSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSS
c
      subroutine table
c
      print*,' River                               ',
     * ' River'
      print*,' Mile    Landmark                    ',
     * ' Mile    Landmark'
      print*,' '
      print*,' 188  Wiley Ford Br. Cumberland',
     * '  57  Dam #3'
      print*,' 180  C&O RR Br (No. Branch)   ',
     * '  56  Mouth Shenandoah R.'
      print*,' 171  Bridge at Oldtown, Md.   ',
     * '  55  Rt 340 Harpers Fy, WVa'
      print*,' 165  Mouth L. Cacapon River   ',
     * '  50  Bridge Brunswick, Md'
      print*,' 161  Paw Paw, W. Va.          ',
     * '  44  Rt 15 Pt of Rocks, Md'
      print*,' 154  C&O RR Br Magnolia, WVa  ',
     * '  38  Mouth of Monocacy R.'
      print*,' 141  Dow Gully, W. Va.        ',
     * '  27  Mouth of Goose Creek'
      print*,' 123  U.S. Highway #522 Hancock',
     * '  18  FCWA Potomac Intake'
      print*,' 102  Dam #5                   ',
     * '  14  WSSC Potomac Intake'
      print*,'  95  Rt 11 Williamsport, Md.  ',
     * '  12  Rockville Intake'
      print*,'  79  Dam #4                   ',
     * '  10  WAD Intake (Gt Falls)'
      print*,'  68  Br. Shepherdstown, WVa   ',
     * '   1  WAD Intake (Lt Falls)'
      print*,' '
      return
      end

cSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSS
c
      subroutine shenan
c
c DATA FOR SHENANDOAH RIVER
c
c This part of the model sets intial data for Shenandoah River and
```

```
c determines location of spill
c
c XSPILL=location of spill measured miles upstream from mouth of creek
c XXSPILL=location where the Shenandoah River enters the Potomac. Measured
c         miles upstream from Chain Bridge.
c
      integer ifs,jfs,path
      real XSPILL,XXSPILL
      common /poto/ X(60),A(60),B(60),C(60),E(60),F(60),
     *P(60),QP(60),QQ(60),XSPILL,XXSPILL,ifs,jfs
c
      common /loop/path,qdur
      data (X(I), I=37,51)/173.2,165.8,159.4,142.6,129.1,121.2,
     *                     106.2,99.2,73.1,57.7,47.5,36.6,22.1,
     *                     8.4,0.0/
      data (A(I), I=37,51)/3.3045,3.6525,3.4979,4.4834,4.6289,
     *                     3.9079,4.5933,4.1656,4.5207,4.5180,
     *                     4.9547,5.2381,5.1017,4.8495,4.8439/
      data (B(I), I=37,51)/1.1365,1.3031,1.2451,1.1848,1.3599,
     *                     1.1612,1.3770,1.1200,0.9996,1.1358,
     *                     1.2959,1.8081,1.6071,1.3429,1.3350/
      data (C(I), I=37,51)/5.3,7.4,6.4,16.8,13.5,7.9,15.0,7.0,26.1,
     *                     15.4,10.2,10.9,14.5,13.7,8.4/
      data (E(I), I=37,51)/3.5209,3.8336,3.5012,4.5256,4.8991,
     *                     4.0815,4.2959,3.7805,4.9146,4.5243,
     *                     5.0442,4.6339,5.0410,5.1069,4.8337/
      data (F(I), I=37,51)/1.2239,1.3821,1.1920,1.1871,1.5086,
     *                     1.2538,1.1100,0.7752,1.1974,1.1153,
     *                     1.3641,1.2032,1.5187,1.4755,1.3025/
      data (P(I), I=37,51)/4.1103,3.6245,3.7082,4.6272,4.4834,
     *                     3.9953,4.1081,3.8939,5.5296,4.5268,
     *                     4.4888,5.1701,5.4880,5.4633,4.9255/
      data (QP(I), I=37,51)/1.5777,1.1604,1.3092,1.1921,1.1848,
     *                      1.0919,0.9214,0.7676,1.5031,1.0806,
     *                      0.9192,1.5906,1.7860,1.6452,1.2820/
      ifs=37
      jfs=51
      XXSPILL=56.
c ************************************************************
c
  100 print 1108
 1108 format(///, ' Type in a real number followed by a carriage',
     * ' return to indicate the',/,
     * ' point at which the spill entered',
     * ' the Shenandoah River.  The value',/' represents the number',
     * ' of miles upstream from the confluence of the',/,
     * ' Shenandoah and Potomac Rivers.  The mileage value must be',
     * ' greater',/,' than zero and it may not exceed 178.5.  The',
     * ' following table provides ',/,' some reference points from',
     * ' which to calculate the river mileage.  ',/,' However, the',
     * ' model is not limited to calculating the impact of',/,
     * ' spills at just these locations.')
      print*,' '
      print*,' '
      print*,'River                        ',
     * 'River'
      print*,'Mile      Landmark           ',
     * 'Mile      Landmark'
      print*,'178.5  Waynesboro            ',
     * ' 99.2  Bixler Bridge'
      print*,'173.2  Hopeman Parkway       ',
```

```
     * ' 73.1  Bentonville'
      print*,'165.8  Crimora                 ',
     * ' 57.5  Front Royal'
      print*,'159.4  Harriston               ',
     * ' 47.5  Morgan Ford'
      print*,'142.6  Island Ford             ',
     * ' 36.6  U.S. Highway 17 and 50'
      print*,'129.1  Shenandoah              ',
     * ' 22.1  State Highway 7'
      print*,'121.2  Grove Hill              ',
     * '  8.4  State Highway 9'
      print*,'106.2  U.S. Highway 211        ',
     * "  0.8  Harper's Ferry"
      print*,' '
      read(5,*) XSPILL
      if (XSPILL.gt.178.5) then
      print 1109
1109 format (/,' The model does not simulate spills occurring more',
    * ' than 178.5 miles',/,' upstream from the confluence of the',
    * ' Shenandoah and Potomac Rivers.',/,' Type in a carriage',
    * ' return to return to the previous menu.',/)
      read(5,*)
      go to 100
      endif
      if (XSPILL.le.0.) then
      print 1110
1110 format (/,' The mileage value must be greater than zero.  Type',
    * ' in a carriage',/,' return to return to the previous menu.'/)
      read (5,*)
      go to 100
      endif
 110 continue
      print 1124
1124 format(//,' On the same line, type in two real discharge values',
    * ' in cfs,'
    * ' seperated',/,' by a blank space, and followed by a carriage',
    * ' return.  The first discharge',/,' value indicates the flow at',
    * ' USGS gaging station:  Shenandoah River at',/,' Millville, WV.,'
    * ' at the time of the spill.  This discharge value should be',/,
    * ' between 350 and 11579 cfs.  The second discharge value',
    * ' indicates the flow',/,' at USGS gaging station:  South Fork',
    * ' Shenandoah River at Front Royal, VA.',/,' at the time of the',
    * ' spill.  This discharge value should be between 130 and',/,
    * ' and 4735 cfs.  A value of zero may be entered if you would',
    * ' like to have',/,' the model calculate the discharge at Front',
    * ' Royal based on the flow',/,' duration value associated with',
    * ' the flow at Millville.  Stage heights',/,' at these gages may',
    * ' be obtained by calling (703) 260-0305.  The operations',/,
    * ' guide contains tables for converting stage heights to',
    * ' discharges.',/)
1127 read(5,*) q1,q2
     path=0
     if ( q1 .le. 0.) then
          print 1125
1125 format (//,' The discharge value for USGS gaging station:',
    * '  Shenandoah River at',/,' Millville, WV., must be between',
    * ' 350 and 11579 cfs.  Type in a carriage',/,' return to return',
    * ' to the previous menu.  Then repeat the discharge input',/,
    * ' process.',/)
          read (5,*)
          go to 110
```

```
     endif
     if ( q2 .le. 0.) then
          call flowdur(qdur,q1,1)
          if (qdur .lt. 0. .or. qdur .gt. 100.) then
          print 1126
1126 format (//, ' The discharge value which was input for the South',
    * ' Fork Shenandoah',/,' River at Front Royal VA., is less than',
    * ' or equal to zero, therefore,',/,' this value will be',
    * ' calculated based on the flow duration value for',/,' the',
    * ' Shenandoah River at Millville, WV.  However, the discharge',/,
    * ' value which was input for the Shenandoah River at Millville,',
    * ' WV.,',/,' results in a flow duration value which is either',
    * ' less than zero or',/,' greater than 100.  Therefore, re-enter',
    * ' a discharge value between 350 cfs',/,' and 11579 cfs for the',
    * ' Shenandoah River at Millville, WV.  On the same',/,' line',
    * ' followed by a blank space, re-enter a discharge value of zero',
    * /,' in order to indicate no flow for the South Fork Shenandoah',
    * ' River at Front',/,' Royal, followed by a carriage return.',/)
              go to 1127
          endif
          call royalq(qdur,q2)
          path=3
          go to 1400
       else
          call flowdur(qdur,q2,2)
     endif
     if (qdur .lt. 0. .or. qdur .gt. 100.) then
     print 1128
1128 format(//, ' The discharge value which was input for the South',
    * ' Fork Shenandoah',/,' River at Front Royal VA., is outside',
    * ' the expected range.  Re-enter',/,' the discharge value in',
    * ' cfs for the Shenandoah River at Millville, WV.,',/,
    * ' followed by a blank space.  On the same line, enter a new',
    * ' discharge',/,' value in cfs for the South Fork Shenandoah',
    * ' River at Front Royal, VA.,',/,' followed by a carriage',
    * ' return.  This value should be between 130 cfs',/,' and 4735',
    * ' cfs.',/)
     go to 1127
     endif
     call flowdur(qdur,q1,1)
     if(qdur.lt.0..or.qdur.gt.100.) then
     print 1129
1129 format(//,' The discharge value which was input for the',
    * ' Shenandoah River at',/,' Millville, WV. results in a flow',
    * ' duration value which is either',/,' less than zero or',
    * ' greater than 100.  Therefore, re-enter a discharge',/,
    * ' value between 350 cfs and 11,579 cfs for the Shenandoah',
    * ' River at',/,' Millville, WV.  On the same line followed',
    * ' by a blank space, re-enter',/,' the discharge value for',
    * ' the South Fork Shenandoah River at Front',/,' Royal followed',
    * ' by a carriage return.'/)
     go to 1127
     endif
     path=5
1400 call shenq(qdur,q3,q4)

     do 150 I=37,39
     QQ(I)=Q4
 150 continue
     do 160 i=40,44
     qq(i) = q3
```

```
  160 continue
      do 170 i=45,46
      qq(I) = q2
  170 continue
      do 180 i=47,51
      qq(i) = q1
  180 continue
      return
      end
cSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSSS
c
      subroutine sbranch
c
c DATA FOR SOUTH BRANCH OF THE POTOMAC
c
c This part of the model sets intial data for the South Branch, and
c determines location of spill
c
c XSPILL=location of spill measured miles upstream from mouth of trib.
c XXSPILL=location where the South Branch enters the Potomac. Measured
c         miles upstream from Chain Bridge.
c
      integer ifs,jfs
      real Q,XSPILL,XXSPILL
      common /poto/ X(60),A(60),B(60),C(60),E(60),F(60),
     *P(60),QP(60),QQ(60),XSPILL,XXSPILL,ifs,jfs
c
      data (X(I), I=52,60)/66.2,58.60,54.0,42.2,31.8,27.1,23.4,13.4,0./
      data (A(I), I=52,60)/3.4206,4.3181,3.9371,5.0185,5.0371,
     *                     4.0306,3.8731,4.5788,4.4420/
      data (B(I), I=52,60)/1.6202,1.5783,1.6771,1.9042,1.8490,
     *                     1.7700,1.3508,1.6486,1.2658/
      data (C(I), I=52,60)/2.8,7.6,4.6,11.8,10.4,4.7,3.7,10.,13.4/
      data (E(I), I=52,60)/3.5289,4.4632,4.1291,4.9825,4.9824,
     *                     4.4231,3.8586,4.6666,4.6759/
      data (F(I), I=52,60)/1.5750,1.6019,1.7261,1.7972,1.7842,
     *                     1.9317,1.2768,1.6523,1.3587/
      data (P(I), I=52,60)/3.8207,4.9412,4.5201,4.7766,5.7374,
     *                     4.1300,4.0914,5.5239,4.8411/
      data (QP(I), I=52,60)/1.4094,1.8935,1.9746,1.5578,2.1256,
     *                      1.3902,1.3386,2.2554,1.3744/
      ifs=52
      jfs=60
      XXSPILL=169.
c ************************************************************

  100 print 1111
 1111 format(///, ' Type in a real number followed by a carriage',
     * ' return to indicate the',/,
     * ' point at which the spill entered',
     * ' the South Branch of the Potomac',/,' River.  The value',
     * ' represents the number of miles upstream from the',/,
     * ' confluence of the South Branch of the Potomac River and',
     * ' the Potomac River.',/,' The mileage value must be greater',
     * ' than zero and it may not exceed ',/,' 69.0.  The following',
     * ' table provides some reference points from which',/,
     * ' to calculate',
     * ' the river mileage.  However, the model is not limited',/,
     * ' to calculating the impact of spills at just these',
     * ' locations')
      print*,' '
```

```
      a(2) = -25./2680.
      b(2) = 44.179
      rl(2)= -5./188.
c
      j = igage
      if ( q .lt. disch(1,j)) then
           qdur = (q - disch(1,j)) * rl(j) + 95.
           go to 500
      endif
c
      qd = 95.
      do 200 i = 2,14
      qd = qd - 5.
      if ( q .lt. disch(i,j)) then
           qdur = ((q - disch(i,j)) * 5. / (disch(i-1,j) - disch(i,j)))
     *             + qd
           go to 500
      endif
 200  continue
c
      qdur = q * a(j) + b(j)
 500  continue
      return
      end
ccccc
ccccc
ccccc
      subroutine shenq(qd,q3,q4)
      dimension qlynn(14), qharr(14)
c
      data qlynn /194.,227.,259.,291.,329.,368.,412.,460.,
     *            517.,581.,658.,740.,844.,944./
      data qharr /58.3,68.0,75.0,82.3,91.0,101.8,112.,125.,
     *            138.5,156.,174.,193.,215.,239./
c
      if (qd .lt. 30) then
          q3 = (-1856./25.) * qd + 3171.2
          q4 = ( -401./25.) * qd +  720.2
          go to 500
      endif
      if (qd .lt. 95.) then
          qdl = qd - amod(qd,5.)
          in1 = 14 - (qdl - 30) / 5
          in2 = in1 - 1
          q3 = (qd - qdl)*(qlynn(in2) - qlynn(in1)) / 5. + qlynn(in1)
          q4 = (qd - qdl)*(qharr(in2) - qharr(in2)) / 5. + qharr(in1)
          go to 500
      endif
      q3 = (qd - 95.) * (-114./5.) + 194.
      q4 = (qd - 95.) * (-32.3/5.) + 58.3
 500  continue
      return
      end
cccccccccccccc
cccccccccccccc
      subroutine royalq(qd,q)
      common /royal/ dum(14), qroy(14)
c
      if (qd .lt. 30) then
          q = (-2680./25.) * qd + 4736.0
          go to 500
```

```
      print*,' '
      print*,' River                                   ',
     * 'River'
      print*,' Mile      Landmark                      ',
     * 'Mile      Landmark'
      print*,' 69.0  Petersburg                        ',
     * ' 31.8  U.S. Rt 50 bridge - Romney'
      print*,' 66.2  U.S. Rt 220 Bridge                ',
     * ' 27.1  Wapocomo'
      print*,' 57.3  South Fork - Moorefield',
     * ' 23.4  W.V. Rt 28 Bridge - Grace'
      print*,' 48.9  Sycamore, B&O RR Bridge',
     * ' 13.4  Springfield, W.V.'
      print*,' 40.9  Stony Run                        '
      print*,' '
      read(5,*) XSPILL
      if (XSPILL.gt.69.0) then
      print 1112
 1112 format (/,' The model does not simulate spills occurring more',
     * ' than 69.0 miles',/,' upstream from the confluence of the',
     * ' South Branch of the Potomac River ',/,' and the Potomac',
     * ' River.  Type in a carriage return to return to the',/,
     * ' previous menu.',/)
      read (5,*)
      go to 100
      endif
      if (XSPILL.le.0.) then
      print 1113
 1113 format (/,' The mileage value must be greater than zero.  Type',
     * ' in a carriage',/,' return to return to the previous menu.',/)
      read (5,*)
      go to 100
      endif
      print 1123
 1123 format (//,' Type in a real discharge value followed by a'
     * ' carriage return to ',/,' indicate the flow in cfs at USGS',
     * ' gaging station:  South Branch ',/,' Potomac River near',
     * ' Springfield, WV., at the time of the spill.  ',
     * /,' The stage height may be obtained by calling (703)',
     * '  260-0305.  ',/,' The operations guide contains tables',
     * ' for converting stage height',/,' to discharge.',/)
      read(5,*) Q
      do 101 I=52,60
      QQ(I)=Q
  101 continue
      return
      end

      Subroutine flowdur(qdur,q,igage)
c
      common /royal/ disch(14,2)
      dimension  a(2), b(2), rl(2)
c
      data (disch(i,1),i=1,14) /585.,635.,683.,741.,789.,842.,941.,
     *                   1140.,1290.,1480.,1730.,2000.,2570.,3210./
      data (disch(i,2),i=1,14) /318.,376.,421.,468.,520.,579.,651.,728.,
     *                   822.,929.,1042.,1190.,1320.,1520./
c
      a(1) = -10./2790.
      b(1) = 41.505
      rl(1)= -5./235.
```

```
      endif
      if (qd .lt. 95.) then
          qdl = qd - amod(qd,5.)
          inl = 14 - (qdl - 30) / 5
          in2 = inl - 1
          q = (qd - qdl)*(qroy(in2) - qroy(inl)) / 5. + qroy(inl)
          go to 500
      endif
      q = (qd - 95.) * (-188./5.) + 318.
  500 continue
      return
      end
```