Chapter 9

FLOOD ROUTING

9.1 RESERVOIR ROUTING

Flood routing is the process of determining the reservoir stage, storage volume of the outflow hydrograph corresponding to a known hydrograph of inflow into the reservoir; this is called reservoir routing. For this, the capacity curve of the reservoir, *i.e.,* 'storage vs pool elevation', and 'outflow rate vs. pool elevation', curves are required. Storage volumes for different pool elevations are determined by planimetering the contour map of the reservoir site. For example, the volume of water stored (V) between two successive contours having areas A_1 and A_2 (planimetered) and the contour interval d, is given by

Cone formula, $$V = \frac{d}{3}\left(A_1 + A_2 + \sqrt{A_1 A_2}\right) \quad ...(9.1)$$

Prismoidal formula, $$V = \frac{d}{6}\left(A_1 + A_2 + 4A_m\right) \quad ...(9.2)$$

where $A_m = \frac{A_1 + A_2}{2}$, *i.e.,* area midway between the two successive contours. The prismoidal formula is more accurate. The outflow rates are determined by computing the discharge through the sluices and the spillway discharge for different water surface elevations of the reservoir. (*i.e.,* pool elevations):

Discharge through sluices, $$Q_{sl} = C_d A\sqrt{2gh} \quad ...(9.3)$$

Discharge over spillway crest, $$Q_{sp} = CLH^{3/2} \quad ...(9.4)$$

Outflow from the reservoir $$O = Q_{sl} + Q_{sp}$$

where h = height of water surface of reservoir above the centre of sluice
H = height of water surface of reservoir above the crest of spillway
C_d = coefficient of discharge for the sluice
C = coefficient of spillway
A = area of sluice opening
L = length of spillway

The problem in flood routing is to determine the relation between the inflow, the outflow and the storage as a function of time. The problem can be solved by applying the hydrologic equation

$$I = O + \Delta S \quad ...(9.5)$$

where I = inflow rate

O = outflow rate

ΔS = incremental storage, at any instant.

Taking a small interval of time, t (called the routing period and designating the initial and final conditions by subscripts 1 and 2 between the interval, Eq. (9.5) may be written as

$$\left(\frac{I_1 + I_2}{2}\right) t - \left(\frac{O_1 + O_2}{2}\right) t = S_2 - S_1 \quad \text{...(9.6)}$$

The routing period, t selected should be sufficiently short such that the hydrograph during the interval 1-2 can be assumed as a straight line, *i.e.,* $I_{mean} = \frac{I_1 + I_2}{2}$.

Eq. (9.6) can be rearranged as

$$\left(\frac{I_1 + I_2}{2}\right) t + S_1 - \frac{O_1 t}{2} = S_2 + \frac{O_2 t}{2} \quad \text{...(9.7)}$$

After selecting a routing period t, curves of O vs. S, and O vs. $S \pm Ot/2$ on either side of O-S curve are drawn. At the beginning of the routing period all the terms on the left side of Eq. (9.7) are known and the value of the right side terms is found out. Corresponding to this O_2 and (S-Ot/2) are read from the graph, which become the initial values for the next routing period and so on.

This method of flood routing was developed by LG Puls of the US Army Corps of Engineers and is called the ISD (Inflow-storage-discharge) method. Here it is assumed that the outflow (*i.e.,* discharge) from the reservoir is a function of the pool elevation provided that the spillway and the sluices have no gates (*i.e.,* uncontrolled reservoirs) or with constant gate openings, if provided with control gates for which poor elevation vs. discharge curves are drawn.

Eq. (9.6) may be rearranged as

$$(I_1 + I_2) + \left(\frac{2S_1}{t} - O_1\right) = \frac{2S_2}{t} + O_2 \quad \text{...(9.8)}$$

After selecting a routing period t, a curve of '$\frac{2S}{t} + O$ vs. O' can be drawn since $\left(\frac{2S}{t} + O\right) - 2O = \frac{2S}{t} - O$, a curve of '$\frac{2S}{t} - O$ vs. O' can also be drawn.

At the beginning of the routing period all terms on the left of Eq. (9.8) are known. This method is called modified puls or Storage Indication Method.

Example 9.1 *For a reservoir with constant gate openings for the sluices and spillway, pool elevation vs storage and discharge (outflow) curves are shown in Fig.* 9.1. *The inflow hydrograph into the reservoir is given below:*

Time (hr)	0	6	12	18	24	30	36	42
Inflow (cumec)	50	70	160	300	460	540	510	440
Time (hr)	48	54	60	66	72	78	84	90
Inflow (cumec)	330	250	190	150	120	90	80	70

Pool elevation at the commencement = 110 *m*

Discharge at the commencement = 124 *cumec*

Route the flood through the reservoir by (a) ISD method, and (b) modified Puls method, and compute the outflow hydrograph, the maximum pool elevation reached, the reduction in the flood peak and the reservoir lag.

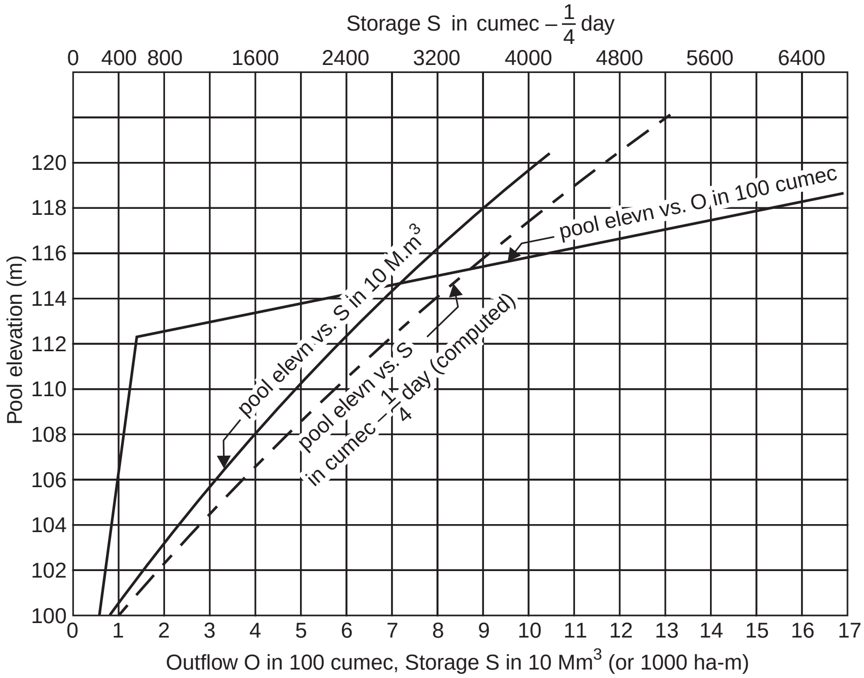

Fig. 9.1 Pool elevation vs. storage and discharge (Example 9.1)

Solution (*a*) *Flood routing by ISD method* Take the routing period as 6 hr or $\frac{1}{4}$ day. It is easier to work the flow rates in cumec and the storage volumes in terms of cumec – $\frac{1}{4}$ day. Hence, the storage in Mm^3 is converted to cumec – $\frac{1}{4}$ day by multiplying by 46.3, Table 9.1. Corresponding to an initial pool elevation of 110 m, O = 124 cumec, S = 49.1 Mm^3 = 49.1 × 46.3 = 2270 cumec – $\frac{1}{4}$ day, $\frac{Ot}{2} = \frac{O}{2} \times t\ \frac{124}{2}$ cumec × $\frac{1}{4}$ day = 62 cumec – $\frac{1}{4}$ day, $S + \frac{Ot}{2}$ = 2270 + 62 = 2332 cumec – $\frac{1}{4}$ day, and $S - \frac{Ot}{2}$ = 2270 – 62 = 2208 cumec – $\frac{1}{4}$ day. First 'O vs. S' curve is drawn. For a particular O on the S curve, $\frac{O}{2}$ abscissa units may be set off on either side of the S curve and this is repeated for other values of O. The points obtained on either side of S curve plot $S + \frac{Ot}{2}$ and $S - \frac{Ot}{2}$ curves as shown in Fig. 9.2.

Table 9.1 Tabulation for drawing (*i*) $S \pm \frac{Ot}{2}$ and (*ii*) $\frac{2S}{t} \pm 0$ curves for routing the flood through the reservoir (Example 9.1)

Pool elevation	*Outflow O*	*Storage S*		*Computation for I.S.D. method* ($t = 6hr = \frac{1}{4}$ *day*)			*Computation for modified Puls method*		
(*m*)	(*cumec*)	(Mm^3)	(*cumec* – $\frac{1}{4}$ *day**)	$\frac{Ot}{2}$ (*cumec* – $\frac{1}{4}$ *day*)	$S + \frac{Ot}{t}$ (*cumec* – $\frac{1}{4}$ *day*)	$S - \frac{Ot}{2}$ (*cumec* – $\frac{1}{4}$ *day*)	$\frac{2S}{t}$ (*cumec*)	$\frac{2S}{t} + O$ (*cumec*)	$\frac{2S}{t} - O$ (*cumec*)
100	60	8.7	400	30	430	370	800	860	740
102	70	15.1	700	35	735	665	1400	1470	1330
104	86	23.4	1480	43	1123	1037	2160	2246	2074
106	100	32.0	1480	50	1530	1430	2960	3060	2860
108	110	40.0	1850	55	1905	1795	3700	3810	3590
110	124	49.1	2270	62	2332	2208	4540	4664	4416
112	138	58.3	2700	69	2769	2631	5400	5538	5262
113	310	63.0	2920	155	3075	2765	5840	6150	5530
114	550	68.3	3160	275	3435	2885	6320	6870	5770
115	800	73.5	3400	400	3800	3000	6800	7600	6000
116	1030	78.8	3650	515	4165	3135	7300	8330	6270
117	1280	83.8	3880	640	4520	3240	7760	9040	6480
118	1520	90.0	4160	760	4920	3400	8320	9840	6800
120	—	101.0	4680	—	—	—	—	—	—

*1 cumec – $\frac{1}{4}$ day = 1 × 6 × 60 = 21600 m^3. 1 million m^3 (Mm^3) = 10^6/21600 = 46.3 cumec – $\frac{1}{4}$ day.

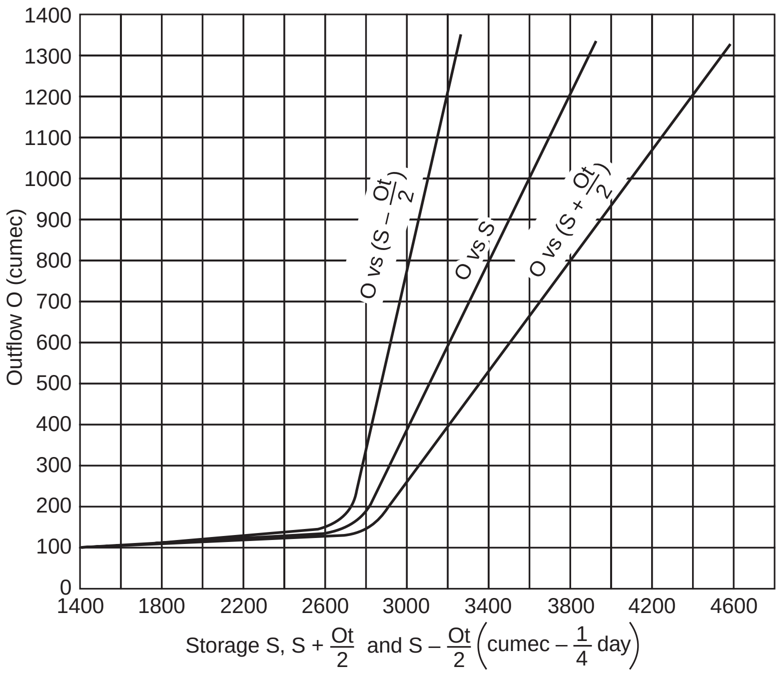

Fig. 9.2 Reservoir routing by ISD method (Example 9.1)

For routing the flood by the I.S.D. method, Table 9.2, for the known outflow at the commoncement of 124 cumec, $S - \dfrac{Ot}{2}$ is read from the curve as 2208 cumec–$\frac{1}{4}$ day and to this $\dfrac{I_1 + I_2}{2}\, t = \dfrac{50 + 70}{2}$ cumec × $\frac{1}{4}$ day = 60 cumec – $\frac{1}{4}$ day is added to get the right hand side of Eq. (9.7); *i.e.*, $S + \dfrac{Ot}{2}$ = 2268 and corresponding to this O = 120 cumec is read from the graph which is the outflow at the beginning of the next routing period. Corresponding to this O = 120 cumec, the pool elevation of 109.2 m is read from the 'pool elevations vs. O' curve. Corresponding to this O = 120 cumec, $S - \dfrac{Ot}{2}$ = 2040 is read from the graph and $\dfrac{I_1 + I_2}{2}\, t = \dfrac{70 + 160}{2}\, t$ = 115 cumec – $\frac{1}{4}$ day is added to get $S + \dfrac{Ot}{2}$ = 2155 for which O is read as 116 cumec and pool elevation as 108.4 m. Thus the process is repeated till the flood is completely routed through the reservoir and the outflow hydrograph is obtained as shown in Fig. 9.3.

(*b*) *Flood routing by modified Puls method*: Corresponding to the initial pool elevation of 110 m, O = 124 cumec, S = 2270 cumec – $\frac{1}{4}$ day, $\dfrac{2S}{t} = \dfrac{2 \times 2270 \text{ cumec} - \frac{1}{4} \text{ day}}{\frac{1}{4} \text{ day}}$ = 4540 cumec, $\dfrac{2S}{t} + O$ = 4540 + 124 = 4664 cumec and $\dfrac{2S}{t} - O$ = 4540 – 124 = 4416 cumec. Thus, for other values of O, values of $\frac{2S}{t} + O$ and $\frac{2S}{t} - O$ are computed and 'O vs. $\frac{2S}{t} + O$ and $\frac{2S}{t} - O$' curves are drawn as shown in Fig. 9.4.

Table 9.2 Reservoir routing—ISD method [Eq. 9.7] (Example 9.1)

Time (hr)	*Inflow* I (cumec)	$\frac{I_1 + I_2}{2} t$ (cumec-$\frac{1}{4}$ day)	*Outflow* O (cumec)	$S - \frac{Ot}{2}$ (cumec-$\frac{1}{4}$ day)	$S + \frac{Ot}{2}$ (cumec-$\frac{1}{4}$ day)	*Pool elevation* (m)
0	50		124			110.0
		60	+	2208	2268	
6	70		120			109.2
		115	+	2040	2155	
12	160		116			108.4
		230	+	1960	2190	
18	300		119			109.1
		380		2020	2400	
24	460		122			109.6
		500		2080	2580	
30	540		130			110.8
		525		2380	2905	
36	510		195			112.5
		475		2730	3205	
42	440		395			113.4
		385		2820	3205	
48	330		395			113.4
		290		2920	3110	
54	250		335			113.1
		220		2790	3010	
60	190		265			112.8
		170		2760	2930	
66	150		210			112.6
		135		2740	2875	
72	120		170			112.4
		105		2720	2825	
78	90		145			112.3
		85		2700	2785	
84	80		132			111.2
		75		2650	2725	
90	70		130			110.8

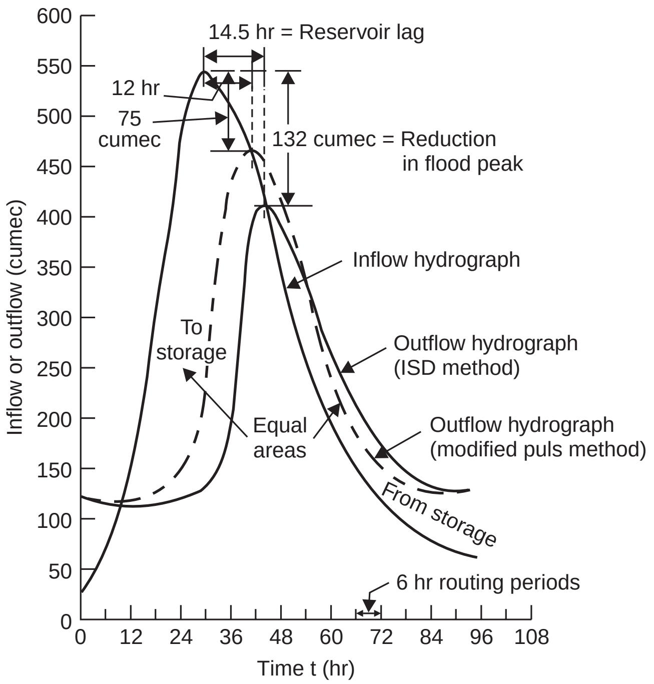

Fig. 9.3 Reservoir routing (Example 9.1)

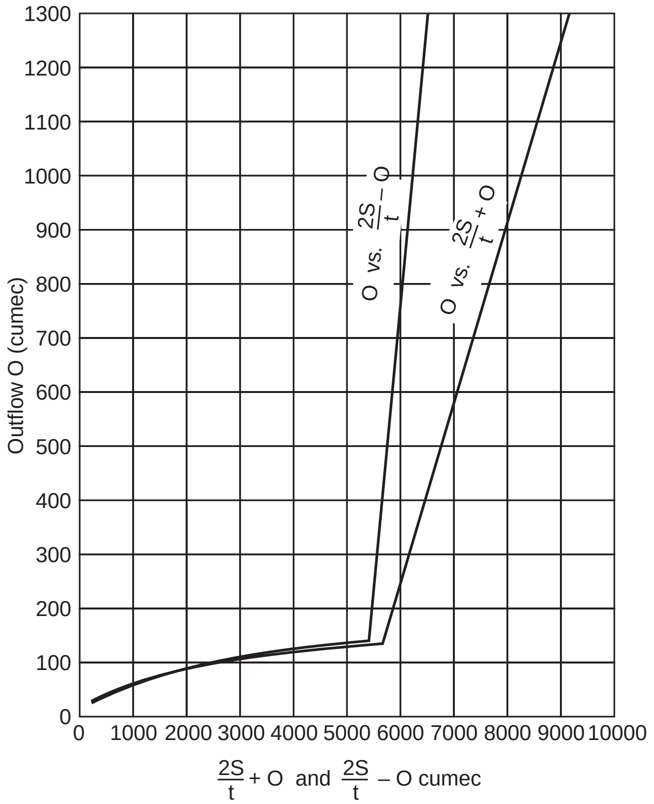

Fig. 9.4 Reservoir routing by modified Puls method (Example 9.1)

For routing the flood by the modified Puls method, Table 9.3, corresponding to the initial pool elevation of 110 m, O = 124 cumec, $\frac{2S}{t} + O$ = 4664 cumec and $\frac{2S}{t} - O$ = 4416 cumec are read off. For this $\frac{2S}{t} - O$ = 4416 cumec, $I_1 + I_2$ = 50 + 70 = 120 cumec is added to get the right hand side of Eq. (9.8), *i.e.*, $\frac{2S}{t} + O$ = 4416 + 120 = 4536 cumec. For this value of $\frac{2S}{t} + O$, O = 123 cumec, and $\frac{2S}{t} - O$ = 4290 cumec are read off from the curves. For O = 123 cumec, the pool elevation of 109.8 m is read off from the 'O vs pool elevation curve'. These values become the initial values for the next routing period. Again, for $\frac{2S}{t} - O$ = 4290 cumec, $I_1 + I_2$ = 70 + 160 = 230 cumec is added to get the right hand side of Eq. (9.8), *i.e.*, $\frac{2S}{t} + O$ = 4290 + 230 = 4520 cumec for which O and $\frac{2S}{t} - O$ values are read off and pool elevation obtained, which become the initial values for the next routing period. Thus the process is repeated till the flood is completely routed through the reservoir and the outflow hydrograph is obtained as shown in Fig. 9.3 by dashed line.

Table 9.3 Reservoir routing–modified Puls method [Eq. 9.8]. (Example 9.1)

Time (hr)	*Inflow O* (*cumec*)	$\frac{2S}{t} - O$* (*cumec*)	$\frac{2S}{t} + O$ (*cumec*)	*Outflow O* (*cumec*)	*Pool elevation* (*m*)
0	50	4416	4464	124	110.0
6	70	4290	4536	123	109.8
12	160	4276	4520	122	109.6
18	300	4482	4736	126	111.8
24	460	4986	5248	131	111.0
30	540	5506	5986	240	112.7
36	510	5696	6556	430	113.5
42	440	5716	6646	465	113.6
48	330	5666	6486	410	113.4
54	250	5586	6246	330	113.0
60	190	5526	6026	250	112.7
66	150	5466	5866	200	112.5
72	120	5436	5736	150	112.3
78	90	5476	5646	135	111.6
84	80	5278	5546	134	111.4
90	70		5428	130	110.8

$* \frac{2S}{t} - 0 = \left(\frac{2S}{t} + 0\right) - 2O$

Results.

		ISD method	*Modified Puls method*
(*i*)	Maximum pool elevn. reached	≈ 113.5 m*	113.6 m
(*ii*)	Reduction in flood peak	132 cumec	75 cumec
(*iii*)	Reservoir lag	$14\frac{1}{2}$ hr	12 hr

*To pass the crest of the outflow hydrograph.

9.2 STREAM FLOW ROUTING

In a stream channel (river) a flood wave may be reduced in magnitude and lengthened in travel time *i.e.,* attenuated, by storage in the reach between two sections. The storage in the reach may be divided into two parts-prism storage and wedge storage, Fig. 9.5, since the water surface is not uniform during the floods. The volume that would be stored in the reach if the flow were uniform throughout, *i.e.,* below a line parallel to the stream bed, is called 'prism storage' and the volume stored between this line and the actual water surface profile due to outflow being different from inflow into the reach is called 'wedge storage'. During rising stages the wedge storage volume is considerable before the outflow actually increases, while during falling stages inflow drops more rapidly than outflow, the wedge storage becoming negative.

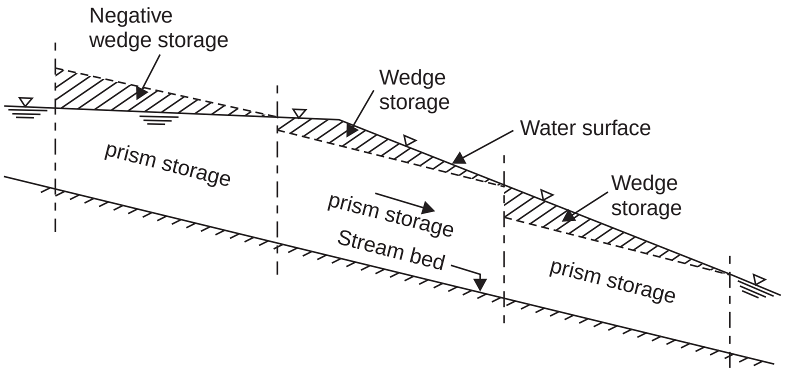

Fig. 9.5 Storage in a stream channel during a flood wave

In the case of stream-flow routing, the solution of the storage equation is more complicated, than in the case of reservoir routing, since the wedge storage is involved. While the storage in a reach depends on both the inflow and outflow, prism storage depends on the outflow alone and the wedge storage depends on the difference $(I - O)$. A common method of stream flow routing is the Muskingum method (McCarthy, 1938) where the storage is expressed as a function of both inflow and outflow in the reach as

$$S = K\,[xI + (1 - x)\,O] \qquad \text{...(9.9)}$$

where K and x are called the Muskingum coefficients (since the Eq. (9.9) was first developed by the U.S. Army Corps of Engineers in connection with the flood control schemes in the Muskingum River Basin, Ohio), K is a storage constant having the dimension of time and x is a dimensionless constant for the reach of the river. In natural riverchannels x ranges from 0.1 to 0.3. The Eq. (9.9) in most flood flows approaches a straight line. Trial values of x are assumed and plots of 'S vs. $[xI + (1 - x) O]$' are in the form of storage loops; for a particular value of x, the plot is a straight line and the slope of the line gives K. If S is in cumec-day and I, O are in cumec, K is in day.

After determining the values of K and x, the outflow O from the reach may be obtained by combining and simplifying the two equations.

$$\left(\frac{I_1 + I_2}{2}\right) t - \left(\frac{O_1 + O_2}{2}\right) t = S_2 - S_1 \qquad ...(9.10)$$

same as (9.6)

and $$S_2 - S_1 = K\,[x\,(I_2 - I_1) + (1 - x)\,(O_2 - O_1)] \qquad ...(9.11)$$

(Eq. 9.11 is the same as Eq. (9.9)); for a discrete time interval the following equation may be obtained

$$O_2 = C_0 I_2 + C_1 I_1 + C_2 O_1 \qquad ...(9.12)$$

where $$C_0 = -\frac{Kx - 0.5t}{K - Kx + 0.5t} \qquad ...(9.12\ a)$$

$$C_1 = \frac{Kx + 0.5t}{K - Kx + 0.5t} \qquad ....(9.12\ b)$$

$$C_2 = \frac{K - Kx - 0.5t}{K - Kx + 0.5t} \qquad ...(9.12\ c)$$

Combining Eq. (9.12 *a, b, c*) gives

$$C_0 + C_1 + C_2 = 1 \qquad ...(9.12\ d)$$

where t is the routing period. The routing period should be less than the time of travel for the flood wave through the reach, otherwise it is possible that the wave crest may pass completely through the reach during the routing period. Usually the routing period is taken as about 1/3 to 1/4 of the flood wave travel time through the reach (obtained from the inflow-hydrograph).

If there is a local inflow due to a tributary entering the mainstream, it should be added to I or O accordingly as it enters the reach at the upstream or downstream end, or the local inflow may be divided, a portion added to I and another portion added to O.

A number of methods have been developed for flood routing. The numerical method of solution of the routing equations is tedious but has the advantage of easy checking and filling. The Sorensen's graphical method of reservoir routing has the advantage that variable time periods can be used. Cheng's graphical method is used for stream flow routing. Quite a number of mechanical instruments, flood routing slide rules and electronic computers, etc. have been used to facilitate computations.

Example 9.2 *The inflow and outflow hydrographs for a reach of a river are given below. Determine the value of the Muskingum coefficients K and x for the reach.*

Time (hr)	0	24	48	72	96	120	144	168	192	216
Inflow (cumec)	35	125	575	740	456	245	144	95	67	50
Outflow (cumec)	39	52	287	624	638	394	235	142	93	60

Solution From the daily readings of the inflow and outflow hydrographs, a routing period t = 24 hr = 1 day is taken. The mean storage is determined from Eq. (9.10) and then the cumulative storage S is tabulated. For trial values of x = 0.2, 0.25 and 0.3, the values of $[xI + (1 - x)\,O]$ are computed in Table 9.4. Storage loops for the reach, *i.e.,* curves of S vs. $[xI + (1 - x)\,O]$ for each trial value of x are plotted as shown in Fig. 9.6. By inspection, the middle value of x = 0.25 approximates a straight line and hence this value of x is chosen. K is determined by measuring the slope of the median straight line which is found to be 0.7 day. Hence, for the given reach of the river, the values of the Muskingum coefficients are

x = 0.25, K = 0.7 day

Example 9.3 *The inflow hydrograph readings for a stream reach are given below for which the Muskingum coefficients of K = 36 hr and x = 0.15 apply. Route the flood through the reach and determine the outflow hydrograph. Also determine the reduction in peak and the time of peak of outflow.*

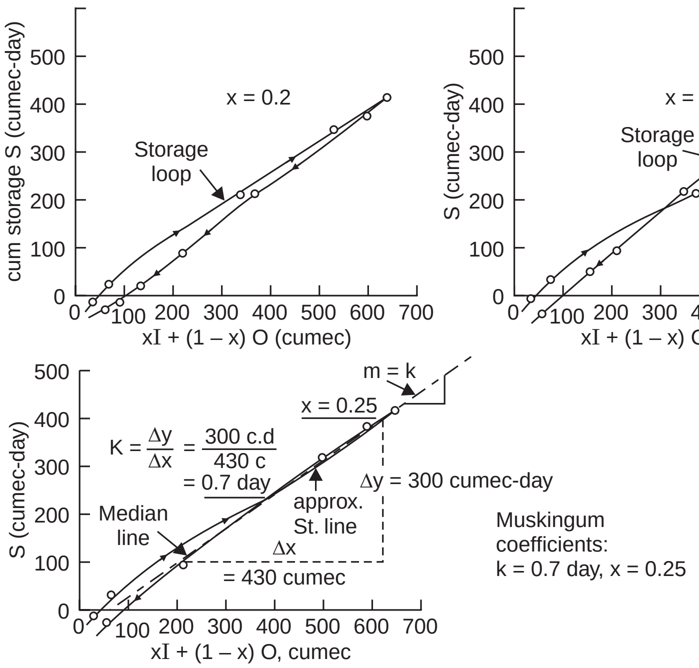

Fig. 9.6 Storage loops for the reach of the river (Example 9.2)

Outflow at the beginning of the flood may be taken as the same as inflow.

Time (hr)	0	12	24	36	48	60	72	84	96	108	120
Inflow (cumec)	42	45	88	272	342	288	240	198	162	133	110
Time (hr)	132	144	156	168	180	192	204	216	228	240	
Inflow (cumec)	90	79	68	61	56	54	51	48	45	42	

Solution Eq. 9.12: $O_2 = C_0 I_2 + C_1 I_1 + C_2 O_1$

x = 0.15, K = 36 hr = 1.5 day; take the routing period (from the inflow hydrograph readings) as 12 hr = $\frac{1}{2}$ day. Compute C_0, C_1 and C_2 as follows:

Table 9.4 Determination of the Muskingum coefficients K and x for a reach of the river. (Example 9.2)

Time (*hr*)	*Inflow* *I* (*cumec*)	*Outflow* *O* (*cumec*)	*I–O* (*cumec*)	*Mean* *storage* (*cumec-day*)	*cumulative* *storage* (*cumec-day*)	x = 0.2			X = 0.25			X = 0.3		
						0.2 *I*	0.8*O*	*Total* (*cumec*)	0.25 *I*	0.75 *O*	*Total* (*cumec*)	0.3*I*	0.7*O*	*Total* (*cumec*)
0	35	39	–4	–2	–2	7	31.2	38.2	8.75	29.25	38.0	10.5	27.3	37.8
24	125	52	73	34	32	25	41.6	66.6	31.25	39.0	70.25	37.4	36.4	73.9
48	575	287	288	180	212	115	229.6	344.6	143.75	215	358.75	172.5	200.9	373.4
72	740	624	116	202	414	148	499.2	647.2	185.0	468	653.0	222.0	436.8	658.8
96	456	638	–182	–33	381	91.2	510.4	601.6	114.0	478	592.0	136.8	446.6	583.4
120	245	394	–149	–165	216	49	315.2	364.2	61.25	295.5	356.75	73.5	275.8	349.3
144	144	235	–91	–120	96	28.8	188.0	216.8	36.0	176.3	212.3	43.2	164.5	207.7
168	95	142	–47	–69	27	19.0	113.6	132.6	23.75	101.64	125.39	28.5	99.4	127.9
192	67	93	–26	–37	–10	13.4	74.4	87.8	16.75	69.7	86.45	20.1	65.1	85.2
216	50	60	–10	–18	–28	10	48.0	58.0	12.5	45.0	57.5	15.0	42.0	57.0

$$C_0 = -\frac{Kx - 0.5t}{K - Kx + 0.5t} = -\frac{1.5 \times 0.15 - 0.5 \times \frac{1}{2}}{1.5 - 1.5 \times 0.15 + 0.5 \times \frac{1}{2}} = -\frac{-0.025}{1.525} = 0.02$$

$$C_1 = \frac{Kx + 0.5t}{K - Kx + 0.5t} = \frac{1.5 \times 0.15 + 0.5 \times \frac{1}{2}}{1.525} = 0.31$$

$$C_2 = \frac{K - Kx - 0.5t}{K - Kx + 0.5t} = \frac{1.5 - 1.5 \times 0.15 - 0.5 \times \frac{1}{2}}{1.525} = 0.67$$

Check: $C_0 + C_1 + C_2 = 0.02 + 0.31 + 0.67 = 1$

$\therefore \quad O_2 = 0.02\, I_2 + 0.31\, I_1 + 0.67\, O_1$

In Table 9.5, I_1, I_2 are known from the inflow hydrograph, and O_1 is taken as I_1 at the beginning of the flood since the flow is almost steady.

Table 9.5 Stream flow routing—Muskingum method [Eq. 9.12]. (Example 9.3)

Time (*hr*)	*Inflow* I (*cumec*)	$0.02\ I_2$ (*cumec*)	$0.31\ I_1$ (*cumec*)	$0.67\ O_1$ (*cumec*)	*Outflow* O (*cumec*)
0	42	—	—	—	42*
12	45	0.90	13.0	28.2	42.1
24	88	1.76	14.0	28.3	44.0
36	272	5.44	27.3	29.5	62.2
48	342	6.84	84.3	41.7	132.8
60	288	5.76	106.0	89.0	200.7
72	240	4.80	89.2	139.0	233.0
84	198	3.96	74.4	156.0	234.0
96	162	3.24	61.4	157.0	221.6
108	133	2.66	50.2	148.2	201.0
120	110	2.20	41.2	134.5	178.9
132	90	1.80	34.1	119.8	155.7
144	79	1.58	27.9	104.0	133.5
156	68	1.36	24.4	89.5	115.3
163	61	1.22	21.1	77.4	99.7
180	56	1.12	18.9	66.8	86.8
192	54	1.08	17.4	58.2	76.7
204	51	1.02	16.7	51.4	69.1
216	48	1.00	15.8	46.3	63.1
228	45	0.90	14.8	42.3	58.0
240	42	0.84	13.9	38.9	53.6

*O_1 is assumed equal to I_1 = 42 cumec

$\therefore \qquad O_2 = 0.02 \times 45 + 0.31 \times 42 + 0.67 \times 42 = 42.06$ cumec

This value of O_2 becomes O_1 for the next routing period and the process is repeated till the flood is completely routed through the reach. The resulting outflow hydrograph is plotted as shown in Fig. 9.7. The reduction in peak is 108 cumec and the lag time is 36 hr, *i.e.,* the peak outflow is after 84 hr (= $3\frac{1}{2}$ days) after the commencement of the flood through the reach.

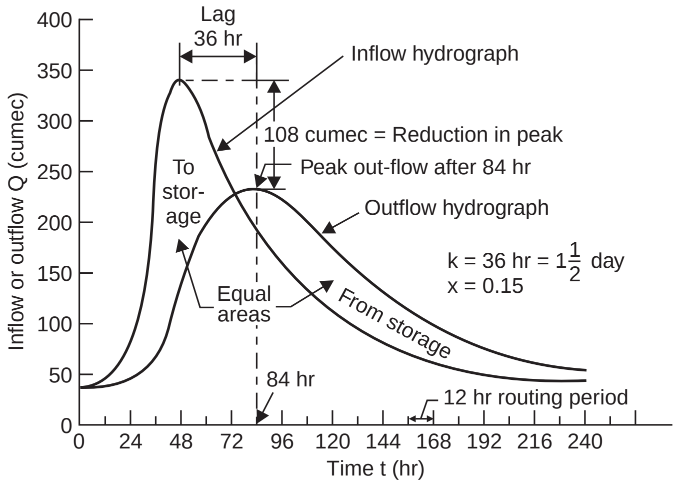

Fig. 9.7 Streamflow routing by Muskingum method (Example 9.3)

QUIZ IX

I Match the items in 'A' with the items in 'B'

A	**B**
(*i*) Flood routing	(*a*) Muskingum method
(*ii*) ISD method	(*b*) $f(I - 0)$
(*iii*) Modified Puls method	(*c*) $f(0)$
(*iv*) Stream-flow routing	(*d*) Sorensen's graphical method
(*v*) Wedge storage	(*e*) Cheng's graphical method
(*vi*) Prism storage	(*f*) $\frac{2S}{t} \pm 0$ curves
(*vii*) Reservoir routing	(*g*) $S \pm \frac{0t}{2}$ curves
(*viii*) Streamflow routing	(*h*) Outflow hydrograph

II Say 'true' or 'false', if false, give the correct statement:

(*i*) In flood routing through reservoir

Given are:

(*a*) Pool elevation vs. storage (*b*) Pool elevation vs. outflow (discharge)

(*c*) Flood hydrograph of inflow