-- Lab 1 --

Rain fall data analysis

Rain fall data analysis need in many application especially in design and planning of soil and water conservation structures .

Basic definition :

Rainfall depth (mm) : Total rainfall accumulated at a point during storm .
Rainfall intensity (mm\h) : The rate at rain is falling at any storm instant .
Return period (yr) : Probable accurence of storm of specified depth and or intensity .

Type of gauges :
1 – simple rain gauges \ gives only rainfall depth .
2 – recorder rain gauges \ gives rainfall depth and time of rain storm .

Ex. of rainfall data analysis

Tim	Tim interval (Min)	Rainfall depth (mm)	Intensity mm\h
14:30	0	0	0
14:35	5	0.5	6
16:00	85	0	0
16:30	30	0.4	0.8
17:05	35	0.9	1.54
17:10	5	2	24
17:40	30	6	12
18:55	75	0.8	0.64
	265 min	10.3 mm	

\
Column 1 \ from the chart of rain gauge .
Column 2 \ extracted from column 1 (first – second time) and second …
Column 3 \ also from the chart of rain gauge .
Column 4 \ from the following equation : I = column 3 \ column 2 *60

Im = Maximum intensity = 24 mm\h
Total time of storm (min) = 265 min =4.41
Total rainfall depth = 10.3 mm
I_{30} = maximum intensity at 30 mine mm\h = 12

No	Time (min) Acumelative	Rainfull depth (mm) Acumlative	Time interval	Rainfall depth	Intensity Mm/hr
١	0	0	٠	٠	
٢	12	5			
٣	42	11			
٤	70	25			
٥	100	35			
٦	130	40			

Calculate

Im , Total time of storm (min), Total rainfall depth , I_{30}

Intensity = (rainfull depth mm / time interval mm)* 60 = …….mm/h

-- Lab 2 --

Soil and water conservation

The rational method

The rational method is simple and theoretically sound method for peak runoff analysis . The equation presented here may be use in design of soil and water conservation structures in watershed of less than 1000 (Ha) .

Peak runoff rate is determined from :

$$q = 0.0028CiA \;. \;. \;. \;. \;. \;. \;. \;. \;. \;. \;. \;. \;. \;(1)$$

where q = design peak runoff rate m^3 / s

C = runoff coefficient

i = rainfall intensity for the design return period and for a duration equal to the time of concentration of the watershed mm \ h .

A = watershed area (Ha)

Time of concentration (Tc) : the time required for water to flow from the most remote point of the watershed to the outlet point .

$$Tc = 0.0195L^{0.77} * S^{-0.385} \;. \;. \;. \;. \;. \;. \;. \;. \;. \;. \;(2)$$

Where Tc = time of concentration in min .

L = max. length of flow (m) .

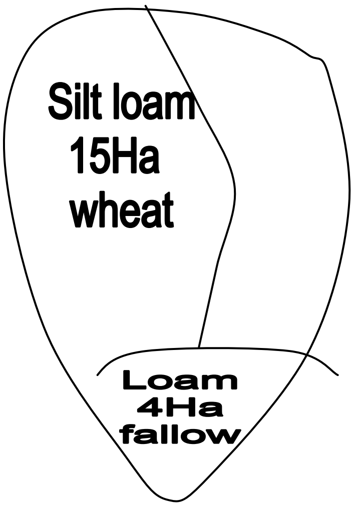
S = average watershed gradient .

The runoff coefficient (C) is the ratio of peak runoff rate to the rainfall intensity .

Enclosed are 3 tables needed to estimate(C) . In the first table soils are classified into 4 groups depending on their runoff producting potential .The second table Lists C values for different cropping systems and rainfall rate for soil group B .

The third table correct these values for other soil groups .

Ex. : The 100 yr — 6hr in Mosul is 90 mm . Determine the design peak runoff rate for the following watershed :



Maximum distante (L) = 1100 m
Average slope = 10 %

Table 4.2 Hydrologic Soil Group Conversion Factors

Cover and hydrologic condition	Factors for converting the runoff coefficient C from group B soils to[a]		
	Group A	Group C	Group D
Row crop, poor practice	0.89	1.09	1.12
Row crop, Good practice	0.86	1.09	1.14
Small grain, poor practice	0.86	1.11	1.16
Small grain, good practice	0.84	1.11	1.16
Meadow, rotation, good	0.81	1.13	1.18
Pasture, permanent, good	0.64	1.21	1.31
Woodland, mature, good	0.45	1.27	1.40

[a] Factors were computed from Table 4.3 by dividing the curve number for the desired soil group by the curve number for group B.

Table 4.3 Runoff Curve Numbers for Hydrologic Soil-Cover Complexes for Antecedent Rainfall Condition II, and $I_a = 0.2S$

Land Use or Cover	Treatment or Practice	Hydrologic Condition	*Hydrologic Soil Group A	B	C	D
Fallow	Straight row	—	77	86	91	94
Row crops	Straight row	Poor	72	81	88	91
	Straight row	Good	67	78	85	89
	Contoured	Poor	70	79	84	88
	Contoured	Good	65	75	82	86
	Terraced	Poor	66	74	80	82
	Terraced	Good	62	71	78	81
Small grain	Straight row	Poor	65	76	84	88
	Straight row	Good	63	75	83	87
	Contoured	Poor	63	74	82	85
	Contoured	Good	61	73	81	84

Table 4.3 (Continued)

Land Use or Cover	Treatment or Practice	Hydrologic Condition	*Hydrologic Soil Group A	B	C	D
Meadow (permanent)		Good	30	58	71	
Woods (farm wood-lots)		Poor	45	66	77	
		Fair	36	60	73	
		Good	25	55	70	
Farmsteads		—	59	74	82	
Roads and right-of-way (hard surface)		—	74	84	90	

*Soil Group	Description	Final infiltration Rate (mm/h)
A	*Lowest Runoff Potential.* Includes deep sands with very little silt and clay, also deep, rapidly permeable loess.	8–12
B	*Moderately Low Runoff Potential.* Mostly sandy soils less deep than A, and loess less deep or less aggregated than A, but the group as a whole has above-average infiltration after thorough wetting.	4–8
C	*Moderately High Runoff Potential.* Comprises shallow soils and soils containing considerable clay and colloids, though less than those of group D. The group has below-average infiltration after presaturation.	1–4
D	*Highest Runoff Potential.* Includes mostly clays of high swelling percent, but the group also includes some shallow soils with nearly impermeable subhorizons near the surface.	0–1

Source: U. S. Soil Conservation Service, *National Engineering Handbook, Hydrology,* Section 4 (1972) and U. S. Dept. Agr. ARS 41-172 (1970).

Table 4.1 Runoff Coefficient "C" for Agricultural Watersheds (Soil Group B)

Cover and hydrologic Condition	Coefficient C for rainfall rates of		
	25 mm/h (1 iph)	100 mm/h (4 iph)	200 mm/h (8 iph)
Row crop, poor practice	0.63	0.65	0.66
Row crop, good practice	0.47	0.56	0.62
Small grain, poor practice	0.38	0.38	0.38
Small grain, good practice	0.18	0.21	0.22
Meadow, rotation, good	0.29	0.36	0.39
Pasture, permanent, good	0.02	0.17	0.23
Woodland, mature, good	0.02	0.10	0.15

Source: Horn and Schwab (1963).

-- Lab 3 --

Direct runoff analysis

Data from gauged watersheds in the U.S showed the following basic relationship between rainfall and runoff :

$$\frac{P - Ia - Q}{S} = \frac{Q}{P - Ia} \qquad \text{- - - - - --(1)}$$

Where P = Precipitation from the storm being analyzed .

Ia = Precipitation abstraction .

Q = Total runoff .

S = Max. potential difference between P and Q at the beginning of the storm .

Equation 1 may be written as :

$$Q = \frac{(P - Ia)^2}{P - Ia + S} \qquad \text{- - - - - - - - - - - - - - - (2)}$$

Data also showed that :

$$Ia = 0.2\,S \qquad \text{- - - - - - - - - - - - - - - - - - -(3)}$$

Hence :

$$Q = \frac{(P - 0.2\,S)^2}{P + 0.8\,S} \qquad \text{- - - - - - - - - - - - - - - - (4)}$$

For convenience , an orbitrary quantity called curve number " CN " was chosen such that :

$$CN = \frac{25400}{S + 254} \qquad \text{- - - - - - - - - - - - - - - - - -(5)}$$

Where S is measured in (mm)

When S ⟶ % , CN⟶ 0 which means there is no runoff .

When S ⟶ 0 , CN⟶ % and all rainfall becomes runoff in an ideal situation .

Selection of a curve number (CN)

The 1st watershed factor affecting CN is soil type . Soils varies from group A with the lowest runoff potential to group D with the highest runoff potential .

The 2nd factor is the antecedent soil moisture condition or AMC.

AMC is classified as follow :

AMC – I : Soils are dry but moisture is above the wilting point .

AMC – II : Average condition usually precedes the occurrence of the max. annual flood .

AMC – III : Soils are nearly saturated .

EX . The 50 yr - 24 h storm in Mosul is 80 mm . Calculate total runoff for the three conditions of soil moisture . Mosul soil is clay loam .

(assuming good pasture) .

Table 4.4 Antecedent Rainfall Conditions and Curve Numbers (for $I_a = 0.2S$)

Curve Number for Condition II	*Factor to Convert Curve Number for Condition II to*	
	Condition I	*Condition III*
10	0.40	2.22
20	0.45	1.85
30	0.50	1.67
40	0.55	1.50
50	0.62	1.40
60	0.67	1.30
70	0.73	1.21
80	0.79	1.14
90	0.87	1.07
100	1.00	1.00

Table 4.2 Hydrologic Soil Group Conversion Factors

Cover and hydrologic condition	Factors for converting the runoff coefficient C from group B soils to*		
	Group A	Group C	Group D
Row crop, poor practice	0.89	1.09	1.12
Row crop, Good practice	0.86	1.09	1.14
Small grain, poor practice	0.86	1.11	1.16
Small grain, good practice	0.84	1.11	1.16
Meadow, rotation, good	0.81	1.13	1.18
Pasture, permanent, good	0.64	1.21	1.31
Woodland, mature, good	0.45	1.27	1.40

* Factors were computed from Table 4.3 by dividing the curve number for the desired soil group by the curve number for group B.

(2)

Table 4.3 Runoff Curve Numbers for Hydrologic Soil-Cover Complexes for Antecedent Rainfall Condition II, and $I_a = 0.2S$

Land Use or Cover	Treatment or Practice	Hydrologic Condition	*Hydrologic Soil Group			
			A	B	C	D
Fallow	Straight row	—	77	86	91	94
Row crops	Straight row	Poor	72	81	88	91
	Straight row	Good	67	78	85	89
	Contoured	Poor	70	79	84	88
	Contoured	Good	65	75	82	86
	Terraced	Poor	66	74	80	82
	Terraced	Good	62	71	78	81
Small grain	Straight row	Poor	65	76	84	88
	Straight row	Good	63	75	83	87
	Contoured	Poor	63	74	82	85
	Contoured	Good	61	73	81	84
	Terraced	Poor	61	72	79	82
	Terraced	Good	59	70	78	81
Close-seeded legumes or rotation meadow	Straight row	Poor	66	77	85	89
	Straight row	Good	58	72	81	85
	Contoured	Poor	64	75	83	85
	Contoured	Good	55	69	78	83
	Terraced	Poor	63	73	80	83
	Terraced	Good	51	67	76	80
Pasture or range		Poor	68	79	86	89
		Fair	49	69	79	84
		Good	39	61	74	80
	Contoured	Poor	47	67	81	88
	Contoured	Fair	25	59	75	83
	Contoured	Good	6	35	70	79

Table 4.3 (Continued)

Land Use or Cover	Treatment or Practice	Hydrologic Condition	*Hydrologic Soil Grou		
			A	B	C
Meadow (permanent)		Good	30	58	71
Woods (farm wood-lots)		Poor	45	66	77
		Fair	36	60	73
		Good	25	55	70
Farmsteads		—	59	74	82
Roads and right-of-way (hard surface)		—	74	84	90

*Soil Group	Description	Final infiltrat Rate (mm/l
A	*Lowest Runoff Potential.* Includes deep sands with very little silt and clay, also deep, rapidly permeable loess.	8–12
B	*Moderately Low Runoff Potential.* Mostly sandy soils less deep than A, and loess less deep or less aggregated than A, but the group as a whole has above-average infiltration after thorough wetting.	4–8
C	*Moderately High Runoff Potential.* Comprises shallow soils and soils containing considerable clay and colloids, though less than those of group D. The group has below-average infiltration after pre-saturation.	1–4
D	*Highest Runoff Potential.* Includes mostly clays of high swelling percent, but the group also includes some shallow soils with nearly impermeable sub-horizons near the surface.	0–1

Source: U. S. Soil Conservation Service, *National Engineering Handbook, Hydrology*, Se (1972) and U. S. Dept. Agr. ARS 41-172 (1970).

The rational method is developed from the assumptions that: (1) r occurs at uniform intensity for a duration at least equal to the time of co tration of the watershed, and (2) rainfall occurs at a uniform intensity ov entire area of the watershed. If these assumptions were fulfilled, the rainfa runoff for the watershed would be represented graphically by Fig. 4.3a figure shows a rain of uniform intensity for a duration equal to the ti concentration, T_c. If a storm of duration greater than T_c occurred, the r rate would be less than q because the rainfall intensity would be less than Chapter 2 for relationships between rainfall intensity and duration). A r

-Lab 4-

Soil and water conservation planning needs an estimate for the amount of erosion occuring in the field . The mathematical formula used to predict erosion are called *MODEL*.

The most common water erosion model is the Universal Soil Loss Equation (USLE) which covers all geographic region and can be applied in addition to agricultural field areas to estimate the soil loss from cultivated , forest , and range lands using the following formula :

A = R * K * L * S * C * P .

Where :

A = Mean annual soil loss t / ha. / yr

R= Rainfall – runoff erosivity factor .

K = Soil erodibility factor

L = Slope length factor.

S= Slope steepness factor.

C= cropping system and soil management factor.

P = Supporting practices factor. 2

Threrfore ,we can use the Universal Soil Loss Equation (USLE) to predicts the long-term average annual rate of water erosion (A) on a field slope based on rainfall pattern (R) , soil type (K) , topography factor (LS) , crop system and management practices (C) with supporting engineering practices factor (P).

-Lab 5-

Rainfall – runoff erosivity factor

R

The simplist method used to estimate the R-factor is using the modified Fourneir Index model , which expressed by the following formula:

$$R = 0.0302 \left(\frac{\Sigma^{n} Pi^{2}}{P} \right)^{1.93}$$

R= Rainfall – runoff erosivity factor .

Pi = Average monthly rainfall depth (mm).

P = Average annual rainfall depth (mm).

n = number of rainy months

Ex: Calculte the rainfall erosivity factor (R) for Mosul city during the following rainy months were :

Month	**Oct.**	**Nov.**	**Dec.**	**Jan.**	**Feb.**	**Mar.**	**Apr.**	**May**
Rainstorm (mm)	**10**	**18**	**20**	**20**	**40**	**25**	**10**	**5**

$$R = 0.0302 \left(\frac{\Sigma^n \quad Pi^2}{P} \right)^{1.93}$$

$$R = 0.0302 \left(\frac{10^2 + 18^2 + 20^2 + 20^2 + 40^2 + 25^2 + 10^2 + 5^2}{10 + 18 + 20 + 20 + 40 + 25 + 10 + 5} \right)^{1.93}$$

$$R = 0.0302 \left(\frac{3573}{148} \right)^{1.93}$$

$$R = 0.0302 \left(24.15 \right)^{1.93}$$

$$R = 0.0302 * 461.1$$

$R = 13.92$ metric unit

-Lab 6-

Soil Erodibility Factor factor

K

Soil Erodibility (K - factor) in the Universal Soil Loss Equation (USLE) represents the susceptibility of the soil to the erosion process. The soil erodibility factor (K), which depends on properties involved

1- Particle size distribution of (% Sand ,% very fine sand , and %silt)

2- % Soil organic matter

3- Soil structure

4- Soil permeability

All the above soil properties were collected in to special curves called erodibility - nomgraph which was publishid by Wischmeier and Smith (1978)

From this nomograph we can conludede that the soil erodibility depend mainly on the three soil physical proerties (texture , structure and permeability) with one soil chemical (% organic matter). Many studies showed that the soil texture is the main factor which dtermined the suspility of soil to water erosion. The following table lists the values of K-factor from the fine soil texture (higher erodibility) to more coarser textures soils (lower erodibility).

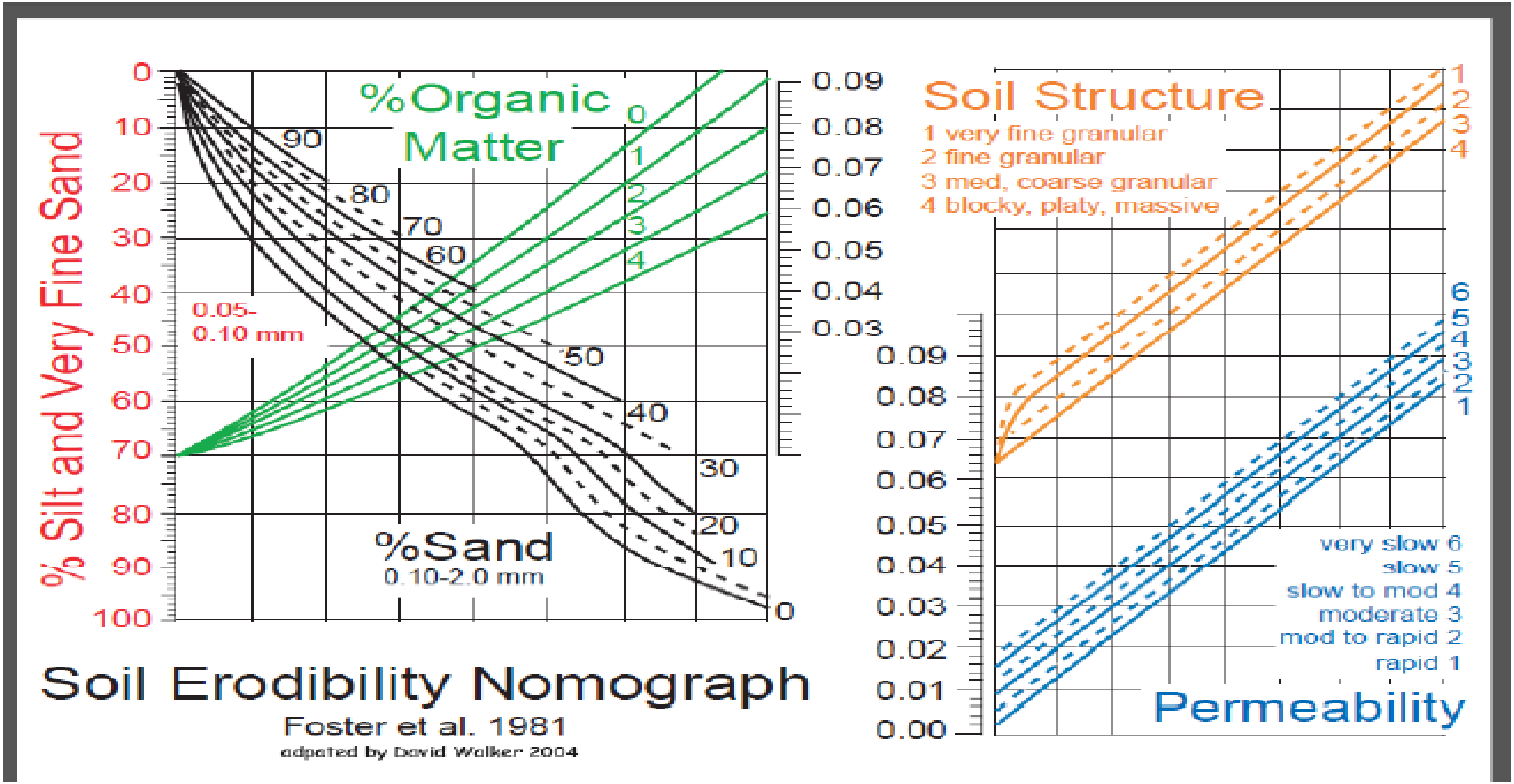


Fig ( ): Nomograph for k-factor calculation

-- Lab 7 --

The Topographic Factor

The Topographic Factor includes the effect of slope length and slope gradient .

Slope length : The distance from the point of origin of over land flow to the point the point ether the slope gradient decreases enough that deposition begins , or the runoff water enters a well defined channel .
Slope gradient : The sine of the slope angle .
Uniform slope : The slope of nearly constant gradient .

LS factor is estimated from :

$$LS = \left(\frac{\lambda}{22.1} \right)^{m} \left(65.41 \, Sin^{2}\Theta + 4.56 \, Sin \, \Theta + 0.065 \right)$$

Where λ = slope length (m) .

Θ = angle of slope .

m = 0.5 if the percent slope is 5 or more , 0.4 on slope of 3.5 to 4.5 percent , 0.3 on slope of 1 – 3 percent and 0.2 on slope of less than 1 % .

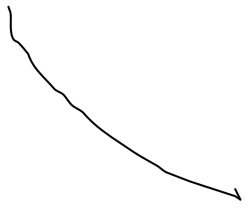
Irregular slope : many filed slopes either steep on toward the lower end (concave slope).

The following procedure is used to obtain LS for irregular slopes :

1 – divide the irregular slope into equal length segments . slopes of these segment is assumed uniform .
2– Lists the segment gradients in the order in which they accure on the slope , beginning at the upper end .
3 – Estimate LS using the above equation for each segment .substitute total slope length for L .
4 – Multiply LS factors in 3 by the corresponding factor from :eg . mention below
5 – Add the values in 4 to obtain total slope length .

Ex : Determine the LS factor for the adjacent slope:

0.15



0.11

segment	slope	LS	factor	product
1	0.14	2	0.35	0.7
2	0.12	1.56	0.65	1
				1.7

ملاحظة / يتخلل بين كل محاضرة وأخرى تطبيق عملي لحل المسائ