United States
Department of
Agriculture

**Soil
Conservation
Service**

Hydrology Training Series

Module 206 A - Time of Concentration

Study Guide

Engineering
Hydrology Training Series
Module 206A

Time of Concentration

National Employee Development Section
Soil Conservation Service
United States Department of Agriculture
March 1990

Preface

This module consists of a study guide which contains step by step procedures for calculating time of concentration from given field data.

Proceed through this module at your own pace. Be sure you completely understand each section before moving on. If you have questions or need help, please request assistance from your supervisor. If your supervisor cannot clear up your problems, he/she will contact the state-appointed resource person. The resource person is familiar with the material and should be able to answer any questions you may have.

Be sure to write out your answers to the included activities. This will help to reinforce your learning. After completing each activity, compare your answers with the included solution.

Acknowledgment

The design and development of this training module is the result of a concentrated effort by practicing engineers in the Soil Conservation Service. The contributions from many technical and procedural reviews have helped make this module one that will provide needed hydrology and hydraulic skills to SCS employees.

Module Description

Objectives

Upon completion of this module, the participant will be able to compute time of concentration (Tc) using the velocity approach concept (TR-55) and the simplified procedure used by SCS. Upon completion of this module, the participant should be able to perform at ASK Level 3 (Perform with Supervision).

Prerequisites

Module 101 - Introduction to Hydrology, Module 102 - Precipitation

Length

Participant should take as long as necessary to complete module. Training time for this module is approximately two hours.

Who May Take the Module

This module is intented for all SCS personnel who calculate time of concentration for a drainage area.

Method of Completion

This module is self-study, but the state or NTC should select a resource person to answer any questions that the participant's supervisor cannot handle.

Content

This module presents a step-by-step procedure for calculating the time of concentration using the velocity approach method from TR-55 and the simplified procedure used by SCS.

Contents

Introduction

The time of concentration (T_c) is the time required for a particle of water to flow from the hydraulically most distant point on a watershed to the design point in question. This definition indicates that T_c is a function of length and velocity.

This module will cover two methods for computing time of concentration. They are the velocity approach method (TR-55) and the simplified procedure found in Chapter 2 (1988 Version or later), EFM.

Velocity Approach Method

In its simplest form, the velocity approach method states:

$$T_c = T_{t1} + T_{t2} + T_{t3} + \cdots + T_{tm} \qquad (1)$$

where

T_c = time of concentration, which is the sum of various travel times

(T_t) = in each flow segment

T_t = time it takes water to move through a segment

m = number of flow segments

Also:

T_c = T_t, sheet flow + T_t, shallow conc. flow + T_t channel flow

Using this approach allows the investigator to compute travel time for each type of flow that is present. The velocity approach is explained in detail in Chapter 3, of TR-55.

Sheet Flow

Travel time for the sheet flow component of T_c can be determined using the kinematic wave theory. SCS has made some simplifying assumptions to eliminate the trial and error problems of solving the kinematic wave equation. These assumptions are as follows:

1. Rainfall intensity duration curve versus duration curve for an SCS standard rainfall distribution is a straight line on log-log paper which gives a relationship between rainfall intensity and duration.

2. Rainfall excess intensity (runoff) equals rainfall intensity, which is reasonable for impervious areas during the most intense portion of the storm.

3. The problem of varying rainfall intensity with recurrence interval should not be overlooked for detailed studies. However, for simplicity, use the 2-yr, 24 hr precipitation.

4. The effect of infiltration on travel time is minimal and can be overlooked.

5. Shallow steady uniform flow exists. Steady implies constant over time, while uniform implies constant over distance. It is assumed the depth does not exceed 0.1 ft.

6. The equation applies or can be used for all standard SCS rainfall distributions.

Therefore, the basic SCS equation for sheet flow is:

$$T_t = \frac{0.007\,(nL)^{0.8}}{(P_2)^{0.5}\,(s)^{0.4}}$$

where

T_t = sheet flow travel time, hr

n = Manning's roughness coefficient for overland flow depths

L = flow length, ft

P_2 = 2-yr, 24 hr precipitation, in

s = slope of the hydraulic grade line (slope of the land), ft/ft

The following apply when using the sheet flow equation:

1. In most watersheds the flow length is probably about 50 feet. Flow length should not exceed 300 feet. A visit to the watershed should be made to determine flow lengths.

2. The typical sheet flow Manning's "n" values are shown in Appendix A (Table 3-1, TR-55). These values were developed from erosion data by Ted Engman of the Agricultural Research Service and are discussed in ASCE-Journal of Irrigation and Drainage, 112 (January, 1986):39-53.

Shallow Concentrated Flow

When the flow length exceeds 300 feet, flow tends to concentrate in small rills or channels, where Manning's open channel flow equation applies. However, these channels are not large enough to survey. The following equation is used to calculated travel time for both shallow concentrated and open channel flow:

$$T_t = \frac{L}{3600\,V} \tag{3}$$

where

T_t = travel time, hr

L = flow length, ft

V = velocity, ft/s

3600 = conversion factor for seconds to hours

SCS has developed the following relationships for velocity and slope for two cover conditions, using Manning's equation, for use in calculating T_t for shallow concentrated flow:

$$V = \frac{1.49\, r^{2/3}\, s^{1/2}}{n} \tag{4}$$

where

r = hydraulic radius and is equal to the depth of flowfor shallow con centrated (wide rectangular) flow, ft

s = slope of the hydraulic grade line (slope of the land), ft/ft

n = Manning's roughness coefficient for open channel flow

For paved conditions: n = 0.025 r = d = 0.2 ft (depth of flow)

$$V = 20.32\, s^{1/2} \tag{5}$$

For unpaved conditions: n = 0.05
r = d = 0.4 ft (depth of flow)

$$V = 16.13\, s^{1/2} \tag{6}$$

These curves are shown in Appendix A (Figure 3-1, TR-55).

The following apply when computing the shallow concentrated flow component:

1. This procedure should be used for that portion of flow between sheet or overland flow and defined channel flow. Defined channels are visible on aerial photo and are shown as blue lines on USGS quad sheets.

2. When the channel slope is less than 0.005 ft/ft, the equations, rather than Figure 3-1, should be used.

3. Wide rectangular channel flow theory applies (hydraulic radius equals depth of flow). This means that water is flowing over the ground and may be flowing in small channels also.

4. Flow may not always be directly down the watershed slope if tillage runs across the slope. This is particularly true if terraces are present in the watershed.

Channel Flow

When the flow is concentrated in defined channels, Manning's open channel flow equation can be used to estimate velocity:

$$T_t = \frac{L}{3600\ V}$$

and

$$V = \frac{1.49\ r^{2/3}\ s^{1/2}}{n}$$

where

V = velocity, in ft/s

r = hydraulic radius = $\frac{a}{p_w} = \frac{\text{flow area}}{\text{wetted perimeter}}$, ft

s = water surface slope, ft/ft

n = Manning's roughness coefficient for open channels flow

Manning's roughness coefficient values for open channel flow can be obtained from standard references.

The following assumptions should be considered when estimating the channel flow component:

1. Bank flow velocity and channel length are the representative values to use in computing channel travel time.
2. The slope of the water surface is equal to channel slope.
3. In watersheds with storm sewers, carefully identify the appropriate flow path to estimate T_t. Storm sewers generally handle only a small portion of a large event. The rest of the flow may travel by streets, lawns etc. to the outlet.

Uses For The Velocity Approach Method

The velocity approach method for computing T_c is the most theoretically correct. This procedure should be used in large watersheds where the impact of urbanization needs to be evaluated or where a major portion of the flow is channel flow.

Activity 1

At this time, complete Activity 1 in your Study Guide to review the material just covered. After finishing the Activity, compare your answers with the solution provided. When you are satisfied that you understand the material, continue with the Study Guide text.

Activity 1

1. Define time of concentration.

2. Name the three flow components that may exist in a watershed.

3. What is the basic SCS equation for sheet flow?

4. What are the two cover types used by SCS in computing the travel time for shallow concentrated flow?

Activity 1 – Solution

1. Define time of concentration.

   The time of concentration required for a particle of water to flow from the hydraulically most distant point on the watershed to the design point in question. T_c is a function of length and velocity.

2. Name the three flow components that may exist in a watershed.

   a. Sheet flow
   b. Shallow concentrated flow
   c. Channel flow

3. What is the basic SCS equation for sheet flow?

$$T_t = \frac{0.007\ (nL)^{0.8}}{P_2^{0.5}\ s^{0.4}}$$

where: T_t = sheet flow travel time
L = flow length, ft
n = Manning's roughness coefficient
s = slope of the hydraulic gradeline
P_2 = 2-yr, 24-hr precipitation

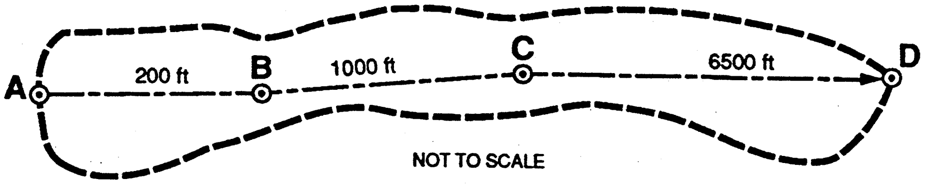
4. What are the two cover types used by SCS in computing the travel time for shallow concentrated flow?

   a. Paved
   b. Unpaved

Velocity Approach Method Example

Worksheet 3 (TR-55) will be used as the guide for manual computation of T_c in either a rural or urban watershed. Using the information provided below, complete the blank worksheet on page 11 as you go from step to step.

Your problem is to estimate T_c for a small rural watershed near Dover, Delaware. The 2-yr, 24-hr rainfall is 3.45 inches. All three types of flow occur.



Segment AB - Sheet flow exists on dense grass where the land slope is 0.01 ft/ft, and the flow length is 200 feet.

Segment BC - Shallow concentrated flow exists on unpaved conditions where land) slope is 0.01 ft/ft, and the flow length is 1000 feet.

Segment CD - Channel flow exists where Manning's n value is 0.05. The flow area of the channel is 27 ft², the wetted perimeter is 28.2 ft, the slope of the water surface is 0.004 ft/ft and the flow length is 6500 feet.

The manual calculations are as follows:

$$T_t, AB = \frac{0.007\,(nL)^{0.8}}{(P_2)^{0.5}\,(s)^{0.4}}$$

n for dense grass is obtained from Table 3-1 in Appendix A

$$T_t, AB = \frac{0.007\left[(0.24)\,(200\,ft)\right]^{0.8}}{(3.45\,in)^{0.5}\,(0.01\,ft/ft)^{0.4}}$$

$$= 0.53\ hr$$

$$T_{t,BC} = \frac{L}{3600\,V}$$

V for unpaved conditions is obtained from Figure 3-1 in Appendix A

$$T_{t,BC} = \frac{L}{3600(1.6\ ft/s)}$$

$$= 0.17\ hr$$

$$T_{t,BC} = \frac{L}{3600\ V}$$

where $V = \frac{1.49\ r^{2/3}\ s^{1/2}}{n}$ and $r = \frac{a}{p_w} = \frac{27\ ft^2}{28.2\ ft} = 0.96\ ft$

$$V = \frac{1.49(0.96\ ft)^{2/3}(0.004\ ft/ft)^{1/2}}{0.05}$$

$$= 1.83\ ft/s$$

$$T_{t,CD} = \frac{6500\ ft}{3600(1.83\ ft/s)}$$

Therefore,

$$\begin{aligned} T_c &= T_{t,AB} + T_{t,BC} + T_{t,CD} \\ &= 0.53\ hr + 0.17\ hr + 0.99\ hr \\ &= 1.69\ hr \end{aligned}$$

Compare your completed worksheet with the solution on page 11.

Activity 2

At this time, complete Activity 2 in your Study Guide to review the material just covered. After finishing the Activity, compare your answers with the solution provided. When you are satisfied that you understand the material, continue with the Study Guide text.

Worksheet 3 – Time of Concentration (Tc) or travel time (Tt)

Project I. M. Hipp By DEW Date 3/88

Location Dover, Delaware Checked MH Date 8/88

Circle one: [✓ Present] Developed

Circle one: [✓ T_c] T_t through subarea

Notes: Space for as many as two segments per flow type can be used for each worksheet. Include a map, schematic, or description of flow segments.

Flow sheet (Applicable to T_c only)	**Segment ID**	AB		
1. Surface description (table 3–1)		dense grass		
2. Manning's roughness cieff., n (table 3–1)		0.24		
3. Flow length, (total L 300 ft)	ft	200		
4. Two–yr 24–hr rainfall, P_2	in	3.45		
5. Land slope, s	ft / ft	0.01		
6. $T_t = \frac{0.007(nL)^{0.8}}{P_2^{0.5} s^{0.4}}$ Compute T_t	hr	0.53 +		= 0.53

Shallow concentrated flow	**Segment ID**	BC		
7. Surface description (paved or unpaved)		unpaved		
8. Flow length, L	ft	1000		
9. Watercourse slope. s	ft / ft	0.01		
10. Average velocity, V (figure 3–1)	ft / s	1.6		
11. $T_t = \frac{L}{3600\,V}$ Compute T_t	hr	0.17 +		= 0.17

Channel flow	**Segment ID**	CD		
12. Cross sectional flow area, a	ft^2	27		
13. Wetted permiter, p_w	ft	28.2		
14. Hydraulic radius, $r = \frac{a}{p_w}$ Compute r	ft	0.96		
15. Channel slope, s	ft / ft	0.004		
16. Manning's roughness coeff., n		0.05		
17. $V = \frac{1.48\, r^{2/3} s^{1/2}}{n}$ Compute V	ft / s	1.83		
18 Flow length, L	ft	6500		
19. $T_t = \frac{L}{3600\,V}$ Compute T_t	hr	0.99 +		= 099
20. Watershed or subarea T_c or T_t (add T_t in steps 6, 11, and 19)	hr			1.69

Source: 210-VI-TR-55, Second edition, June 1986

Activity 2

Given:

The watershed is near Dover, Delaware and is being urbanized. The urban condition T_c at the outlet is needed to determine the impact of urbanization on peak discharge. The flow path information is as follows:

Segment AB - Sheet flow exists on dense grass where the land slope is 0.01 ft/ft and the flow length is 50 feet. The 2-yr, 24-hr precipitation is 3.45 inches.

Segment BC - Shallow concentrated flow exists on paved conditions where the watercourse land slope is 0.01 ft/ft, and the flow length is 800 feet.

Segment CD - Channel flow exists in lined channel where Manning's n value is 0.035. The flow area is 30 ft^2, the wetted perimeter is 30 ft, and the water slope is 0.0047 ft/ft. Flow length is 6500 feet.

Find:

T_c, using the velocity approach method. Complete Worksheet 3. Show your computations below and on the following page.

Solution:

Worksheet 3 – Time of Concentration (Tc) or travel time (Tt)

Project ________________ By ________ Date ________
Location ________________ Checked ________ Date ________
Circle one: Present Developed ________
Circle one: T_c T_t through subarea ________

Notes: *Space for as many as two segments per flow type can be used for each worksheet. Include a map, schematic, or description of flow segments.*

Flow sheet (Applicable to T_c only) **Segment ID**

1. Surface description (table 3–1) ....
2. Manning's roughtness cieff., n (table 3–1) ....
3. Flow length, (total L 300 ft) .... ft
4. Two–yr 24–hr rainfall, P_2 .... in
5. Land slope, s .... ft / ft
6. $T_t = \frac{0.007(nL)^{08}}{P_2^{05} s^{0.4}}$ Compute T_t .... hr ☐ + ☐ = ☐

Shallow concentrated flow **Segment ID**

7. Surface description (paved or unpaved) ....
8. Flow length, L .... ft
9. Watercourse slope. s .... ft / ft
10. Average velocity, V (figure 3–1) .... ft / s
11. $T_t = \frac{L}{3600V}$ Compute T_t .... hr ☐ + ☐ = ☐

Channel flow **Segment ID**

12. Cross sectional flow area, a .... ft^2
13. Wetted permiter, p_w .... ft
14. Hydraulic radius, $r = \frac{a}{p_w}$ Compute r .... ft
15. Channel slope, s .... ft / ft
16. Manning's roughtness coeff., n ....
17. $V = \frac{148 r^{2/3} s^{1/2}}{n}$ Compute V .... ft / s
18 Flow length, L .... ft
19. $T_t = \frac{L}{3600V}$ Compute T_t .... hr ☐ + ☐ = ☐
20. Watershed or subarea T_c or T_t (add T_t in steps 6, 11, and 19) .... hr ☐

Source: 210-VI-TR-55, Second edition, June 1986

Activity 2 – Solution

Given:

The watershed is near Dover, Delaware and is being urbanized. The urban condition T_c at the outlet is needed to determine the impact of urbanization on peak discharge. The flow path information is as follows:

Segment AB - Sheet flow exists on dense grass where the land slope is 0.01 ft/ft and the flow length is 50 feet. The 2-yr, 24-hr precipitation is 3.45 inches.

Segment BC - Shallow concentrated flow exists on paved conditions where the watercourse land slope is 0.01 ft/ft, and the flow length is 800 feet.

Segment CD - Channel flow exists in lined channel where Manning's n value is 0.035. The flow area is 30 ft², the wetted perimeter is 30 ft, and the water slope is 0.0047 ft/ft. Flow length is 6500 feet.

Find:

Tc, using the velocity approach method. Complete Worksheet 3. Show your computations below and on the following page.

Solution:

Sheet flow - Segment AB

1. Surface description: dense grass
2. From Table 3-1, Appendix A: Manning's n, = 0.24
3. Flow length: L = 50 ft
4. 2-yr, 24-hr rainfall: P2 = 3.45 in
5. Land slope: s = 0.01 ft/ft
6. $$T_t = \frac{0.007\,(nL)^{0.8}}{(P_2)^{0.5}\,(s)^{0.4}} = \frac{0.007\,[(0.24)\,(50\text{ ft})]^{0.8}}{(3.45\text{ in})^{0.5}\,(0.01\text{ ft}/\text{ft})^{0.4}}$$

$$= \frac{0.007\,(7.30)}{(1.86)\,(0.16)} = 0.17\text{ hr}$$

Shallow concentrated flow - Segment BC

7. Surface description: paved

8. Flow length: L = 800 ft

9. Land slope: s = 0.01 ft/ft

10. From Figure 3-1, Appendix A, average velocity: V = 2.0 ft/s

11. $T_t = \frac{L}{3600\ V} = \frac{800\ \text{ft}}{3600\ (2.0\ \text{ft}/\text{s})}$

$$= \frac{800}{7200} = 0.11\ \text{hr}$$

Channel flow - Segment CD

12. Cross-sectional flow area: a = 30 ft^2

13. Wetted perimeter: Pw = 30 ft

14. Hydraulic radius: $r = \frac{a}{p_w} = \frac{30\ \text{ft}^2}{30\ \text{ft}} = 1.0\ \text{ft}$

15. Channel slope: s = 0.0047 ft

16. Manning's n = 0.035

17. $V = \frac{1.49\ r^{2/3}\ s^{1/2}}{n} = \frac{1.49\ (1.0\ \text{ft})^{2/3}\ (0.0047\ \text{ft})^{1/2}}{0.035}$

$$= \frac{1.49\ (1.0)\ (0.07)}{0.035} = 2.98\ \text{ft}/\text{s}$$

18. Flow length: L = 6500 ft

19. $T_t = \frac{L}{3600\ V} = \frac{6500\ \text{ft}}{3600\ (2.98\ \text{ft}/\text{s})}$

$$= \frac{6500}{10{,}728} = 0.61\ \text{hr}$$

Watershed Tc

20. $T_c = T_{t,AB} + T_{t,BC} + T_{t,CD}$

$$= 0.17\ \text{hr} + 0.11\ \text{hr} + 0.61\ \text{hr} = 0.89\ \text{hr}$$

Worksheet 3 – Time of Concentration (Tc) or travel time (Tt)

Project I. M. Hipp By DEW Date 3/88

Location Dover, Delaware Checked NPEG-I Date 8/88

Circle one: Present [✓ Developed]

Circle one: [✓ T_c] T_t through subarea

Notes: *Space for as many as two segments per flow type can be used for each worksheet.*
Include a map, schematic, or description of flow segments.

Flow sheet (Applicable to T_c only) **Segment ID**		AB		
1. Surface description (table 3–1)		dense grass		
2. Manning's roughtness cieff., n (table 3–1)		0.24		
3. Flow length, (total L 300 ft)	ft	50		
4. Two–yr 24–hr rainfall, P_2	in	3.45		
5. Land slope, s	ft / ft	0.01		
6. $T_t = \frac{0.007(nL)^{0.8}}{P_2^{0.5}\ s^{0.4}}$ Compute T_t	hr	0.17	+	= 0.17

Shallow concentrated flow **Segment ID**		BC		
7. Surface description (paved or unpaved)		paved		
8. Flow length, L	ft	800		
9. Watercourse slope. s	ft / ft	0.01		
10. Average velocity, V (figure 3–1)	ft / s	2.0		
11. $T_t = \frac{L}{3600\,V}$ Compute T_t	hr	0.11	+	= 0.11

Channel flow **Segment ID**		CD		
12. Cross sectional flow area, a	ft^2	30		
13. Wetted permiter, p_w	ft	30		
14. Hydraulic radius, $r = \frac{a}{p_w}$ Compute r	ft	1		
15. Channel slope, s	ft / ft	0.0047		
16. Manning's roughness coeff., n		0.035		
17. $V = \frac{1.48\,r^{2/3}\,s^{1/2}}{n}$ Compute V	ft / s	2.92		
18 Flow length, L	ft	6500		
19. $T_t = \frac{L}{3600\,V}$ Compute T_t	hr	0.62	+	= 062
20. Watershed or subarea T_c or T_t (add T_t in steps 6, 11, and 19)	hr			0.90

Source: 210-VI-TR-55, Second edition, June 1986

Simplified Procedure

If the watershed is rural, less than 2000 acres in size, and the impact of urbanization will not be evaluated, a simplified method of estimating T_c can be used.

This computed T_c will be used in the design of on-farm conservation practices or in the computation of peak discharge in Chapter 2 (1988 Version or later), EFM:

$$T_c = \frac{\ell^{0.8}\left(\frac{1000}{CN} - 9\right)^{0.7}}{1140\,Y^{0.5}}$$

where

Tc = the time of concentration, hr

ℓ = flow length, ft

CN = curve number

Y = average watershed slope, %.

The average watershed slope (Y), which is the slope of the land and not the watercourse, is available at most field office locations from soil survey data or topographic maps. The individual land slope can be measured with a hand level in the direction of overland flow. The average watershed slope is a simple arithmetic average of individual land slopes.

Flow length (ℓ) is the longest flow path in the watershed from the watershed divide to the outlet. It is the path water travels on the way to the outlet. The flow length can be determined either by using a map wheel or by marking along the edge of a paper, then comparing this with the map scale to get feet.

This T_c equation has been incorporated into the graphs in Chapter 2, (1988 Version or later), EFM, as the suggested method for computing T_c where the chapter applies. The following limitations apply when using the simplified T_c equation:

1. The watershed must be rural and have less than 10% urban land use.
2. The drainage area of the watershed should be less than 2000 acres.
3. The weighted CN should be between 40 and 95. If it is outside these limits, use the velocity approach method to compute T_c.
4. The average watershed slope should be between 0.5 and 64 percent. If outside these limits, use the velocity approach method to compute T_c.

5. The hydraulic flow length should be greater than 100 ft and less than 15,000 ft. If it is outside these limits, use the velocity method to compute T_c.

6. The watershed may have only one main stream.

Example

For a 90 acre field on I. M. Hipp farm, compute T_c using the equation from Chapter 2 (1988 Version or later), EFM. The curve number is 78, the flow length is 3400 ft, and the average watershed slope is 1%. The watershed is 90 ac and is in rural conditions. The rainfall distribution is Type II.

Solution

The given data is transferred to Worksheet 206A. Then, the formula provided was used to compute T_c. Spend enough time reviewing Worksheet 206A-1 to be sure you fully understand the procedure.

Example

Worksheet 206A-1 EstimatingTime of Concentration
(simplified procedure)

Project I.M. Hipp By DEW Date DEW

Location Field #2 Checked MH Date MH

Practice Field Office DoverDEW

MH

1. Data:

Rainfall distribution type .... =	II	(I, IA, II, III)
Drainage area ....A =	90	ac
Runoff curve number..CN =	78	
Watershed slope ....Y =	1	%
Flow length ....ℓ =	3400	ft

2. $$T_c = \frac{\ell^{0.8}\left(\frac{1000}{CN} - 9\right)^{0.7}}{1140\,y^{0.5}} = \frac{(668.63)(2.56)}{1140(1)} = 1.5 \text{ hr}$$

Activity 3

At this time, complete Activity 3 in your Study Guide to review the material just covered. After finishing the Activity, compare your answers with the solution provided. When you are satisfied that you understand the material, continue with the Study Guide text

Activity 3

Given:

A waterway for a 100 acre drainage area is planned for the I. M. Rich farm. The average curve number is 75, flow length is 4,000 feet, and the average watershed slope is 0.5%. (Rainfall distribution type = II).

Find:

T_c, using the procedure in Chapter 2, EFM.

Solution:

Show all work on Worksheet 206A-1. When you are finished,compare your answer with the solution on the next page.

Example

Worksheet 206A-1 EstimatingTime of Concentration (simplified procedure)

Project ______________ By ____________________ Date ______________

Location ______________ Checked____________________Date ______________

Practice ______________ Field Office ______________________________

1. Data:

Rainfall distribution type	=	________	(I, IA, II, III)
Drainage area	A =	________	ac
Runoff curve number...	CN =	________	
Watershed slope	Y =	________	%
Flow length	ℓ =	________	ft

2. $$T_c = \frac{\ell^{0.8}\left(\frac{1000}{CN} - 9\right)^{0.7}}{1140\,y^{0.5}} = \frac{(\qquad)(\qquad)}{1140(\qquad)} = \text{hr}$$

Activity 3 – Solution

Given:

A waterway for a 100 acre drainage area is planned for the I. M. Rich farm. The average curve number is 75, flow length is 4,000 feet, and the average watershed slope is 0.5%. (Rainfall distribution type = II).

Find:
Tc, Using the procedure in Chapter 2, EFM.

Solution:

Show all work on Worksheet 206A-1. When you are finished, compare your answer with the solution on thist page.

Worksheet 206A-1 EstimatingTime of Concentration
(simplified procedure)

Project I.M. Hipp By DEW Date 8/87

Location Checked MH Date 8/88

Practice Waterway Field Office Dover

1. Data:

Rainfall distribution type .... =	II	(I, IA, II, III)
Drainage area ....A =	100	ac
Runoff curve number..CN =	75	
Watershed slope ....Y =	0.5	%
Flow length ....ℓ =	4000	ft

2. $$T_c = \frac{\ell^{0.8}\left(\frac{1000}{CN} - 9\right)^{0.7}}{1140\, y^{0.5}} = \frac{(761.46)(7.79)}{1140(0.71)} = 2.6\text{ hr}$$

Summary

The velocity approach method discussed in TR-55 is the most flexible and theoretical procedure available for calculating the time of concentration. This procedure can be used for rural, urban and/or urbanizing, large or small watersheds. A majority of the flow paths can be channel flow.

SCS has developed a simplified Tc equation in that could be used in small rural watersheds where only a part of the flow path is channel flow. This procedure is the back bone of Chapter 2, EFM.

The use of the velocity approach method requires that the designer visit the watershed to determine flow lengths by type and cover. This is one advantage of the velocity method.

Retain the Study Guide as a reference until you are satisfied that have mastered all methods covered. It will provide an easy review at any time if you should encounter a problem.

If you have had problems understanding the module or if you would like to take additional, related modules, contact your supervisor.

When you are satisfied that you have completed this module, remove the Certification of Completion sheet (last page of the Study Guide), fill it out, and give it to your supervisor to submit, through channels, to your State or NTC Training Officer.

Appendix A
Charts and Tables

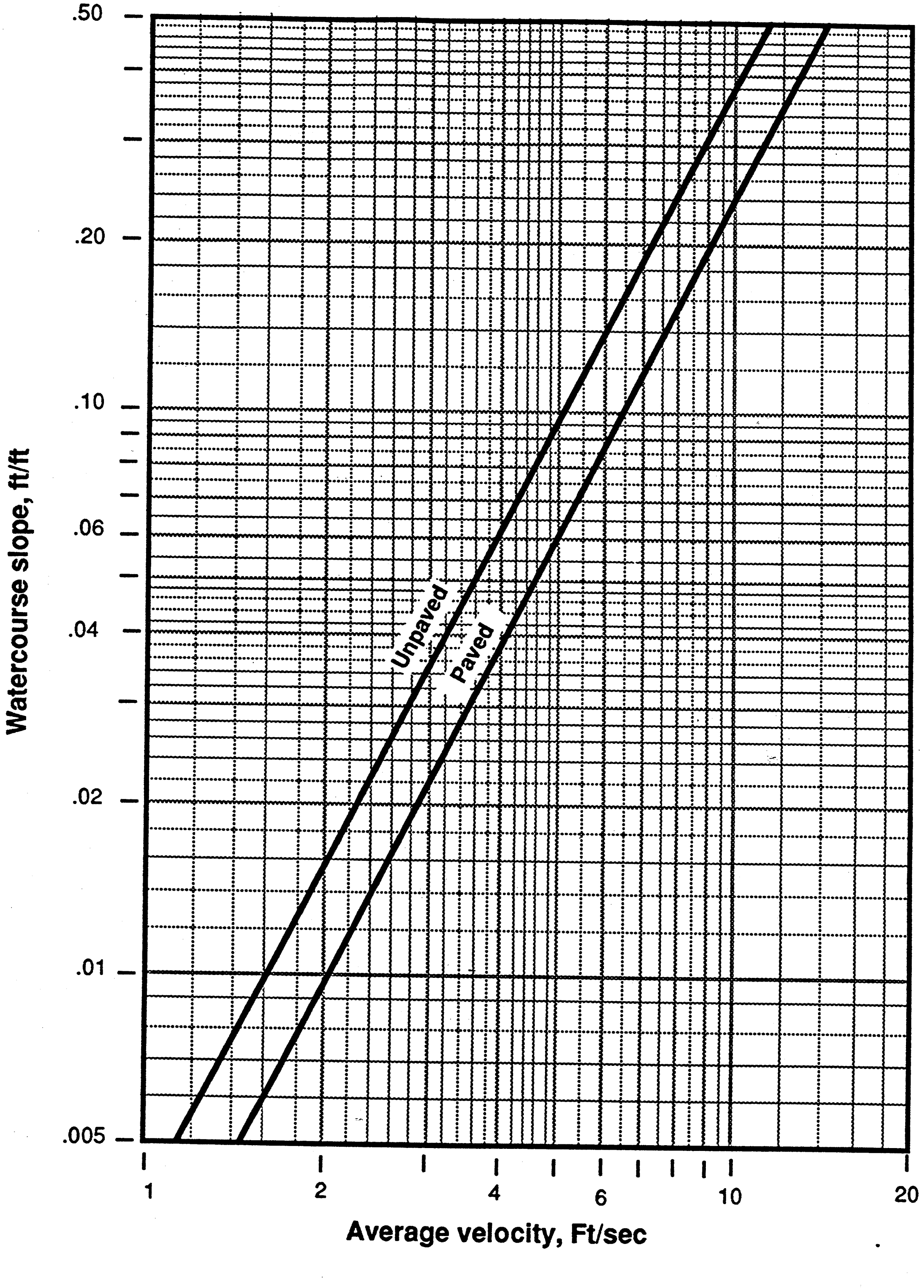


Figure 3–1 *Average velocities for estimating travel time for shallow concentrated flow.*

SOURCE: Technical Release, 210-VI-TR-55, Second Ed., June 1986

Worksheet 3 – Time of Concentration (Tc) or travel time (Tt)

Project ______________________ By ______________ Date ____________

Location ______________________ Checked ______________ Date ____________

Circle one: Present Developed ______________

Circle one: T_c T_t through subarea ______________

Notes: Space for as many as two segments per flow type can be used for each worksheet. Include a map, schematic, or description of flow segments.

Flow sheet (Applicable to T_c only) **Segment ID**

1. Surface description (table 3–1) ....
2. Manning's roughness cieff., n (table 3–1) ....
3. Flow length, (total L 300 ft) .... ft
4. Two–yr 24–hr rainfall, P_2 .... in
5. Land slope, s .... ft / ft
6. $T_t = \frac{0.007 (nL)^{08}}{P_2^{05} \, s^{0.4}}$ Compute T_t .... hr ☐ + ☐ = ☐

Shallow concentrated flow **Segment ID**

7. Surface description (paved or unpaved) ....
8. Flow length, L .... ft
9. Watercourse slope. s .... ft / ft
10. Average velocity, V (figure 3–1) .... ft / s
11. $T_t = \frac{L}{3600 V}$ Compute T_t .... hr ☐ + ☐ = ☐

Channel flow **Segment ID**

12. Cross sectional flow area, a .... ft^2
13. Wetted permiter, p_w .... ft
14. Hydraulic radius, $r = \frac{a}{p_w}$ Compute r .... ft
15. Channel slope, s .... ft / ft
16. Manning's roughness coeff., n ....
17. $V = \frac{148 \, r^{2/3} \, s^{1/2}}{n}$ Compute V .... ft / s
18 Flow length, L .... ft
19. $T_t = \frac{L}{3600 V}$ Compute T_t .... hr ☐ + ☐ = ☐
20. Watershed or subarea T_c or T_t (add T_t in steps 6, 11, and 19) .... hr ☐

Source: 210-VI-TR-55, Second edition, June 1986

Hydrology Training Series
Module 206A
Time of Concentration

CERTIFICATION OF COMPLETION

This is to certify that

____

completed Hydrology Training Series Module 206A
Time of Concentration,

on ________________ and should be credited with 1 hour of training.
Date

Signed ________________________ ________________________
Supervisor/Trainer Participant

Completion of Hydrology Training Series Module 206A
Time of Concentration, is acknowledged and documented in the above-named employee's record.

Signed ________________________ ________________________
Training Officer Date