CE 3354 Engineering Hydrology
Exercise Set 7

Exercises

Figure 1 is a Google-Earth image of some watershed. The red boundary defines the watershed; The distance on the image from Rain Gage R-1 to the Rocky Run Branch Gage is 1,500 feet.

Figure 1: Rocky Run Branch Watershed

1. Estimate the time of concentration using the Kerby-Kirpich method assuming the slope is 0.006 along the main channel (which drains to the outlet). The channel is clearly visible at the gage and running northward to the utility easement about 2/3 up the watershed. Beyond the easement use your judgment as to the channel alignment.

   Solution

An annotated Figure 1 is shown below on Figure 2. The blue line is main channel, it is approximately 4300 feet long using the R1 to Outlet distance as a reference distance. The orange lines are representative overland flow paths. The flow path near R1 to outlet is at least 1500 feet (given), so will use the 1,200 foot maximum length in Kerby-Kirpich method.

Figure 2: Rocky Run Branch Watershed, Annotated with Main Channel and Overland Paths

The overland slope would be at least equal to the channel slope (otherwise incised channel would not form) so use overland slope of 0.006.

In hydrology, when there is evidence of an incised channel, the slopes of overland areas (overland slopes) would generally be larger than the main channel slope.

Here's why:

- Incised channels often indicate that the main channel has cut downward

into the landscape, resulting in a deeper and flatter channel profile. The process of incision typically reduces the steepness of the main channel slope compared to surrounding areas.

- Overland slopes are the slopes of the land surface that drain into the channel. These areas tend to be steeper because they represent the natural terrain, which hasn't undergone the same degree of erosion and flattening as the main channel.
- Erosive processes: Overland areas experience more intense surface runoff and erosion, particularly in hilly or mountainous regions, leading to steeper slopes. In contrast, the channel, especially if incised, may have been eroded and widened over time, leading to a reduction in its gradient as it matures.

In summary, with an incised channel, the overland slopes are generally steeper than the main channel slope.

Next select a retardance somewhere between Poor Grass and Pasture (N=0.3), finally apply the Kerby-Kirpich method as depicted in Figure 3.

	A	B	C
1	Kerby-Kirpich Tc Estimator		
2			
3	--- Overland Flow Portion ---		
4	Unit Conversion, K (US)	0.828	
5	Retardance Coefficient, N	0.3	Table Look Up
6	rland Length, L_{ov}	1200	Feet
7	Slope, S	0.006	Feet/Feet
8	Tc-overland	*43.0*	Minutes
9	--- Channel Flow Portion ---		
10	Unit Conversion, K (US)	0.0078	
11	Channel Length, L_{ch}	4300	Feet
12	Channel Slope, S	0.006	Feet/Feet
13	Tc-channel	*35.1*	Minutes
14	Tc (overland+channel)	***78.1***	Minutes

Generalized Terrain Condition	N
Pavement	0.02
Smooth, bare, packed soil	0.1
Poor grass, cultivated row crops, or moderately rough packed surfaces	0.2
Pasture, average grass	0.4
Deciduous forest	0.6
Dense grass, coniferous forest, or deciduous forest with deep litter	0.8

Figure 3: Kerby-Kirpich Spreadsheet

The completed spreadsheet is located at `http://54.243.252.9/ce-3354-webroot/2-Exercises/ES-7/ES7-SourceCode/KerbyKirpich-US.xlsx`

2. Estimate the time of concentration using the NRCS-Upland method assuming the slope is 0.006 along the main channel (which drains to the outlet). The channel is clearly visible at the gage and running northward to the utility easement about 2/3 up the watershed. Beyond the easement use your judgment as to the channel alignment.

Solution

An annotated Figure 1 is shown above on Figure 2. The blue line is main channel, it is approximately 4300 feet long using the R1 to Outlet distance as a reference distance. The orange lines are representative overland flow paths. A reasonable value is to compute two times; the main channel length and the overland flow portion.

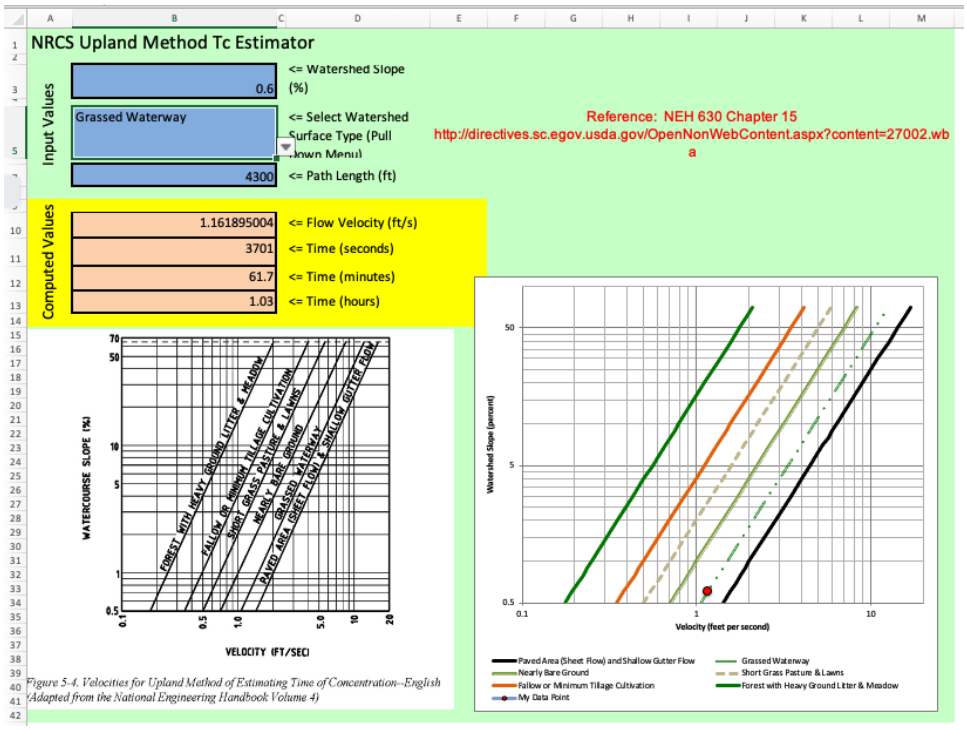

Figure 4: NRCS Overland Spreadsheet

MCL = 4300 feet; Slope =0.6%; Time = 61.7 minutes OVER = 1500 feet; Slope =0.7% (an educated guess from the image); Time = 19.9 minutes

Overall time is 81.6 minutes.

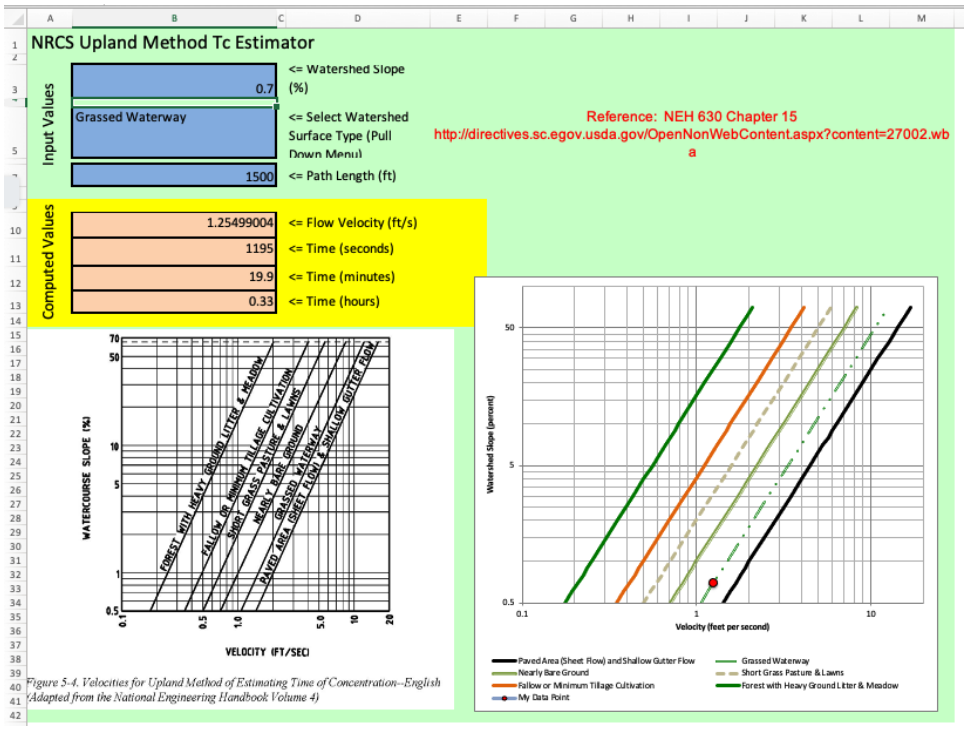

Figure 5: NRCS Overland Spreadsheet

3. Research the readings and the internet and select an additional (different) method to estimate the time of concentration – compare the three estimates and select the estimate you would choose and explain why you would make that choice.

Table 1: List of Methods to Estimate T_C

Method	Best Application	Key Parameters
Kirpich Method	Small, steep, rural watersheds	L, S
TR-55 Method	Urban/rural watersheds, mixed land use	L, S, CN
Kinematic Wave	Overland and shallow flow	n, L, P_2, S
Bransby-Williams	Watersheds with defined channels	A, L, S
Kerby-Hathaway	Small, rural watersheds	L, S
Manning's	Overland flow, especially in urban areas	n, L, P_2, S
Johnstone-Cross	Urban areas with shallow flow (pipes/gutters)	L, S
Izzard	Sheet flow over smooth/paved surfaces	L, S
FAA	Urban areas, especially airports	L, S, C

The TR-55 appears to be a good alternate method for the location, and available data. The method is summarized in Figure 6 below

2. SCS (NRCS) TR-55 Method

- **Description:** Developed by the Soil Conservation Service (now NRCS), widely used for small to medium watersheds with a mix of land uses.
- **Equation:**

$$T_c = \frac{(L^{0.8} \cdot (1000/CN - 9)^{0.7})}{1140 \cdot (S^{0.5})}$$

Where CN is the curve number, L is the flow path length (ft), and S is the slope (ft/ft).

- **Best for:** Both urban and agricultural watersheds.

Figure 6: TR-55 Method

A bit subjective, but the cover suggests a HSG A or B, probably B. The cover is pasture and woods. Using 5800 feet as an overall path length, with a CN=50. The time of concentration is 66 minutes. The method is selected as pretty simple to compare to two other simple methods.

	A	B	C	D	E	F
1	Length	5800	feet			
2	Slope	0.006	dimensionless			
3	CN	50	NRCS CN value			
4						
5	L^0.8	1025.04373				
6	(1000/CN)-9	12				
7	A6^0.7	5.69412337				
8	S^0.5	0.07745967				
9						
10	Numerator	5836.72547				
11	Denominator	88.3040203				
		66.0980718	minutes			

Figure 7: TR-55 Calculations

4. Assume the utility easment is a barrier to overland flow, and runoff can only cross at a culvert as depicted in Figure 8. The easement divides the watershed into two smaller watersheds; the upper watershed whose outlet is the culvert, and the lower watershed with same outlet as before.

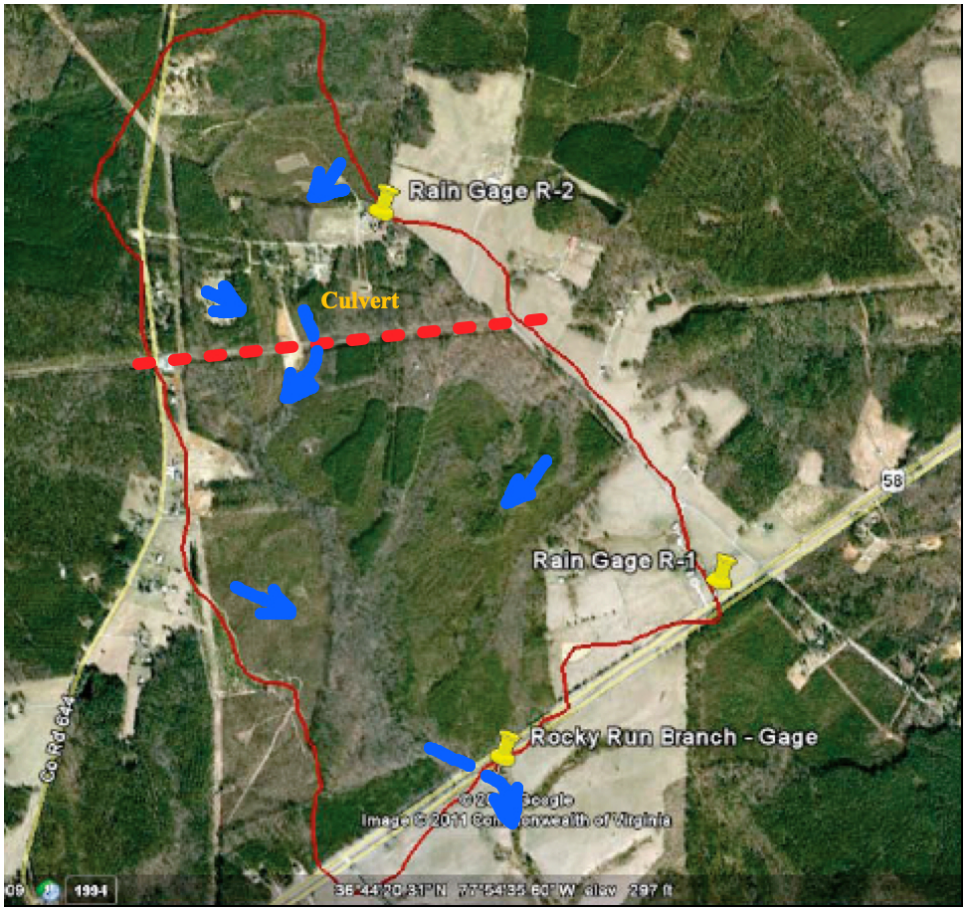

Figure 8: Rocky Run Branch Watershed - Utility Easement as Barrier

Estimate the time of concentration(s) using the three methods in both the upper and lower watershed.[1]

Solution

The main channel in the upper portion is about 1500 feet, the longest overland flow is roughly 750 feet.

The main channel in the lower portion is about 2800 feet, the longest overland flow is

[1]The SCS Reservoirs in the Hardin Creek project behave similarly in that they divide the watershed into several parts which behave independently with regards to T_C.

1500 feet.

CN both parts is about 50 (probably bigger). Apply the tools above to complete Table 2 below.

Table 2: List of Methods to Estimate T_C

Method	Length(feet)(MC+OV)	Slope	Time(minutes)
Upper Basin Kerby-Kirpich	2250	0.006	42
Lower Basin Kerby-Kirpich	4300	0.006	64
Upper Basin Overland	2250	0.006	32
Lower Basin Overlands	4300	0.006	61
Upper Basin TR-55	2250	0.006	29
Lower Basin TR-55	4300	0.006	49

To summarize the total T_C for the two-part watershed, where all flow from upper basin passes through the culvert is 106 minutes (Kerby-Kirpich); 93 minutes (NRCS Upland); 78 minutes (TR-55). All different, but roughly same order of magnitude. Such variability is typical for the various methods.