Unit Seven

SOILS, EROSION, AND RUNOFF

Introduction

Selecting effective soil erosion and sedimentation control (SESC) measures requires a working understanding of how soil properties and site conditions affect the erosion, runoff, and sediment control processes.

Soil Texture

Soil texture is one of the major factors in determining erosion, runoff, and sediment control at sites undergoing an earth change. Texture refers to the size or combination of sizes of the soil particles. The three major size categories of soil, from smallest to largest, are clay, silt, and sand. Soils consisting of 100% clay, silt, or sand are rarely found in Michigan. Generally, soils consist of varying percentages of clay, silt, and sand and names such as sandy loam, silty clay, and clay loam are used to categorize soils based on the relative percentages of clay, silt, and sand (Figure 7-1).

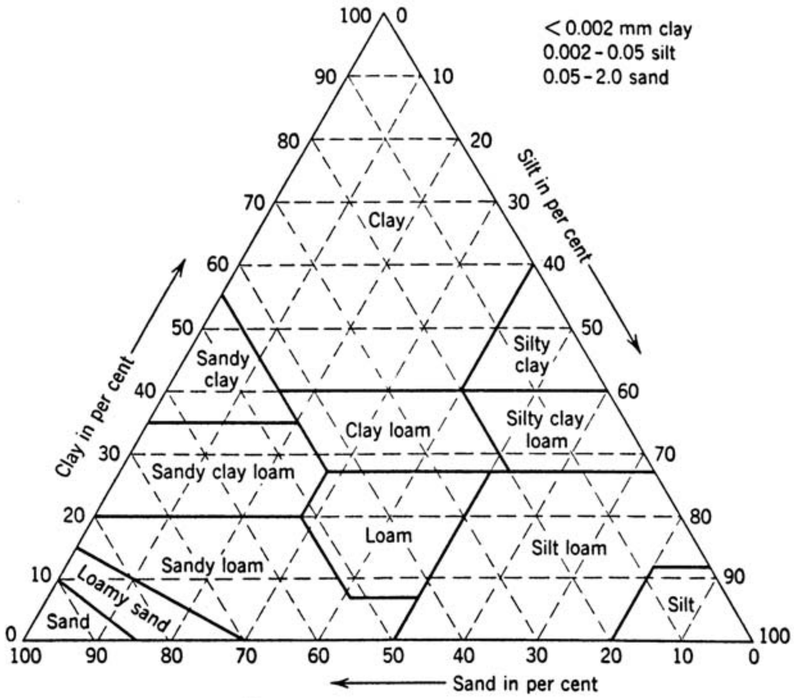


Figure 7-1: NRCS Textural Triangle

Information about the soils on a particular site can be obtained in several ways; the most common are from published soil surveys or from field inspections. Soil surveys are published on a county basis through a cooperative effort by the Natural Resources Conservation Service, the Michigan Department of Agriculture, and other federal, state, and local agencies. In addition to soil texture, information within each survey includes maps of the location of soil series within a county, a description of the soils physiochemical properties, and an evaluation of the soil's suitability to support and sustain a variety of uses and activities.

For projects which will include cuts below the level identified in soil surveys, a more detailed soils investigation may be necessary to identify soil texture at several locations at the site. Also, projects which include fill should identify the texture of the fill to be utilized.

The texture of a soil can be determined in the field by rubbing a sample between the thumb and fingers. There are three easily distinguishable extremes: sand feels gritty, silt feels floury, and clay feels smooth. For best results in identification, perform the field test in Appendix A on both dry and moist samples. Below is a partial list of common soil textures and associated properties.

Sand is a coarse textured soil. The individual grains are readily distinguished by sight and feel. Squeezed in the hand when dry, sand falls apart as soon as the hand is opened. Squeezed when moist, sand forms a cast. The shape holds as the hand opens, but crumbles when touched.

Sandy loam texture consists primarily of sand, but contains some silt and clay. Individual sand grains are, again, distinguished by sight and feel. Squeezed in the hand when dry, sandy loam falls apart once the hand is opened. Squeezed when moist, it forms a cast and holds its shape, withstanding careful handling without crumbling.

Loam consists of a mixture of sand, silt, and clay. Squeezed in the hand when dry, it forms a cast that holds its shape and withstands careful handling without crumbling. The cast formed with moist soil can be handled freely without breaking. When rolled between the hands, loam can be pointed as fine as pencil lead, but is easily broken.

Silt loam consists of a moderate amount of sand, a small amount of clay, and a large amount of silt. Either dry or moist, casts formed by squeezing can be handled freely without breaking. When a moist ball is pressed between the thumb and finger, it displays a broken appearance. When wet silt is vibrated in the hand, a surface sheen of water appears. When rolled between the hands, silt loam forms a thick, soft, easily broken thread.

Clay loam is a fine textured soil. It breaks into clods or lumps, which harden as they dry. A ball of moist soil pressed between the thumb and finger forms a thin ribbon that breaks readily, barely sustaining its own weight. Moist casts formed by squeezing withstand considerable handling. Clay loam can be formed to a pinpoint when rolled between the hands.

Clay is a very fine textured soil. It breaks into very hard clods or lumps when dry. When wet, it is plastic and sticky. A ball of moist soil pressed between the thumb and finger produces a long ribbon. When rolled between the hands, clay forms a strong, plastic thread that can be shaped to a pinpoint. Cracking of the ground surface when it dries is a good indication of high clay content in the soil.

Once the texture of a soil has been determined, an SESC planner can make certain inferences about how that soil will affect the erosion, runoff, and sedimentation processes on the construction site.

Erodibility And Erosion

Erodibility is a measure of a soil's susceptibility to raindrop impact, runoff, and other erosive forces. Soil texture is one of the major factors which determine the erodibility of a certain soil. Factors such as cohesion, structure, and compaction can also affect erodibility, even in soils with similar textures. The NRCS has assigned all soils in Michigan an erodibility status, or K factor. Higher K factors indicate a higher erodibility. In general, silty soils tend to be highly erosive, clayey and loamy soils tend to have moderate erodibility, and sandy soils generally have low erodibility (although very fine sands can also be very erodible).

The amount of any given soil that will erode through the forces of wind and water is dependent on many factors in addition to soil erodibility. Slope steepness, slope length, soil cover, soil management practices, and the intensity of wind, rainfall, or runoff also have an impact on the total amount of erosion from a site.

Potential erosion from a site is important when prioritizing Part 91 site Inspections. The NRCS' Revised Universal Soil Loss Equation (RUSLE) is one method of estimating soil loss. An online version of RUSLE is available at http://www.iwr.msu.edu/rusle.

Table 7-1 provides outputs from the RUSLE equation for estimating sheet and rill erosion from a site. Take note of how changes in individual factors can change the amount of erosion that can be expected to leave a site.

Table 7-1 Outputs from the NRCS RUSLE equation

Texture	% Slope	Slope Length (ft)	Cover	County	Soil Loss (tn/ac/yr)	Soil Loss (yd^3)
Silt Loam	**6**	**300**	**None**	**Clinton**	**62**	**54**
Sandy Loam	6	300	None	Clinton	**35**	**24**
Clay Loam	6	300	None	Clinton	**46**	**45**
Silt Loam	**1**	300	None	Clinton	**8**	**7**
Silt Loam	**12**	300	None	Clinton	**158**	**138**
Silt Loam	6	**150**	None	Clinton	**41**	**35**
Silt Loam	6	**1000**	None	Clinton	**128**	**111**
Silt Loam	6	300	**Straw***	Clinton	**7**	**6**
Silt Loam	6	300	**Dense Veg**	Clinton	**0.4**	**0.3**
Silt Loam	6	300	None	**Berrien**	**93**	**81**
Silt Loam	6	300	None	**Mackinac**	**52**	**45**

***1.5 tons/acre loose straw**

Sedimentation And Sediment Control

Although preventing soil particles from eroding is always the most effective method, preventing all erosion from occurring during an earth change is generally not feasible. Therefore, sediment control measures are often necessary to prevent damage to waterways and adjacent properties.

Once soil particles have been dislodged through the erosion process, they are transported and deposited as sediment. The properties of the soil particles that are eroded have a strong impact on when and where those particles will be deposited. The most critical of these properties is once again soil texture. Therefore, the soil texture is critical information for selecting effective sediment control measures for a site.

Physical sediment control devices such as sediment basins and silt fence are most effective on sandy soils, moderately effective on loam soils, and have little effectiveness on silt and clay soils. Therefore, an SESC plan for a site with a soil that has significant amounts of silt and clay should be heavily reliant on soil erosion measures rather than sediment control. If heavy reliance on sediment control measures is unavoidable, chemical controls (such as polyacrylamides) will be necessary to assure compliance with Part 91.

Runoff

Runoff refers to the water that runs off the land as a result of melting snow or rainfall. An accurate estimation of the location, volume, and rate of runoff on a construction site during the plan development phase is critical in determining the eventual effectiveness of planned SESC measures. In general, disturbing natural vegetation and developing a site, will increase the amount of runoff from a site, thus increasing the potential for erosion. There are three important considerations when planning for runoff from construction sites:

1. Where and how will the runoff travel on the site?
2. How much water will runoff in total?
3. How much water will be moving at any one time?

Runoff Characterization

The nature and direction by which the runoff flows is a major consideration for selecting effective SESC measures. In general, there are two different types of runoff on construction sites: Sheet flow and concentrated flow.

<u>Sheet flow</u> is the movement of water over the land’s surface at a relatively shallow and uniform depth. Almost all runoff from construction sites start as sheet flow.

Even with slight variability along slopes, sheet flows begin to accumulate, forming <u>concentrated flow</u>. Concentrated flow can be created by natural topography or human activities (ditches, berms, storm water systems, etc.). Concentrated flows move at a greater velocity and depth than sheet flows, thus creating greater erosive force on the substrate soil. Also, the more common and inexpensive SESC measures such as silt fence and loose mulch generally do not function properly in concentrated flows.

It is critical to identify the direction of sheet flow and location of concentrated flows on construction sites. One important consideration is identifying these patterns before, during, and after construction, as construction practices often change the direction of sheet flow and the location and number of concentrated flows.

It is necessary to have an accurate understanding of site topography to understand runoff patterns. For smaller, less complicated sites, this may be accomplished with a site visit. For larger or more complex sites, an accurate topographic map may be required in addition to a site visit. Runoff flows perpendicular to contour lines on a topographic map. In general, areas with low slopes and relatively straight and parallel contours are most likely to maintain sheet flows. Contours that are irregular in shape tend to represent areas where concentrated flows might form. Contour lines that come to an upslope point or curve generally represent concentrated flows. Figure 7-2 is a topographic map which represents likely to sheet and concentrated flows on a construction site.

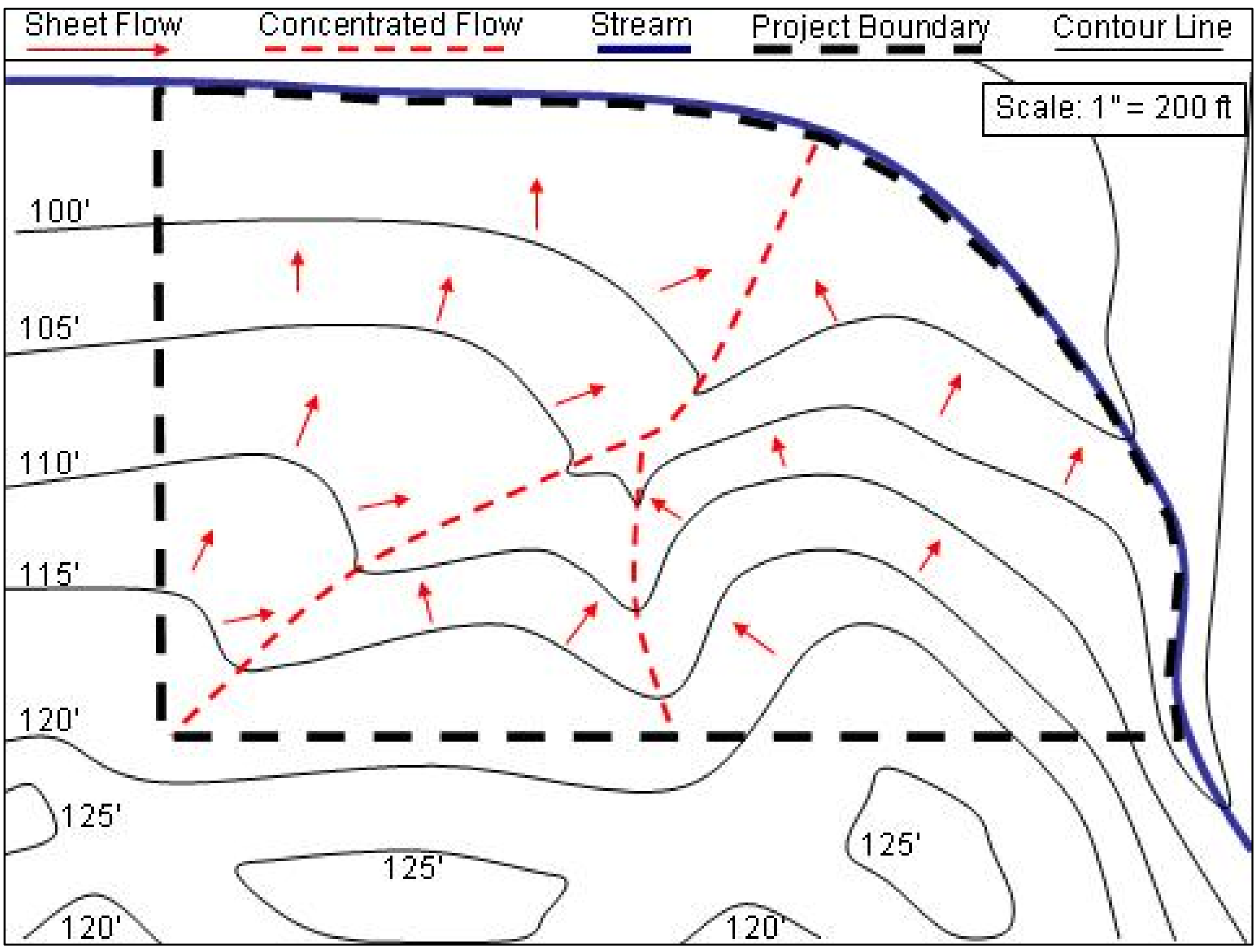


Figure 7-2: Identifying likely sheet and concentrated flow paths on a topographic map

Runoff Volume and Discharge Rate

Soil Hydrologic Group

The rate that water infiltrates into the soil and moves through the soil affects the amount and rate of runoff leaving the site. The infiltration rate is the rate at which water enters the soil at the surface and is controlled by surface conditions. The transmission rate is the rate at which the water moves through the soil and is controlled by the soil layers. In general, when the rate of infiltration and transmission through the soil is higher, the volume of runoff is lower.

As a result of low infiltration and transmission rates, fine textured soils, such as clay, produce a higher runoff volume than do coarse textured soils, such as sand. Sites having clay soils may require the construction of more elaborate drainage systems than sites having sandy soils.

Soil scientists have assigned all soils to one of four hydrologic groups based on infiltration and transmission rates (see Appendix 7B). The four hydrologic soil groups based on infiltration and transmission rates are:

1. Group A (low runoff potential): These soils exhibit high infiltration and transmission rates and low runoff volume. They are chiefly deep, well drained sands or gravel.

2. Group B: When thoroughly wet, but not saturated, these soils display moderate infiltration and transmission rates and runoff volume. They are moderately to well drained soils, generally moderate in depth, moderately fine to moderately coarse in texture, including sandy loam, loam, silt loam, and silt.

3. Group C: These soils have slow infiltration and transmission rates and high runoff volume when wet. They are distinguished by a layer that impedes downward movement of water and are moderately fine to finely textured. This group includes clay loam.

4. Group D (high runoff potential): These soils have the slowest infiltration and transmission rates and the highest runoff volume. They are chiefly clay soils with a high swelling potential or have a permanent high water table. Other characteristics may include a claypan at or near the surface and shallow soils over nearly impervious material.

The infiltration rates, transmission rates, and runoff volumes of all soils are affected by climatic conditions such as freezing. Regardless of its hydrologic soil group, all frozen soils exhibit a high runoff volume.

Surface Characteristics

The surface characteristics of a site greatly influence the volume and rate of water running off the land. Typical site development may increase the runoff volume substantially. For example, runoff will range from less than 5% or 10% of the total rainfall on heavily vegetated areas like woodlands, to nearly 100% of the rainfall for impervious surfaces like pavement.

While there is no authority to regulate storm water volume in Part 91, some communities have elected to pass regulations that limit the volume and rate of water discharged from a site to that originally discharged from the site prior to development. Controlling the discharge prevents downstream flooding brought on by urbanization of the watershed and makes on-site management and storage of storm water runoff imperative.

Development of a site normally increases the runoff volume and rate, thus increasing the potential for erosion (Figure 7-3). Therefore, vegetative and structural erosion control measures are often required to minimize any potential adverse impacts.

Table 7-2 presents land use categories, the four hydrologic soil groups, and respective runoff curve numbers (RCN) for various land use and soil group combinations. Each curve number developed by the NRCS provides an index to the potential runoff. The higher the curve number, the higher the runoff volume. When a site has several combinations of soils and/or land uses, an average curve number must be computed for the site to represent the runoff volume from the site.

Figure 7-4

Table 7-2: Runoff Curve Numbers for Selected Site Conditions

LAND USE DESCRIPTION			Hydrologic Soil Group A	B	C	D
CULTIVATED LAND:	without conservation		72	81	88	91
	with conservation		62	71	78	81
PASTURE OR RANGE LAND:	poor condition		68	79	86	89
	good condition		39	61	74	80
MEADOW:	good condition		30	58	71	78
FOREST LAND:	thin stand, poor cover		45	66	77	83
	good cover		25	55	70	77
OPEN SPACES, LAWNS, PARKS, GOLF COURSE						
	fair condition: grass on *50-75 %* of area		49	69	79	84
	good condition: grass on 75% of area		39	61	74	80
COMMERCIAL AND BUSINESS AREAS: 85% imp.			89	92	94	95
INDUSTRIAL DISTRICTS: 72% impervious			81	88	91	93
RESIDENTIAL	avg. lot size	% impervious				
	1/8 acre or less	65	77	85	90	92
	1/4 acre	38	61	75	83	87
	1/3 acre	30	57	72	81	86
	1/2 acre	25	54	70	80	85
	1 acre	20	51	68	79	84
PAVED PARKING, ROOFS, DRIVEWAYS, ETC.			98	98	98	98
STREETS AND ROADS						
	paved with curbs and storm sewers		98	98	98	98
	gravel		76	85	89	91
	dirt		72	82	87	89
WATER SURFACES (LAKES, PONDS, RESERVOIRS)			100	100	100	100
SWAMP at least 1/3 is open water			85	85	85	85
SWAMP (VEGETATED)			78	78	78	78
DEVELOPING URBAN AREAS						
	Newly graded areas (Pervious areas only, no vegetation)		77	86	91	94

Rainfall Duration and Frequency

The amount of rainfall used in estimating the potential runoff volume and discharge rate from a site is dependent on the site location and rainfall duration and frequency. Figure 7-4 provides the 24-hour Michigan rainfall values (in inches) for frequencies of 2, 5, 10, and 25 years. A 5-year rainfall, for example, is a rainfall that is expected to occur on an average of once every 5 years, or has a 20% chance of occurring in any given year. Similarly, a 25-year rainfall is a rainfall that is expected to occur on an average of once every 25 years, or has a 4% chance of occurring in any given year.

It is important to remember that rainfall frequencies are based on long-term averages. In any given year, it is possible to have multiple rain events that exceed the expected frequency. For example, two or three 25-year rainfalls could occur within the same year or even within a one or two week period. On the other hand, it is possible that it may be 50-75 years before another 25-year rainfall occurs. Remember, there is a 4% chance that a 25-year rainfall will occur in any given year.

Communities that have adopted storm water ordinances generally specify the rainfall frequency to be used in designing control structures. Where storm frequencies are not specified, three factors should be considered in selecting a design rainfall frequency: length and season of the construction period, construction cost, and the consequences of failure of an erosion or storm water control structure.

The length and season of a construction period should be considered before selecting a design storm frequency. Generally, it is not necessary to use the same storm frequency for a project lasting one month compared to one lasting two years or construction during April as opposed to August.

It is also important to consider construction costs. It is impractical to always design for the most intense rainfall event that may occur, or to set criteria for an unusually conservative frequency. The amount of rainfall expected from a 100-year storm can be double that of a 2-year storm, and would require a considerable difference in the storage volume of basins and the size of the outlet and conveyance structures. It is often recommended to design temporary controls for at least a 10-year storm.

The last factor to consider in selecting a design rainfall frequency is the evaluation of the consequences of failure for each implemented control measure. For example, consider the damage a flood would cause if a storm sewer overloads, or the consequences of the washing out of a sediment basin dike.

Rainfall Frequencies, 24-hour duration (rainfall in inches)

Numbers in parenthesis indicate the percent chance of the rainfall occurring in any given year.

Zone	2-year (50%)	5-year (20%)	10-year (10%)	25-year (4%)
1	2.39	3.00	3.48	4.17
2	2.09	2.71	3.19	3.87
3	2.09	2.70	3.21	3.89
4	2.11	2.62	3.04	3.60
5	2.28	3.00	3.60	4.48
6	2.27	2.85	3.34	4.15
7	2.14	2.65	3.05	3.56
8	2.37	3.00	3.52	4.45
9	2.42	2.98	3.43	4.09
10	2.26	2.75	3.13	3.60

Figure 7-4: Climatic Zones and Corresponding Rainfall Values

Estimating Runoff Volume and Peak Discharge

The runoff volume refers to the total amount of water that runs off a site as the result of a storm. Generally, as a site becomes more impervious, the runoff volume increases.

The depth of runoff leaving the site can be estimated using Table 7-3 which converts inches of rainfall to inches of runoff based on the runoff curve number (RCN) assigned for the site (Table 7-2). The total runoff volume is calculated by multiplying the runoff depth by the site area.

Peak discharge refers to the maximum rate at which the runoff passes a given location in terms of volume and time. It is measured in cubic feet per second (cfs) and must be determined to properly size water control structures, such as diversions and spillways.

The discharge rate is greatly influenced by the slope of the land that the water passes over, the steeper the slope, the higher the discharge rate. The "effective slope" of the site is the slope of the water path or water channel. It can be calculated by dividing the elevation difference of the site by the flow length. Flow length is the water travel distance along the main stream or water path from the site outlet point to the most distant high point on the site. Topographic maps and site plans are very useful in determining elevations and flow length.

$$\text{Effective Slope (\%)} = \frac{\text{Elevation Difference}}{\text{Flow Length}} \times 100$$

Table 7-4 is a tabular summary of unit peak discharge rates based on the effective slope and flow length. These values must be multiplied by the runoff depth (in inches) and watershed area (in acres) to determine the estimated total peak discharge rate. *This procedure is an approximate way of estimating runoff rates from small areas (less than a few hundred acres) for planning and review purposes only.*

Runoff volume and peak discharge calculations must consider all the water entering and leaving the site, not just what falls directly on the site. Therefore, one must determine the entire land area (commonly called a watershed) which contributes water to a given discharge point (Figure 7-5). As depicted in Figure 7-5, the entire "upstream" area must be included in the runoff calculations for Site "A." Runoff calculations for Site "B," however, would only include the rain that falls directly on the site because there is no "upstream" contributing area.

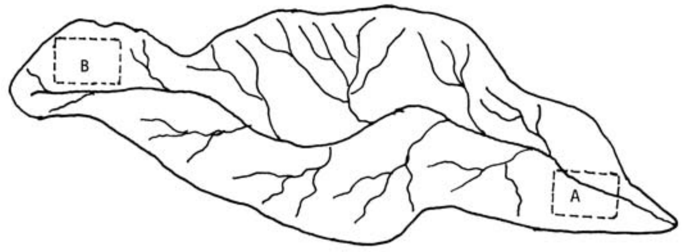


Figure 7-5: Watershed for Site A

Table 7-3: Expected Runoff Depth in Inches

Rainfall	Curve Numbers														
(Inches)	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74
1.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.02	0.02
1.1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.02	0.02	0.03	0.03	0.04	0.04
1.2	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.02	0.02	0.03	0.04	0.05	0.05	0.06
1.3	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.03	0.03	0.04	0.05	0.06	0.07	0.08	0.09
1.4	0.00	0.00	0.00	0.01	0.02	0.02	0.03	0.04	0.04	0.05	0.06	0.07	0.09	0.10	0.12
1.5	0.00	0.01	0.02	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09	0.11	0.12	0.14	0.15
1.6	0.01	0.02	0.03	0.03	0.04	0.05	0.06	0.07	0.09	0.10	0.11	0.13	0.15	0.16	0.18
1.7	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.10	0.11	0.13	0.14	0.16	0.18	0.21	0.23
1.8	0.03	0.04	0.05	0.07	0.08	0.09	0.11	0.12	0.14	0.15	0.17	0.19	0.22	0.24	0.27
1.9	0.05	0.06	0.08	0.09	0.11	0.12	0.14	0.16	0.17	0.19	0.21	0.24	0.26	0.29	0.31
2.0	0.06	0.08	0.09	0.11	0.12	0.14	0.16	0.18	0.20	0.22	0.24	0.27	0.30	0.32	0.35
2.1	0.08	0.10	0.12	0.14	0.15	0.17	0.19	0.22	0.24	0.26	0.28	0.32	0.35	0.37	0.40
2.2	0.01	0.13	0.14	0.17	0.18	0.20	0.23	0.25	0.28	0.30	0.33	0.36	0.40	0.42	0.45
2.3	0.13	0.15	0.17	0.19	0.21	0.24	0.26	0.29	0.32	0.35	0.37	0.41	0.44	0.47	0.51
2.4	0.15	0.18	0.19	0.22	0.24	0.27	0.30	0.32	0.36	0.39	0.42	0.45	0.49	0.52	0.56
2.5	0.17	0.20	0.22	0.25	0.27	0.30	0.33	0.36	0.40	0.43	0.46	0.50	0.54	0.57	0.61
2.6	0.20	0.23	0.26	0.29	0.31	0.34	0.37	0.41	0.45	0.48	0.51	0.55	0.60	0.63	0.67
2.7	0.23	0.27	0.29	0.30	0.35	0.38	0.42	0.45	0.50	0.53	0.56	0.61	0.65	0.69	0.73
2.8	0.27	0.30	0.33	0.36	0.39	0.43	0.46	0.50	0.54	0.58	0.62	0.66	0.71	0.74	0.79
2.9	0.30	0.34	0.36	0.40	0.43	0.47	0.51	0.54	0.59	0.63	0.67	0.72	0.76	0.80	0.85
3.0	0.33	0.37	0.40	0.44	0.47	0.51	0.55	0.59	0.64	0.68	0.72	0.77	0.82	0.86	0.91
3.1	0.37	0.41	0.45	0.49	0.52	0.56	0.60	0.65	0.70	0.74	0.78	0.83	0.89	0.93	0.98
3.2	0.42	0.46	0.49	0.54	0.57	0.61	0.66	0.70	0.75	0.80	0.84	0.90	0.95	0.99	1.05
3.3	0.46	0.50	0.54	0.58	0.62	0.67	0.71	0.76	0.81	0.86	0.90	0.96	1.02	1.06	1.12
3.4	0.50	0.55	0.59	0.63	0.67	0.72	0.77	0.81	0.87	0.92	0.96	1.02	1.08	1.13	1.19
3.5	0.55	0.59	0.64	0.68	0.73	0.77	0.82	0.87	0.93	0.98	1.03	1.09	1.15	1.20	1.26
3.6	0.59	0.63	0.68	0.73	0.78	0.82	0.87	0.93	0.98	1.03	1.09	1.15	1.21	1.26	1.32
3.7	0.63	0.68	0.73	0.78	0.83	0.87	0.93	0.98	1.04	1.09	1.15	1.21	1.28	1.33	0.39
3.8	0.67	0.72	0.78	0.82	0.88	0.93	0.98	1.04	1.10	1.15	1.21	1.27	1.34	1.40	1.46
3.9	0.72	0.77	0.82	0.87	0.93	0.98	1.04	1.09	1.15	1.21	1.27	1.34	1.41	1.46	1.53
4.0	0.76	0.81	0.87	0.92	0.98	1.03	1.09	1.15	1.21	1.27	1.33	1.40	1.47	1.53	1.60
4.1	0.81	0.87	0.93	0.98	1.04	1.09	1.15	1.22	1.28	1.34	1.40	1.47	1.54	1.61	1.68
4.2	0.87	0.92	0.98	1.04	1.10	1.15	1.22	1.28	1.34	1.41	1.47	1.54	1.62	1.68	1.75
4.3	0.92	0.98	1.04	1.10	1.16	1.22	1.28	1.35	1.41	1.48	1.54	1.62	1.69	1.76	1.83
4.4	0.98	1.03	1.10	1.16	1.22	1.28	1.35	1.41	1.48	1.55	1.61	1.69	1.76	1.83	1.91
4.5	1.03	1.09	1.16	1.22	1.28	1.34	1.41	1.48	1.55	1.62	1.69	1.76	1.84	1.91	1.99
4.6	1.08	1.15	1.21	1.27	1.34	1.40	1.47	1.55	1.61	1.68	1.76	1.83	1.91	1.99	2.06
4.7	1.14	1.20	1.27	1.33	1.40	1.46	1.54	1.61	1.68	1.75	1.83	1.90	1.98	2.06	2.14
4.8	1.19	1.26	1.33	1.39	1.46	1.53	1.60	1.68	1.75	1.82	1.90	1.98	2.05	2.14	2.22
4.9	1.25	1.31	1.38	1.45	1.52	1.59	1.67	1.74	1.81	1.89	1.97	2.05	2.13	2.21	2.29
5.0	1.30	1.37	1.44	1.51	1.58	1.65	1.73	1.81	1.88	1.96	2.04	2.12	2.20	2.29	2.37
5.1	1.36	1.43	1.51	1.58	1.65	1.72	1.80	1.88	1.95	2.04	2.12	2.20	2.28	2.37	2.45
5.2	1.42	1.50	1.57	1.64	1.72	1.79	1.87	1.95	2.03	2.11	2.19	2.28	2.36	2.45	2.53
5.3	1.50	1.56	1.64	1.71	1.78	1.86	1.94	2.03	2.10	2.19	2.27	2.35	2.44	2.53	2.61
5.4	1.55	1.63	1.70	1.78	1.85	1.93	2.01	2.10	2.18	2.26	2.34	2.43	2.52	2.61	2.69
5.5	1.61	1.69	1.77	1.85	1.92	2.00	2.09	2.17	2.25	2.34	2.42	2.51	2.60	2.69	2.78
5.6	1.67	1.75	1.83	1.91	1.99	2.07	2.16	2.24	2.32	2.41	2.50	2.59	2.67	2.77	2.86
5.7	1.73	1.82	1.90	1.98	2.06	2.14	2.23	2.31	2.40	2.49	2.57	2.67	2.75	2.85	2.94
5.8	1.80	1.88	1.96	2.05	2.12	2.21	2.30	2.39	2.47	2.56	2.65	2.74	2.83	2.93	3.02
5.9	1.86	1.95	2.03	2.11	2.19	2.28	2.37	2.46	2.55	2.64	2.72	2.82	2.91	3.01	3.10
6.0	1.92	2.01	2.09	2.18	2.26	2.35	2.44	2.53	2.62	2.71	2.80	2.90	2.99	3.09	3.18
6.1	2.00	2.08	2.16	2.25	2.33	2.43	2.52	2.61	2.70	2.79	2.88	2.98	3.07	3.18	3.27
6.2	2.06	2.15	2.23	2.32	2.41	2.50	2.59	2.69	2.78	2.87	2.96	3.07	3.16	3.26	3.35
6.3	2.12	2.22	2.30	2.40	2.48	2.58	2.67	2.76	2.86	2.95	3.05	3.15	3.24	3.35	3.44
6.4	2.19	2.29	2.37	2.47	2.56	2.65	2.74	2.84	2.94	3.03	3.13	3.23	3.33	3.43	3.52
6.5	2.26	2.36	2.45	2.54	2.63	2.73	2.82	2.92	3.02	3.12	3.21	3.32	3.41	3.52	3.61
6.6	2.33	2.42	2.52	2.61	2.70	2.80	2.90	3.00	3.09	3.20	3.29	3.40	3.49	3.60	3.70
6.7	2.40	2.49	2.59	2.68	2.78	2.88	2.97	3.08	3.17	3.28	3.37	3.48	3.58	3.69	3.78
6.8	2.46	2.56	2.66	2.76	2.85	2.95	3.05	3.15	3.25	3.36	3.46	3.56	3.66	3.77	3.87
6.9	2.53	2.63	2.73	2.83	2.93	3.03	3.12	3.23	3.33	3.44	3.54	3.65	3.75	3.86	3.95
7.0	2.60	2.70	2.80	2.90	3.00	3.10	3.20	3.31	3.41	3.52	3.62	3.73	3.83	3.94	4.04

Table 7-3: Expected Runoff Depth in Inches (Continued)

Rainfall (Inches)	Curve Numbers 75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90
1.0	0.03	0.04	0.05	0.06	0.07	0.08	0.10	0.12	0.13	0.15	0.17	0.20	0.23	0.26	0.29	0.32
1.1	0.05	0.06	0.08	0.09	0.11	0.12	0.14	0.16	0.16	0.18	0.22	0.25	0.29	0.32	0.36	0.39
1.2	0.07	0.09	0.10	0.12	0.13	0.15	0.17	0.20	0.22	0.25	0.27	0.31	0.35	0.38	0.42	0.46
1.3	0.10	0.12	0.14	0.16	0.18	0.20	0.23	0.25	0.28	0.30	0.33	0.37	0.41	0.46	0.50	0.54
1.4	0.13	0.15	0.17	0.20	0.22	0.24	0.27	0.30	0.33	0.36	0.39	0.43	0.48	0.52	0.57	0.61
1.5	0.17	0.19	0.22	0.24	0.27	0.29	0.32	0.36	0.39	0.43	0.46	0.51	0.55	0.60	0.64	0.69
1.6	0.20	0.23	0.26	0.28	0.31	0.34	0.38	0.41	0.45	0.48	0.52	0.57	0.62	0.66	0.71	0.76
1.7	0.25	0.28	0.31	0.33	0.36	0.39	0.42	0.44	0.47	0.49	0.52	0.59	0.65	0.72	0.78	0.85
1.8	0.29	0.32	0.35	0.38	0.41	0.44	0.48	0.52	0.57	0.61	0.65	0.71	0.76	0.82	0.87	0.93
1.9	0.34	0.37	0.40	0.44	0.47	0.50	0.55	0.59	0.64	0.68	0.73	0.79	0.84	0.90	0.95	1.01
2.0	0.38	0.42	0.45	0.50	0.52	0.56	0.61	0.66	0.70	0.75	0.80	0.86	0.92	0.97	1.03	1.09
2.1	0.43	0.48	0.51	0.56	0.58	0.63	0.68	0.73	0.77	0.82	0.88	0.94	1.00	1.05	1.12	1.18
2.2	0.49	0.53	0.57	0.62	0.65	0.69	0.75	0.80	0.84	0.90	0.95	1.02	1.08	1.14	1.20	1.27
2.3	0.54	0.59	0.63	0.67	0.71	0.76	0.81	0.87	0.92	0.97	1.03	1.09	1.16	1.22	1.29	1.35
2.4	0.60	0.64	0.69	0.73	0.78	0.82	0.88	0.94	0.99	1.05	1.10	1.17	1.24	1.31	1.37	1.44
2.5	0.65	0.70	0.75	0.79	0.84	0.89	0.95	1.01	1.06	1.12	1.18	1.25	1.32	1.39	1.46	1.53
2.6	0.71	0.76	0.82	0.86	0.91	0.96	1.02	1.09	1.14	1.20	1.26	1.33	1.41	1.48	1.55	1.62
2.7	0.77	0.83	0.88	0.93	0.98	1.03	1.10	1.16	1.22	1.28	1.34	1.42	1.49	1.56	1.64	1.71
2.8	0.84	0.89	0.95	0.99	1.05	1.11	1.17	1.24	1.29	1.36	1.43	1.50	1.58	1.65	1.72	1.80
2.9	0.90	0.96	1.01	1.06	1.12	1.18	1.25	1.31	1.37	1.44	1.51	1.59	1.66	1.73	1.81	1.89
3.0	0.96	1.02	1.08	1.13	1.19	1.25	1.32	1.39	1.45	1.52	1.59	1.67	1.75	1.82	1.90	1.98
3.1	1.03	1.09	1.15	1.21	1.27	1.33	1.40	1.47	1.53	1.61	1.68	1.76	1.84	1.91	1.99	2.07
3.2	1.10	1.16	1.23	1.28	1.35	1.41	1.48	1.55	1.62	1.69	1.76	1.85	1.93	2.00	2.09	2.17
3.3	1.17	1.24	1.30	1.36	1.42	1.49	1.56	1.64	1.70	1.78	1.85	1.93	2.02	2.10	2.18	2.26
3.4	1.24	1.31	1.38	1.43	1.50	1.57	1.64	1.72	1.79	1.86	1.94	2.02	2.11	2.19	2.27	2.36
3.5	1.32	1.38	1.45	1.51	1.58	1.65	1.72	1.80	1.87	1.95	2.03	2.11	2.20	2.28	2.37	2.45
3.6	1.39	1.45	1.52	1.59	1.66	1.72	1.80	1.88	1.95	2.04	2.11	2.20	2.28	2.37	2.46	2.54
3.7	1.46	1.52	1.60	1.66	1.74	1.80	1.88	1.96	2.04	2.12	2.20	2.29	2.37	2.46	2.55	2.64
3.8	1.53	1.60	1.67	1.74	1.81	1.88	1.96	2.05	2.12	2.21	2.29	2.37	2.46	2.56	2.64	2.73
3.9	1.60	1.67	1.75	1.81	1.89	1.96	2.04	2.13	2.21	2.29	2.37	2.46	2.55	2.65	2.74	2.83
4.0	1.67	1.74	1.82	1.89	1.97	2.04	2.12	2.21	2.29	2.38	2.46	2.55	2.64	2.74	2.83	2.92
4.1	1.75	1.82	1.90	1.97	2.05	2.13	2.21	2.30	2.38	2.47	2.55	2.64	2.73	2.83	2.93	3.02
4.2	1.83	1.90	1.98	2.05	2.14	2.21	2.29	2.38	2.47	2.56	2.64	2.73	2.83	2.93	3.02	3.11
4.3	1.90	1.98	2.06	2.14	2.22	2.30	2.38	2.47	2.56	2.65	2.73	2.83	2.92	3.02	3.12	3.21
4.4	1.98	2.06	2.14	2.22	2.30	2.38	2.47	2.56	2.65	2.74	2.82	2.92	3.01	3.12	3.21	3.30
4.5	2.06	2.14	2.23	2.30	2.39	2.47	2.56	2.65	2.74	2.83	2.92	3.01	3.11	3.21	3.31	3.40
4.6	2.14	2.22	2.31	2.38	2.47	2.55	2.64	2.73	2.82	2.91	3.01	3.10	3.20	3.30	3.40	3.50
4.7	2.22	2.30	2.39	2.46	2.55	2.64	2.73	2.82	2.91	3.00	3.10	3.19	3.29	3.40	3.50	3.59
4.8	2.29	2.38	2.47	2.55	2.63	2.72	2.82	2.91	3.00	3.09	3.19	3.29	3.38	3.49	3.59	3.69
4.9	2.37	2.46	2.55	2.63	2.72	2.81	2.90	2.99	3.09	3.18	3.28	3.38	3.48	3.59	3.69	3.78
5.0	2.45	2.54	2.63	2.71	2.80	2.89	2.99	3.08	3.18	3.27	3.37	3.47	3.57	3.68	3.78	3.88
5.1	2.53	2.62	2.72	2.80	2.89	2.98	3.08	3.17	3.27	3.36	3.46	3.56	3.67	3.78	3.88	3.98
5.2	2.62	2.71	2.80	2.88	2.98	3.07	3.17	3.26	3.36	3.46	3.56	3.66	3.76	3.87	3.97	4.07
5.3	2.70	2.79	2.89	2.97	3.06	3.16	3.26	3.35	3.45	3.55	3.65	3.75	3.86	3.97	4.07	4.17
5.4	2.78	2.88	2.97	3.06	3.15	3.25	3.35	3.44	3.54	3.64	3.74	3.85	3.95	4.06	4.16	4.27
5.5	2.87	2.96	3.06	3.15	3.24	3.34	3.44	3.54	3.64	3.74	3.84	3.94	4.05	4.16	4.26	4.37
5.6	2.95	3.04	3.14	3.23	3.33	3.42	3.52	3.63	3.73	3.83	3.93	4.03	4.14	4.25	4.36	4.46
5.7	3.03	3.13	3.23	3.32	3.42	3.51	3.61	3.72	3.82	3.92	4.02	4.13	4.24	4.35	4.45	4.56
5.8	3.11	3.21	3.31	3.41	3.50	3.60	3.70	3.81	3.91	4.01	4.11	4.22	4.33	4.44	4.55	4.66
5.9	3.20	3.30	3.40	3.49	3.59	3.69	3.79	3.90	4.00	4.11	4.21	4.32	4.43	4.54	4.64	4.75
6.0	3.28	3.38	3.48	3.58	3.68	3.78	3.88	3.99	4.09	4.20	4.30	4.41	4.52	4.63	4.74	4.85
6.1	3.37	3.47	3.57	3.67	3.77	3.87	3.97	4.08	4.18	4.29	4.40	4.51	4.62	4.73	4.84	4.95
6.2	3.45	3.56	3.66	3.76	3.86	3.96	4.06	4.17	4.28	4.39	4.49	4.60	4.71	4.82	4.93	5.04
6.3	3.54	3.64	3.75	3.85	3.95	4.05	4.16	4.27	4.37	4.48	4.59	4.70	4.81	4.92	5.03	5.14
6.4	3.63	3.73	3.84	3.94	4.04	4.14	4.25	4.36	4.47	4.58	4.68	4.79	4.90	5.01	5.13	5.24
6.5	3.72	3.82	3.93	4.03	4.13	4.24	4.34	4.45	4.56	4.67	4.78	4.89	5.00	5.11	5.23	5.34
6.6	3.80	3.91	4.01	4.11	4.22	4.33	4.43	4.54	4.65	4.76	4.87	4.98	5.10	5.21	5.32	5.43
6.7	3.89	4.00	4.10	4.20	4.31	4.42	4.52	4.63	4.75	4.86	4.97	5.08	5.19	5.30	5.42	5.53
6.8	3.98	4.08	4.19	4.29	4.40	4.51	4.62	4.73	4.84	4.95	5.06	5.17	5.29	5.40	5.52	5.63
6.9	4.06	4.17	4.28	4.39	4.49	4.60	4.71	4.82	4.94	5.05	5.16	5.27	5.38	5.49	5.61	5.72
7.0	4.15	4.26	4.37	4.47	4.58	4.69	4.80	4.91	5.03	5.14	5.25	5.36	5.48	5.59	5.71	5.82

TABLE 7-4: Unit Peak Discharge
cfs/acre/inch of runoff depth

Slope percent	Flow Length (feet)													
	200	300	400	500	600	800	1000	1500	2000	2500	3000	4000	5000	6000
0.10	1.46	1.37	1.21	1.07	0.99	0.85	0.76	0.61	0.51	0.45	0.39	0.33	0.23	0.20
0.15	1.46	1.45	1.33	1.20	1.08	0.95	0.85	0.68	0.58	0.51	0.45	0.37	0.33	0.24
0.20	1.46	1.46	1.39	1.28	1.17	1.02	0.90	0.74	0.63	0.55	0.50	0.41	0.36	0.32
0.25	1.46	1.46	1.44	1.34	1.24	1.07	0.97	0.78	0.67	0.59	0.53	0.44	0.38	0.34
0.30	1.46	1.46	1.46	1.39	1.29	1.11	1.01	0.82	0.70	0.63	0.56	0.47	0.41	0.36
0.35	1.46	1.46	1.46	1.42	1.33	1.17	1.04	0.85	0.73	0.65	0.59	0.49	0.43	0.38
0.40	1.46	1.46	1.46	1.45	1.37	1.21	1.07	0.88	0.76	0.67	0.61	0.51	0.45	0.39
0.50	1.46	1.46	1.46	1.46	1.42	1.28	1.14	0.93	0.81	0.71	0.65	0.54	0.48	0.43
0.75	1.46	1.46	1.46	1.46	1.46	1.38	1.27	1.03	0.89	0.80	0.72	0.62	0.54	0.49
1.00	1.46	1.46	1.46	1.46	1.46	1.44	1.34	1.09	0.97	0.86	0.78	0.67	0.59	0.53
1.50	1.46	1.46	1.46	1.46	1.46	1.46	1.43	1.23	1.06	0.95	0.87	0.75	0.66	0.60
2.00	1.46	1.46	1.46	1.46	1.46	1.46	1.46	1.31	1.14	1.02	0.93	0.81	0.71	0.65
2.50	1.46	1.46	1.46	1.46	1.46	1.46	1.46	1.37	1.21	1.07	0.99	0.85	0.76	0.68
3.00	1.46	1.46	1.46	1.46	1.46	1.46	1.46	1.41	1.27	1.12	1.03	0.89	0.80	0.72
4.00	1.46	1.46	1.46	1.46	1.46	1.46	1.46	1.46	1.34	1.22	1.09	0.97	0.86	0.78
5.00	1.46	1.46	1.46	1.46	1.46	1.46	1.46	1.46	1.39	1.28	1.17	1.02	0.90	0.83
6.00	1.46	1.46	1.46	1.46	1.46	1.46	1.46	1.46	1.43	1.33	1.23	1.06	0.95	0.87
7.00	1.46	1.46	1.46	1.46	1.46	1.46	1.46	1.46	1.46	1.37	1.28	1.09	0.99	0.90
8.00	1.46	1.46	1.46	1.46	1.46	1.46	1.46	1.46	1.46	1.40	1.31	1.14	1.02	0.93
9.00	1.46	1.46	1.46	1.46	1.46	1.46	1.46	1.46	1.46	1.42	1.34	1.18	1.05	0.97

NOTE: The values in Table 7-4 are a function of the time it takes for runoff to travel through the watershed. This travel time becomes shorter as the flow length decreases and the slope increases. The shortest travel time for which the MDNRE computes runoff is 6 minutes, corresponding to a flow of 1.46 cfs/acre/inch of runoff. For combinations of flow length and slope that produce a travel time shorter than 6 minutes, a constant flow of 1.46 cfs/acre/inch of runoff should be used.

Please complete Practice Problems A and B in Appendix 7C.

Runoff Problem #1: Undeveloped Site

For the 40-acre site illustrated in Figure 7-6 (a hypothetical undeveloped site), compute the runoff volume and peak discharge for a 10-year, 24-hour rainfall. The site is located within a 120-acre watershed in Cheboygan County. Therefore, runoff calculations must be based on the total 120-acre watershed, not the 40-acre project site. The soils within the watershed are predominantly sandy loam. The project site has 8 acres under cultivation without conservation practices, 5 acres of woodland with good cover, and 27 acres of pasture in good condition. The remaining 80 acres in the watershed includes a 55-acre golf course in good condition, 15 acres of woodland with good cover, and 10 acres of pasture in good condition. The effective watershed slope averages 2% and flow length is 6000 feet.

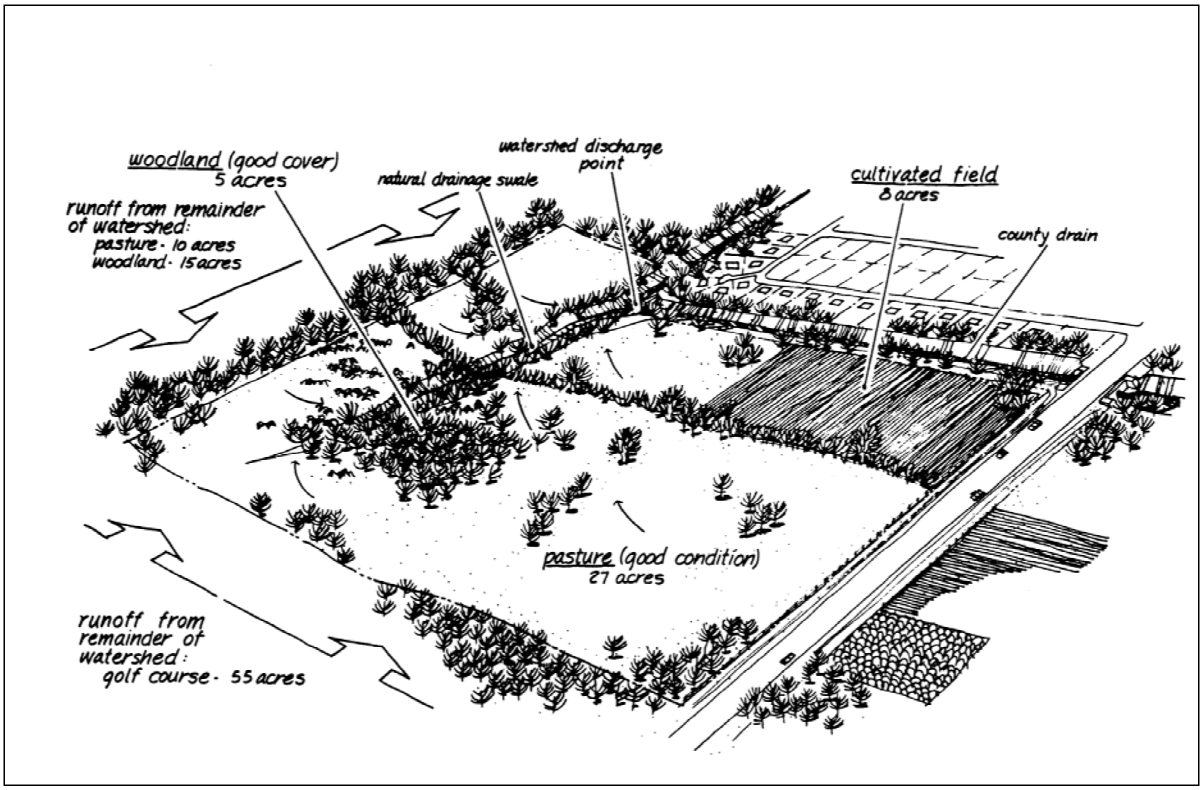


Figure 7-6: Undeveloped Agricultural Land

<u>Step 1</u>
Determine from Figure 7-4 that the 10-year, 24-hour rainfall in Cheboygan County is 3.04 inches (round to 3.0 inches).

<u>Step 2</u>
Determine from Page 7-7 that sandy loam soils are in hydrologic soil group "B."

Step 3
Compute the average runoff curve number for the watershed using Table 7-2:

Land Use	Acres		RCN		Product
Cultivated (without conservation)	8	x	81	=	648
Pasture (good condition)	37	x	61	=	2,257
Woodland (good cover)	20	x	55	=	1,100
Golf course (good condition)	55	x	61	=	3,355
	120				7,360

$$\text{Average RCN} = \frac{\text{Total Product}}{\text{Total Acres}} = \frac{7360}{120} = 61.33 \text{ (use 61).}$$

Step 4
Utilize Table 7-3 to determine runoff of 0.37 inches based on a curve number of 61 and rainfall of 3.0 inches. Total runoff from the watershed would be 156,816 cubic feet, computed as follows:

0.37 inches of runoff divided by 12 inches/foot = 0.03 feet
120 acres x 43,560 square feet/acre = 5,227,200 square feet
0.03 ft. x 5,227,200 square feet = 156,816 cubic feet

Step 5
Refer to Table 7-4 to compute peak discharge. Given that the slope is 2 percent and the watershed flow length is 6000 feet, the unit peak discharge is 0.65 cfs/acre/inch of runoff. Using the total runoff of 0.37 inches, the total peak discharge from the site (watershed) is 28.9 cfs, computed as follows:

0.65 cfs/acre/inch of runoff x 120 acres x 0.37 inches of runoff = 28.9 cfs

Runoff Problem #2: Site under Construction

Compute the volume and peak discharge for a 10-year, 24-hour rainfall for the same 40-acre site during the construction of a shopping center (Figure 7-7). The project site will include 10 acres of bare construction area, 9 acres of graveled parking and storage area, 9 acres of pasture in good condition, 7 acres of temporary grass cover, and 5 acres of woodland with good cover. The other 80 acres in the watershed remains the same as in Problem #1: golf course of 55 acres in good condition, 15 acres of woodland with good cover, and 10 acres of pasture in good condition. (Note: Table 7-2 does not include curve numbers for temporary cover; therefore, one must select a land use category that approximates the condition of the site. For example, if the grass is just starting to sprout, runoff characteristics may be similar to "newly developed areas." If the grass is established, "fair grass cover" or "poor pasture land" may be better choices. Use poor pasture land when working the problem.)

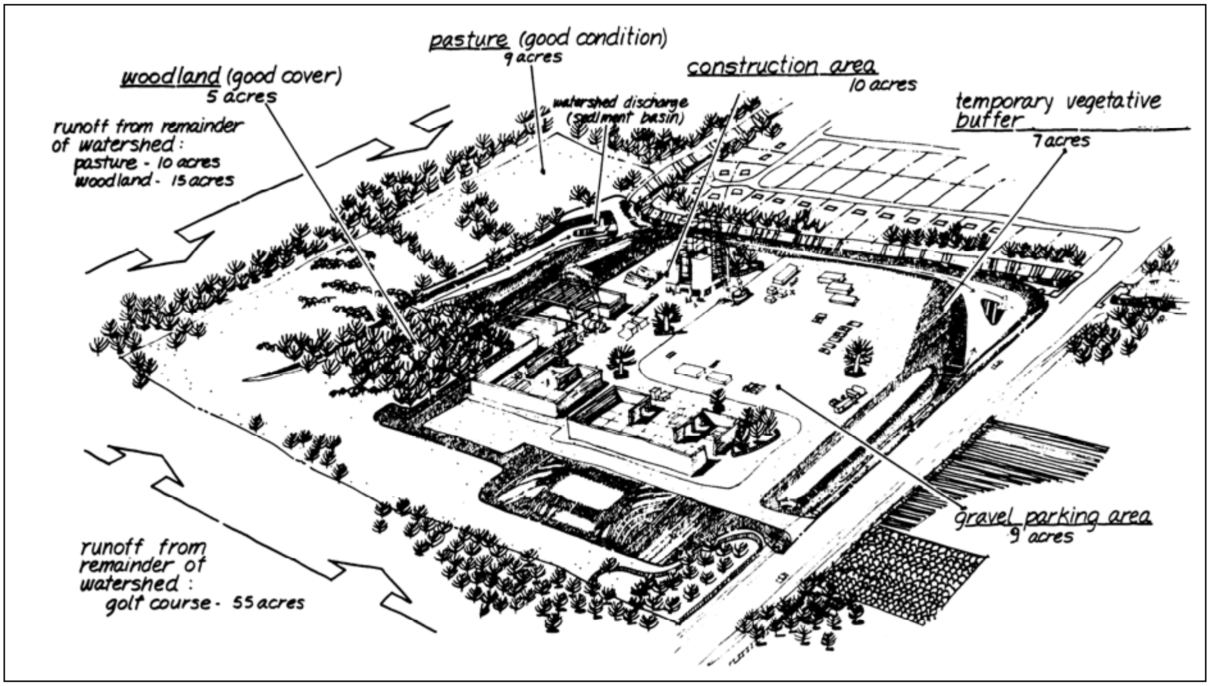


Figure 7-7: Shopping Center under Construction

Step 1

Compute the average runoff curve number for the watershed using Table 7-2 for hydrologic soil group "B," as determined in Problem 1.

Land Use	Acres		RCN		Product
Bare construction area	10	x	86	=	860
Graveled parking	9	x	85	=	765
Pasture (good condition)	19	x	61	=	1,159
Temporary grass cover	7	x	79	=	553
Woodland (good cover)	20	x	55	=	1,100
Golf course	55	x	61	=	3,355
	120				7,792

Average RCN = Total Product / Total Acres = 7792 / 120 = 64.9 (use RCN of 65)

Step 2

Utilize Table 7-3 to determine runoff of 0.51 inches based on curve number of 65 and rainfall of 3.0 inches (determined from Problem #1). Total runoff from the watershed would be 209,088 cubic feet, computed as follows:

0.51 inches of runoff divided by 12 inches/foot = 0.043 feet = 0.04 feet
120 acres x 43,560 square feet/acre = 5,227,200 square feet
0.04 ft. x 5,227,200 square feet = 209,088 cubic feet

Step 3

Assuming that neither the effective watershed slope nor the flow length has been modified, the unit peak discharge remains the same as determined in Problem #1 (0.65 cfs/acre/inch of runoff). Using total runoff of 0.51 inches, the peak discharge for the watershed is 39.8 cfs computed as follows:

0.65 cfs/acre/inch of runoff x 120 acres x 0.51 inches of runoff = 39.8 cfs

Please complete Practice Problem C in Appendix 7C.

Runoff Problem #3: Developed Site

Compute the runoff volume and peak discharge for a 10-year, 24-hour rainfall for the same 40-acre site in Runoff Problem #2 after the shopping center has been constructed (Figure 7-8). The site will include 21 acres of paved surfaces, 9 acres of meadow in good condition, 5 acres of maintained lawn, and 5 acres of woodland with good cover. The other 80 acres in the watershed remains the same as in Problem #1: a golf course of 55 acres in good condition, 15 acres of woodland with good cover, and 10 acres of pasture in good condition.

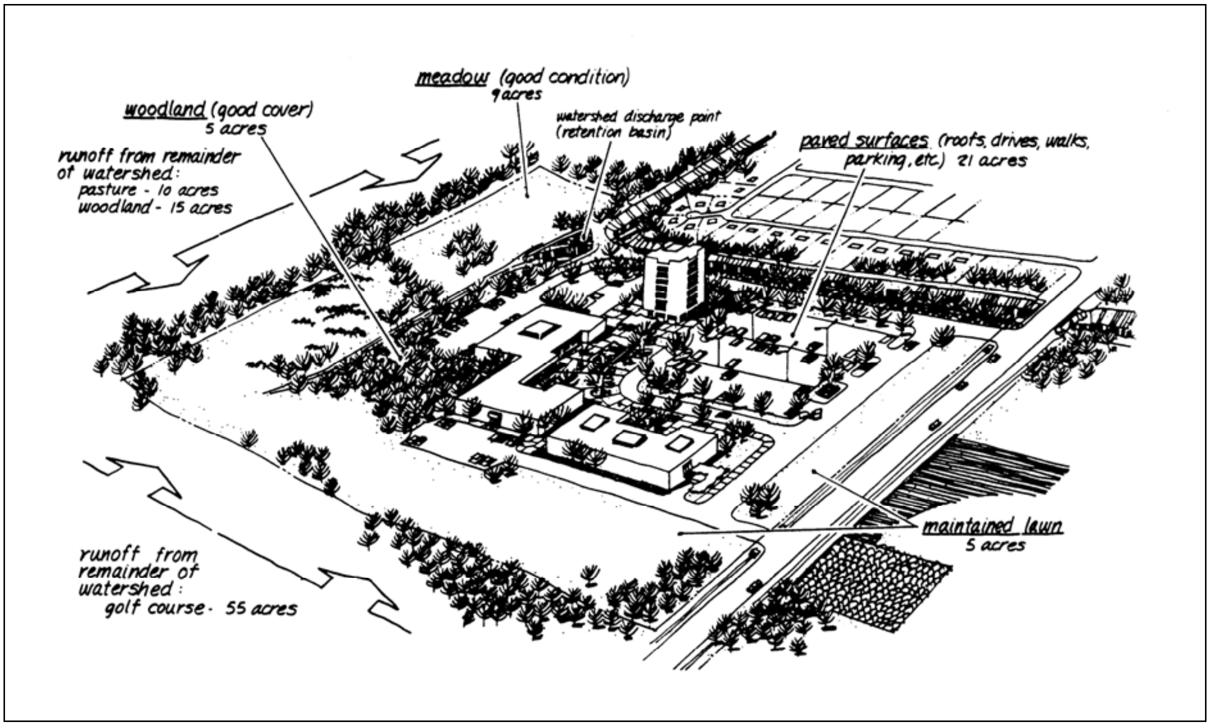


Figure 7-8: Proposed Shopping Center Development

Step 1

Compute the average runoff curve number for the watershed using values from Table 7-2 for hydrologic soil group "B" as determined in Problem #1.

Land Use	Acres		RCN		Product
Paved surfaces	21	x	98	=	2,058
Maintained lawn	5	x	61	=	305
Woodland (good cover)	20	x	55	=	1,100
Pasture (good condition)	10	x	61	=	610
Meadow	9	x	58	=	522
Golf course	55	x	61	=	3,355
	120				7,950

$$\text{Average RCN} = \frac{\text{Total Product}}{\text{Total Acres}} = \frac{7950}{120} = 66.25 \text{ (use 66).}$$

Step 2
Utilize Table 7-3 to determine runoff of 0.55 inches based on a curve number of 66 and rainfall of 3.0 inches (determined in Problem #1). Total runoff from the watershed would be 261,360 cubic feet, computed as follows:

> 0.55 in. runoff divided by 12 inches/foot = 0.046 feet= 0.05 feet
> 120 ac. x 43,560 square feet/acre = 5,227,200 square feet
> 0.05 ft. x 5,227,200 square feet = 261,360 cubic feet

Step 3
As in the previous problem, the effective watershed slope and flow length has not changed, so the unit peak discharge remains the same (0.65 cfs/acre/inch of runoff). Using total runoff of 0.55 inches, the total peak discharge for the watershed is 42.9 cfs, computed as follows:

> 0.65 cfs/acre/inch of runoff x 120 acres x 0.55 inches of runoff = 42.9 cfs

These problems illustrate the effect that site development has on the volume and peak discharge of storm water runoff. All of the factors affecting the runoff, except storm frequency, are taken directly from tables based on knowledge of the site condition (soil type, land use, area, slope, etc.) and are, for the most part, not variable. Storm frequency, however, is variable and can greatly affect the runoff calculations.

Application of Runoff Calculations

Determining the runoff volume and discharge rate is necessary to develop a comprehensive SESC plan, both during construction and after project completion. It is necessary to know the quantity of runoff to design adequate water storage facilities, such as sediment basins and storm water retention ponds (Figure 7-9).

Figure 7-9

It is necessary to know the peak discharge of runoff at a given point to design adequate water conveyance devices, such as ditches, diversions, culverts, and outlets for sediment basins and storm water ponds. Refer to the NRCS and local conservation district standards and specifications for specific applications for the open channel type devices, such as ditches and diversions. For temporary pipes and culverts in non-critical areas, such as temporary channel crossings or the outlets of temporary sediment basins, the manufacturers' specifications may be appropriate to use for determining the size of the pipe necessary to accommodate the calculated discharge. For critical applications, such as permanent stream crossings, permanent storm water retention basin outlets and underground storm drainage systems, the project should be thoroughly engineered and all variables considered.

Summary

The proper design and implementation of virtually all erosion and sedimentation control measures is dependent on an understanding of the erodibility and settlement rate of the different soil types found on a construction site (Table 7-5).

The ability to identify soils, in conjunction with knowledge of how soil properties influence erodibility, runoff potential, and settlement rate, will allow one to identify potential problem areas both on and off the site. Knowledge of on-site soils is essential when making decisions regarding erosion control, vegetation stabilization, runoff control structures, and the effectiveness of sedimentation basins. The effectiveness of specific erosion and sedimentation control measures varies with each general soil type.

Table 7-5. The influence of soil properties on erodibility, runoff potential, and settlement rate.

General Soil Type	Erodibility	Runoff Potential	Settlement Rate
SILTY SOILS, silt, silt loam	High	Moderate	Low
CLAYEY SOILS – clay, clay loam	Moderate	High	Low
LOAMY SOILS – loam, sandy loam	Moderate	Moderate	Moderate
SANDY SOILS – sand, loamy sand	Low	Low	High

Erodibility

Erodibility gives an indication of how easily wind or water will detach and transport soils on a site.

All soils have been assigned an erodibility status by the NRCS. Silty soils tend to be highly erosive, clayey and loamy soils tend to have moderate erodibility, and sandy soils generally have low erodibility (although very fine sands can also be very erodible).

Settlement Rate

Settlement refers to the rate at which eroded soil particles settle out of suspension after being detached by flowing water. Sandy soils have a high settlement rate. Loamy soils have a moderate settlement rate. Clay and silty soils have a low settlement rate.

Where soils have a low settlement rate it can mean that it can be extremely difficult or costly to remove these soils from runoff once they become mobile. When soils indicate a low settlement rate, plan designers should attempt to prevent the soils from becoming mobilized whenever possible.

Silty Soils

The presence of silty soils dictates that a very comprehensive soil erosion and sedimentation control plan be developed because silty soils are more susceptible to erosion and sedimentation problems than other soils. These soils are extremely erodible and must be effectively stabilized with a vegetative or mechanical (paved) cover. Large sediment collecting areas are required to allow the easily eroded soil particles a chance to settle out.

Clayey Soils

The presence of clay soils requires a comprehensive SESC plan, with particular emphasis on controlling runoff. Clay soils are only moderately erodible, but are difficult to remove from runoff water prior to leaving a site. Sediment control measures are ineffective for settling out the small clay sized particles without the addition of polymers. Vegetative stabilization is important because of the soil's moderate erodibility.

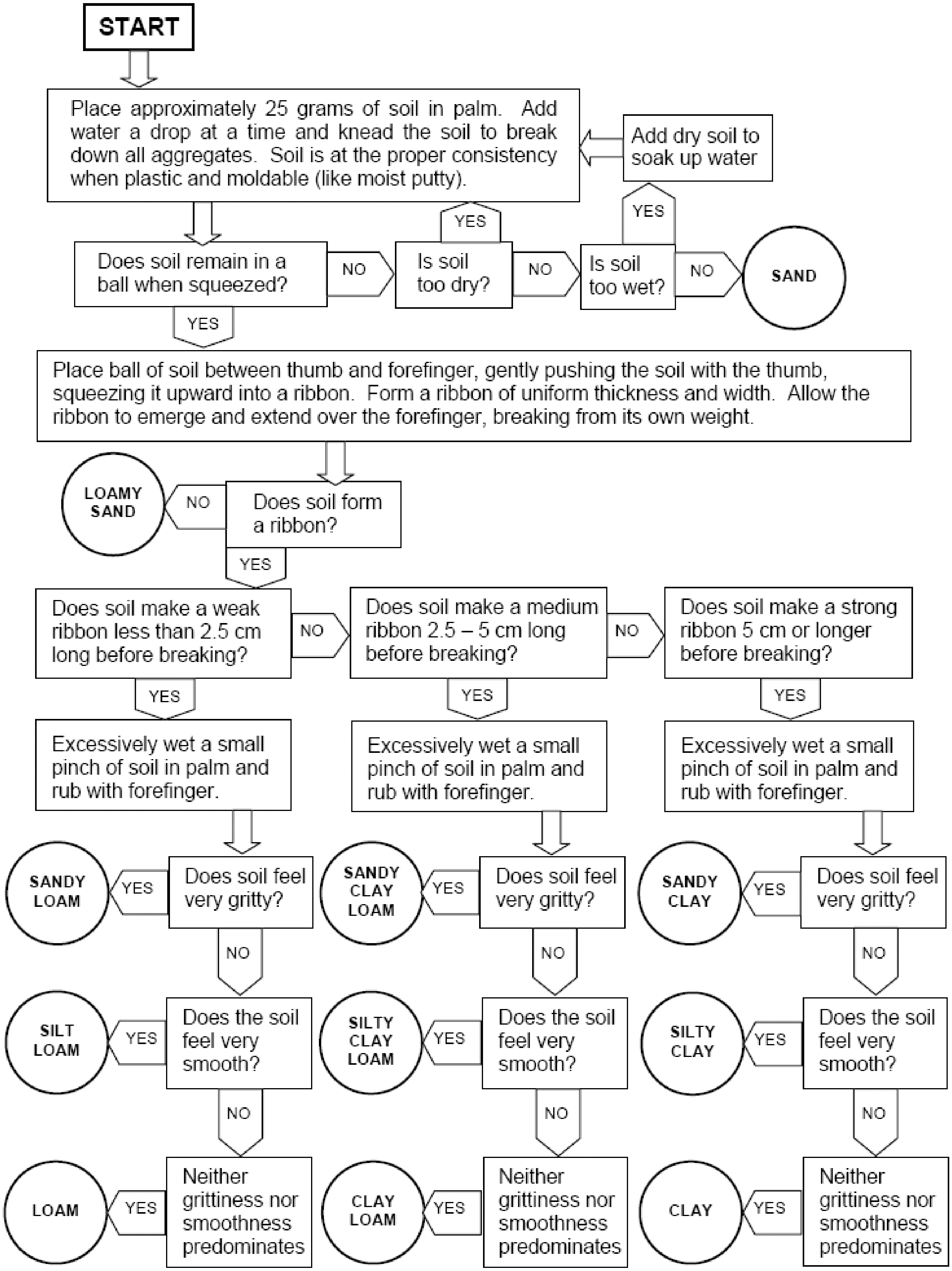
Loamy Soils

The presence of loamy soils requires a comprehensive SESC plan, with equal emphasis on all control measures. Water control devices and sediment collection areas do not have to be as large or extensive as those required for silty or clay soils.

Sandy Soils

The presence of sandy soils requires the least extensive SESC plan, since they are relatively resistant to erosion. If sand is eroded, the particles are generally not transported far because of minimal runoff potential and the rapid particle settlement rate. Water control devices seldom need to be large and sediment collection areas can be small. Particular attention must be paid to concentrated flow areas because sand soils are particularly susceptible to erosion under concentrated flow conditions. Vegetation is difficult to establish so it is often difficult to completely stabilize these soils. The lack of stabilization makes sandy soils difficult to manage since they tend to "shift" and be deposited locally, often clogging drainage ways and storm sewers. Emphasis must be given to frequent maintenance of control measures, particularly cleaning out of traps and channels.

Appendix 7A
Determining Soil Texture In The Field



Source: Steve Thien, Kansas State University

Appendix 7B

HYDROLOGIC SOIL GROUPS FOR MICHIGAN SOILS

(July 2000)

Soil series	Group	Soil series	Group	Soil series	Group
Abbaya	B	Brassar	C	Dighton	B
Abscota	A	Breckenridge	D/B	Dixboro	B
Adrian	D/A	Brems	A	Dora	D/B
Alcona	B	Brevort	D/B	Dowagiac	B
Algansee	B	Brimley	B	Dresden	B
Allendale	B	Bronson	B	Dryburg	B
Allouez	B	Brookston	D/B	Dryden	B
Alpena	A	Bruce	D/B	Duel	A
Alstad	C	Burleigh	D/A	Dungridge	B
Amasa	B	Burt	D	East Lake	A
Angelica	D/B	Cadmus	B	Eastport	A
Arkona	B	Capac	C	Edmore	D
Arkport	B	Carbondale	D/A	Edwards	D/B
Arnheim	D	Carlisle	D/A	Eel	B
Ashkum	D/B	Caasopolis	B	Eleva	B
Assinins	B	Cathro	D/A	Elmdale	B
Aubarque	D/C	Celina	C	Elston	B
Aubbeenaubbee	B	Ceresco	B	Elvers	D/B
Au Gres	B	Champion	B	Emmet	B
Aurelius	D/B	Channahon	D	Ensign	D
Avoca	B	Channing	B	Ensley	D/B
Bach	D/B	Charity	D	Epoufette	D/B
Badaxe	B	Charlevoix	B	Epworth	A
Banat	B	Chatham	B	Ermatinger	D/B
Barry	D/B	Cheboygan	B	Esau	A
Battlefield	D/A	Chelsea	A	Escanaba	A
Beavertail	D	Chesaning	B	Essexville	D/A
Beechwood	C	Chestonia	D	Evart	D
Belding	B	Chippeny	D	Fabius	B
Belleville	D/B	Cohoctah	D/B	Fairport	C
Benona	A	Coloma	A	Fence	B
Bergland	D	Colonville	C	Fibre	D/B
Berville	D/B	Colwood	D/B	Filion	D
Biscuit	D/B	Conover	C	Finch	C
Bixby	B	Coral	C	Fox	B
Bixler	C	Corunna	D/B	Frankenmuth	C
Blount	C	Coupee	B	Frenchette	B
Blue Lake	A	Covert	A	Freda	D
Bohemian	B	Crosier	C	Froberg	D
Bonduel	C	Croswell	A	Fulton	D
Bono	D	Cunard	B	Gaastra	C
Boots	D/A	Cushing	B	Gagetown	B
Borski	B	Dawson	D/A	Gay	D/B
Bowers	C	Deer Park	A	Genesee	B
Bowstring	D/A	Deerton	A	Gilchrist	A
Boyer	B	Deford	D/A	Gilford	D/B
Brady	B	Del Rey	C	Gladwin	A
Branch	B	Detour	B	Glawe	D/B

Two soil groups, such as D/B, indicates the undrained/drained condition.

HYDROLOGIC SOIL GROUPS FOR MICHIGAN SOILS
(July 2000)

Soil series	Group	Soil series	Group	Soil series	Group
Glendora	D/A	Keowns	D/B	Miami	B
Glynwood	C	Kerston	D/A	Michigamme	C
Gogebic	B	Keweenaw	A	Millsdale	D/B
Gogomain	D/B	Kibbie	B	Milton	C
Goodman	B	Kidder	B	Minoa	C
Gorham	D/B	Kilmanagh	C	Minocqua	D/B
Grace	B	Kingsville	D/A	Minong	D
Granby	D/A	Kinross	D/A	Misery	C
Grattan	A	Kiva	A	Mitiwanga	C
Graveraet	B	Klacking	A	Moltke	B
Graycalm	A	Kokomo	D/B	Monico	C
Grayling	A	Koontz	D	Monitor	C
Greenwood	D/A	Krakow	B	Montcalm	A
Grindstone	C	Lacota	D/B	Moquah	B
Grousehaven	D	Lamson	D/B	Morley	C
Guardlake	A	Landes	B	Morocco	B
Guelph	B	Lapeer	B	Mudsock	D/B
Gutport	D	Latty	D	Munising	B
Hagensville	C	Leelanau	A	Munuscong	D/B
Halfaday	A	Lenawee	D/B	Mussey	D/B
Hatmaker	C	Leoni	B	Nadeau	B
Henrietta	D/B	Liminga	A	Nahma	D/B
Hessel	D/B	Linwood	D/A	Napoleon	D/A
Hettinger	D/C	Locke	B	Nappanee	D
Hillsdale	B	Lode	B	Nester	C
Hodenpyl	B	Londo	C	Net	C
Houghton	D/A	Longrie	B	Newaygo	B
Hoytville	D/C	Loxley	D/A	Newton	D/A
Huntington	B	Lupton	D/A	Nottawa	B
Ingalls	B	Mackinac	B	Nunica	C
Ingersoll	B	Macomb	B	Oakville	A
Ionia	B	Mancelona	A	Ockley	B
Iosco	B	Manistee	A	Oconto	B
Isabella	B	Manitowish	B	Ocqueoc	A
Ishpeming	A	Markey	D/A	Ogemaw	D/C
Ithaca	C	Marlette	B	Okee	B
Jacobsville	D	Martinsville	B	Oldman	C
Jeddo	D/C	Martisco	D/B	Olentangy	D/A
Jesso	C	Matherton	B	Omega	A
Johnswood	B	Maumee	D/A	Omena	B
Kalamazoo	B	McBride	B	Onaway	B
Kalkaska	A	Mecosta	A	Onota	B
Kallio	C	Melita	A	Ontonagon	D
Karlin	A	Menagha	A	Ormas	B
Kawbawgam	C	Menominee	A	Oshtemo	B
Kakkawlin	C	Mervin	D/A	Otisco	A
Kendallville	B	Metamora	B	Ottokee	A
Kent	D	Metea	B	Owosso	B

Two soil groups, such as D/B, indicates the undrained/drained condition.

HYDROLOGIC SOIL GROUPS FOR MICHIGAN SOILS
(July 2000)

Soil series	Group	Soil series	Group	Soil series	Group
Paavola	B	Saganing	D/A	Thomas	D/B
Padus	B	Sanilac	B	Tobico	D/A
Palms	D/A	Saranac	D/C	Toledo	D
Parkhill	D/B	Sarona	B	Tonkey	D/B
Paulding	D	Satago	D	Toogood	A
Pelkie	A	Saugatuck	C	Trenary	B
Pella	D/B	Saylesville	C	Trimountain	B
Pemene	B	Sayner	A	Tula	C
Pence	B	Scalley	B	Tuscola	B
Pendleton	C	Schoolcraft	B	Tustin	B
Pequaming	A	Sebewa	D/B	Twining	C
Perrin	B	Selfridge	B	Tyre	D/A
Perrinton	C	Selkirk	C	Ubly	B
Pert	D	Seward	B	Velvet	C
Peshekee	D	Shebeon	C	Vestaburg	D/A
Petticoat	B	Shelldrake	A	Vilas	A
Pewamo	D/C	Shelter	B	Volinia	B
Pickford	D	Shiawassee	C	Wainola	B
Pinconning	D/B	Shinrock	C	Waiska	B
Pinnebog	D/A	Shoals	C	Wakefield	B
Pipestone	B	Sickles	D/B	Wallace	B
Plainfield	A	Sims	D	Wallkill	D/C
Pleine	D	Sisson	B	Warners	D/C
Ponozzo	C	Skanee	C	Wasepi	B
Posen	B	Sleeth	C	Washtenaw	D/C
Poseyville	C	Sloan	D/B	Watton	C
Potagannissing	D	Solona	C	Waucedah	D
Poy	D	Soo	D/C	Wauseon	D/B
Proctor	B	Sparta	A	Wautoma	D/B
Randolph	C	Spinks	A	Wega	B
Rapson	B	Springlake	A	Westbury	C
Remus	B	St. Clair	D	Whalan	B
Rensselaer	D/B	St. Ignace	D	Wheatley	D/A
Richter	B	Stambaugh	B	Whitaker	C
Riddles	B	Steuben	B	Whitehall	B
Rifle	D/A	Sturgeon	B	Willette	D/A
Riggsville	C	Sugar	B	Winneshiek	B
Rimer	C	Summerville	D	Winterfield	D/A
Riverdale	A	Sundell	B	Wisner	D/B
Rockbottom	B	Sunfield	B	Witbeck	D/B
Rockcut	B	Superior	D	Wixom	B
Rodman	A	Tacoosh	D/B	Wolcott	D/B
Ronan	D	Tallula	B	Woodbeck	B
Rondeau	D/A	Tamarack	B	Yalmer	B
Roscommon	D/A	Tappan	D/B	Ypsi	C
Roselms	D	Tawas	D/A	Zeba	B
Rousseau	A	Teasdale	B	Ziegenfuss	D
Rubicon	A	Tedrow	B	Zilwaukee	D
Rudyard	D	Tekenink	B	Zimmerman	A
Ruse	D	Thetford	A		

Two soil groups, such as D/B, indicates the undrained/drained condition.

Appendix 7C
PRACTICE PROBLEMS

Practice Problems A, B, and C

Practice Problem A: Calculating Runoff from an Undisturbed Site

Situation: A factory and parking lot is proposed to be constructed on five (5) acres near Lansing (Ingham County). Runoff from the surrounding area is diverted away from the site. Assume that all runoff originating on the site leaves at the southeast corner.

Site: Soil: Boyer Loamy Sand
Slope: 2 percent
Water Flow Length: 800 feet

Problem: Calculate the volume of runoff and the peak discharge (Q_2) generated at the outlet of the site during a 5-year, 24-hour rainfall for the present undisturbed (dense grass) condition.

Solution: **5-year rainfall** for Ingham County: ________ inches
(Figure 7-4, Page 7-10)

Hydrologic Group for Boyer Loamy Sand: __________
(Appendix 7B)

Runoff Curve Number (RCN) for site: ________
(Table 7-2, Page 7-8)

Expected Runoff from Site: _________ inches
(Based on RCN of ___________ and Rainfall of _________ inches)
(Table 7-3, Page 7-12)

Volume of Runoff = Runoff Depth **x** Watershed Area
(To express volume in cubic feet, convert runoff and area to "feet")

_______ inches of runoff divided by 12 inches/foot = _______ feet

_______ acres **x** 43,560 square feet/acre = __________ square feet

_______ feet of runoff **x** ________ square feet = ________ cubic feet

Unit Peak Discharge: Q_1 = ____________ cfs/acre/inch
(Based on Slope of ________ and Flow Length of ________ feet)
(Table 7-4, Page 7-14)

Peak Discharge of Site: $Q_2 = Q_1$ **x** area **x** runoff

____ cfs/acre/inch **x** ____ acres **x** ____ inches of runoff = ______ cfs

NOTE: cfs = cubic feet per second
X = means to multiply

Practice Problem B: Calculating Runoff during Construction

Situation: A factory and parking lot is proposed to be constructed on five acres near Lansing (Ingham County). Runoff from the surrounding area is diverted away from the site. Assume that all runoff originating on the site leaves at the southeast corner.

Site: Soil: Boyer Loamy Sand
Slope: 2 percent
Water Flow Length: 800 feet

Problem: Calculate the volume of runoff and the peak discharge (Q_2) generated at the outlet of the site during a 5-year, 24-hour rainfall during construction after the grass has been removed.

Solution: **5-year rainfall** for Ingham County: ________ inches
(Figure 7-4, Page 7-10)

Hydrologic Group for Boyer Loamy Sand: _________
(Appendix 7B)

Runoff Curve Number (RCN) for site ________
(Table 7-2, Page 7-8)

Expected Runoff from Site (Appendix A): _________ inches
(Based on RCN of ___________ and Rainfall of _________ inches)
(Table 7-3, Page 7-12)

Volume of Runoff = Runoff Depth **x** Watershed Area
(To express volume in cubic feet, convert runoff and area to "feet")

_______ inches of runoff divided by 12 inches/foot = _______ feet

_______ acres **x** 43,560 square feet/acre = __________ square feet

_______ feet of runoff **x** ________ square feet = ________ cubic feet

Unit Peak Discharge: Q_1 = ____________ cfs/acre/inch
(Based on Slope of ________ and Flow Length of ________ feet)
(Table 7-4, Page 7-14)

Peak Discharge of Site: $Q_2 = Q_1$ **x** area **x** runoff

____ cfs/acre/inch **x** ____ acres **x** ____ inches of runoff = ______ cfs

Practice Problem C: Calculating Runoff from a Developed Site

Situation: Twenty-one (21) acres within a 120-acre watershed with mixed land cover were recently developed in Cheboygan County.

Site: Soil: Rapson Loamy Sand
Slope: 2 percent
Water Flow Length: 6000 feet

Problem: Calculate the volume of runoff and the peak discharge (Q_2) generated from the above described site during a 10-year, 24-hour rainfall.

Solution: **10-year rainfall** for Cheboygan County: ________ inches
(Figure 7-4, Page 7-10)

Hydrologic Group for Rapson Loamy Sand (Appendix 7B): __________

Weighted Runoff Curve Number (RCN) for site (Table 7-2, page 7-8):

Land Cover	Acres		RCN		Product
Roofs, Driveways, Parking	21	x	_____	=	_______
Open Space (good)	5	x	_____	=	_______
Forest Land (good)	20	x	_____	=	_______
Range Land (good)	10	x	_____	=	_______
Meadow (good)	9	x	_____	=	_______
Parks (good)	55	x	_____	=	_______
Totals:	____				_______

Weighted RCN = $\frac{\text{Total Product}}{\text{Total Acres}}$ = ________; round to __________

Expected Runoff from Site (Table 7-3, page 7-12): _______ inches
(Based on RCN of ________ and Rainfall of _______ inches)

Volume of Runoff = Runoff Depth **x** Watershed Area
(To express volume in cubic feet, convert runoff and area to "feet")

_______ inches of runoff divided by 12 inches/foot = _______ feet

_______ acres **x** 43,560 square feet/acre = ___________ square feet

_______ feet of runoff **x** ________ square feet = ________ cubic feet

Unit Peak Discharge: Q_1 = _____________ cfs/acre/inch
(Based on Slope of ________ and Flow Length of ________ feet)
(Table 7-4, page 7-14)

Peak Discharge of Site: $Q_2 = Q_1$ **x** area **x** runoff

____ cfs/acre/inch **x** ____ acres **x** ____ inches of runoff = ______ cfs

Answers to Practice Problems A, B, and C

Answers to Practice Problem A

5-year rainfall for Ingham County: **2.98** inches **(use 3.0 inches)**

Hydrologic Group for Boyer Loamy Sand: **B**

Runoff Curve Number (RCN) for site): **61**

Expected Runoff from Site: **0.37** inches
(Based on RCN of **61** and Rainfall of **3.0** inches)

Volume of Runoff = Runoff Depth **x** Watershed Area
(To express volume in cubic feet, convert runoff and area to “feet”)

0.37 inches of runoff divided by 12 inches/foot = **0.03** feet

5 acres **x** 43,560 square feet/acre = **217,800** square feet

0.03 feet of runoff **x** **217,800** square feet = **6,534** cubic feet

Unit Peak Discharge: Q_1 = **1.46** cfs/acre/inch
(Based on Slope of **2%** and Flow Length of **800** feet)

Peak Discharge of Site: $Q_2 = Q_1$ **x** area **x** runoff

1.46 cfs/acre/inch **x** **5** acres **x** **0.37** inches of runoff = **2.7** cfs

Answers to Practice Problem B

5-year rainfall for Ingham County: **2.98** inches **(use 3.0 inches)**

Hydrologic Group for Boyer Loamy Sand: **B**

Runoff Curve Number (RCN) for site): **86**

Expected Runoff from Site: **1.67** inches
(Based on RCN of **86** and Rainfall of **3.0** inches)

Volume of Runoff = Runoff Depth **x** Watershed Area
(To express volume in cubic feet, convert runoff and area to "feet")

1.67 inches of runoff divided by 12 inches/foot = **0.14** feet

5 acres **x** 43,560 square feet/acre = **217,800** square feet

0.14 feet of runoff **x** **217,800** square feet = **30,492** cubic feet

Unit Peak Discharge: Q_1 = **1.46** cfs/acre/inch
(Based on Slope of **2%** and Flow Length of **800** feet)

Peak Discharge of Site: $Q_2 = Q_1$ **x** area **x** runoff

1.46 cfs/acre/inch **x** **5** acres **x** **1.67** inches of runoff = **12.2** cfs

Answers to Practice Problem C

Situation: Twenty-one (21) acres within a 120-acre watershed with mixed land cover were recently developed in Cheboygan County.

Site: Soil: Rapson Loamy Sand
Slope: 2 percent
Water Flow Length: 6000 feet

Problem: Calculate the volume of runoff and the peak discharge (Q_2) generated from the above described site during a 10-year, 24-hour rainfall.

Solution: Use the **Soils and Runoff Manual**

10-year rainfall for Cheboygan County: **3.04** inches **(use 3.0 inches)**

Hydrologic Group for Rapson Loamy Sand (Appendix 7B): **B**

Weighted Runoff Curve Number (RCN) for site (Table 7-2, page 7-8):

Land Cover	Acres		RCN		Product
Roofs, Driveways, Parking	21	x	**98**	=	**2058**
Open Space (good)	5	x	**61**	=	**305**
Forest Land (good)	20	x	**55**	=	**1100**
Range Land (good)	10	x	**61**	=	**610**
Meadow (good)	9	x	**58**	=	**522**
Parks (good)	55	x	**61**	=	**3355**
Totals:	**120**				**7950**

Weighted RCN = $\frac{\text{Total Product}}{\text{Total Acres}}$ = **7950 / 120 acres** = **66.25**; round to **66**

Expected Runoff from Site (Table 7-3, page 7-12): **0.55** inches
(Based on RCN of **66** and Rainfall of **3.0** inches)

Volume of Runoff = Runoff Depth **x** Watershed Area
(To express volume in cubic feet, convert runoff and area to "feet")

0.55 inches of runoff divided by 12 inches/foot = **0.05** feet

120 acres **x** 43,560 square feet/acre = **5,227,200** square feet

0.05 feet of runoff **x** **5,227,200** square feet = **261,360** cubic feet

Unit Peak Discharge: Q_1 = **0.65** cfs/acre/inch
(Based on Slope of **2%** and Flow Length of **6,000** feet)

Peak Discharge of Site: $Q_2 = Q_1$ **x** area **x** runoff

0.65 cfs/acre/inch **x** **120** acres **x** **0.55** inches of runoff = **42.9** cfs