REVIEW SCHEDULE

DAY	DESCRIPTION	TIMES
Friday	Introduction and overview	12:00 pm to 12:15 pm
	Review pre-assignment	12:15 pm to 12:30 pm
	Test-taking strategies; basic grading, grading formulas and grading exercises	12:30 pm to 3:00 pm
	First afternoon break	3:00 pm to 3:15 pm
	Drainage and drainage exercises	3:15 pm to 5:15 pm
	Second afternoon break	5:15 pm to 5:30 pm
	Continue with exercises; introduction to vignettes; assignment of "homework"	5:30 pm to 7:00 pm
Saturday	Practice on exercises and vignettes	8:00 am to 10:15 am
	Morning break	10:15 am to 10:30 am
	Continue working on vignettes	10:30 am to 12:00 pm
	Lunch on own	12:00 pm to 1:00 pm
	Continue working on vignettes	1:00 pm to 2:30 pm
	Afternoon Break	2:30 pm to 2:45 pm
	Continue working on vignettes	2:45 pm to 5:00 pm
Saturday	Continue working on vignettes	8:00 am to 10:15 am
	Morning break	10:15 am to 10:30 am
	Continue working on vignettes	10:30 am to 12:00 pm
	Lunch on own	12:00 pm to 1:00 pm
	Continue working on vignettes	1:00 pm to 2:30 pm
	Afternoon Break	2:30 pm to 2:45 pm
	Continue working on vignettes	2:45 pm to 3:30 pm
	Review solutions and wrap up	3:30 pm to 5:00 pm

LARE Section E: An Intensive Review

Grading Basics–
A Grading Primer

By Jerry P. Hastings, ASLA

PRIMER

According to the Merriam Webster Online Dictionary, the word primer is defined as "a small introductory book on a subject." That's what this Primer is: a small introductory book that focuses on the use of the grading formulas to solve common grading problems.

What you will learn: The primer begins with a discussion of decimal numbers and numbers expressed in percentage form, inches and tenths of a foot, number precision and rounding off, and basic rules guiding the use of calculators. It then looks at the basic grading formulas, how they're used, and how they can be applied to solving virtually any grading problem. The emphasis is on speed and accuracy.

THE "BASIC" BASICS — A REVIEW

Grades can be expressed in two ways:

- As a percentage, i.e., the number followed by a percentage sign, such as 2%

- In decimal form, i.e., 2% is written as .02.

For grade callouts placed on plans to communicate the grade

Grades may be expressed in either percentage or decimal form unless one or the other is specifically required in the problem statement. Exceptions: when a percentage sign appears in the space where you are required to write in a grade, *the grade must be expressed as a percentage.* Check carefully on drainlines, where length and pipe size are customarily given on each run of drainline. Along with this, there is often a space with a percentage sign where you are required to write in the slope of the pipe in *percentage form.* In such cases, the slopes are usually calculated based on the invert elevations at the drain inlets. (In the design of drainlines, the term slope, rather than grade, is customary.)

Grades may be expressed in either percentage or decimal form.

For grades that will be used in performing calculations

Grades that are to be used in calculations must be written in decimal form. If a grade is written as a percentage, that is, a number followed by a percentage sign, (e.g., 2%), it must first be converted to decimal form (e.g., .02) prior to performing calculations. To convert a grade from a percentage grade to a decimal grade, move the decimal point *two places to the left* of the number. For example, 2% will be written as .02. Notice that a zero, or zeros, are added to the left of the number as a place keeper, or place keepers, as required.

Examples:

When the percentage is less than 1%, two or more zeros are added to the left of the number as place keepers.

$$.5\% = .005 \qquad .75\% = .0075$$

When the percentage is greater than 1% but less than 10% one zero is added as a place keeper.

$1-1/2\% = .015$ $3\% = .03$ $7\% = .07$

When the percentage is greater than 10%, the decimal is simply moved two places to the left.

$10\% = .1$ $25\% = .25$ $50\% = .5$

Inches and Tenths of a Foot

Elevations are *always* given in feet and tenths of a foot, never in feet and inches, or fractions of an inch. Therefore, you need to be familiar with the relationship between inches and tenths of a foot, and be able to convert inches to tenths, and tenths to inches. Committing the inches-to-tenths conversions shown with an asterisk (*) to memory will save you time and avoid possible confusion or error.

Fact: each .01 foot equals roughly 1/8 inch.

Inches		Tenths	Inches		Tenths
1"	=	.08*	7"	=	.58
2"	=	.17	8"	=	.67
3"	=	.25*	9"	=	.75*
4"	=	.33*	10"	=	.83*
5"	=	.42	11"	=	.92
6"	=	.50*	12"	=	1.00*

- To convert from *inches to tenths of a foot*, **divide** inches by 12. Example:

  7-inches is what when converted to tenths of a foot? $7 \div 12 = .58$

- To convert from *tenths of a foot to inches* on your calculator, **multiply** tenths by 12. Example:

  .25 is what when converted to inches? $.25 \times 12 = 3$ inches

Number Precision

- A tenth is a number having one significant digit to the right of the decimal point, e.g., .1 (ten percent).

- A hundredth is a number having two significant digits to the right of the decimal point, e.g., .02 (two percent).

- A thousandth is a number having three significant digits to the right of the decimal point, e.g., .005 (one half of one percent).

General Rules Governing Precision

The rules provided below should be viewed as general guidelines. Always read the problem statement carefully. Often on the LARE, the problem statement will give specific requirements that must be adhered to. In the absence of specific requirements, common sense and the context of the problem should be considered.

1. Spot Elevations — The generally required precision for spot elevations is either to the nearest tenth of a foot (e.g., 101.4) or to the nearest hundredth of a foot (e.g., 101.46). Again, check for specific requirements in the problem statement. Note that in recent exam administrations, the trend has been to require that spot elevations be shown to the nearest tenth of a foot (one place to the right of the decimal point).

2. Grades — Apply the following guidelines:

   - Grades of less than 1% should be expressed to the nearest thousandth (e.g., a half a percent written as a percentage is .5%, or written in decimal form is .005).

   - Grades of between 1% and 9.9% are usually expressed to the nearest hundredth (e.g., two percent written as a percentage is 2%, or written in decimal form is .02).

   - Grades of 10% or greater are expressed to the nearest tenth (e.g., ten percent written as a percentage is 10%, or written in decimal form is .1).

   - Grades greater than 10% or 12% are usually expressed as a *slope ratio* rather than as a grade. Since steep slopes are usually represented with contour lines, slope ratios are an easier, more direct way, for working with contour lines. Ratios are usually expressed as a ratio of some number of feet horizontal to one foot vertical. 3:1 and 5:1 are examples of common slope ratios. A 3:1 slope is a slope where for every three-feet of horizontal length, there is one foot of elevation gain; a 5:1 slope ratio is a slope where for every five-feet of horizontal length, there is one foot of elevation gain, and so on. As is sometimes the case, the definition sounds more confusing than the execution — think of a slope ratio as a simple way of expressing the ***minimum spacing*** permitted between contour lines. For instance, for a slope ratio of 5:1, you would space the contour lines at least five-feet apart; however, they could be further apart.

3. Drainage — For drainage problems, elevations are usually required to the nearest hundredth of a foot.

4. Pipes — Pipe slopes of less than 1% are usually expressed to the nearest thousandth (e.g., .005). For slopes greater than 1%, they are usually expressed to the nearest hundredth (e.g., .01).

Calculator Rules

Basic tenant: When a calculated grade is to be used to perform further calculations, do not clear the display and reenter the grade in rounded-off form!

- When plotting whole number contour lines on a plane surface, reentering and rounding off numbers seriously compromises the accuracy of the plot. **Note well that it is entirely possible**

to lose, or gain, one or more contours in a hundred feet if the grade has been rounded off!

- Clearing and re-entering numbers wastes time! Each keystroke costs time.
- Clearing and re-entering numbers introduces the risk of error. Common types of errors that often result from reentry are the transposition of numbers, or the unintentional omission of numbers.
- Best of all, it takes zero effort to leave the entire number displayed and available for further calculations, regardless of the number of digits. The calculator has done all the work.

Rounding Off

A distinction is made between using a grade for further calculations versus showing that grade on a solution. As pointed out above under Basic Calculator Rules, when a number is to be used in performing calculations, the rule is not to round it off. On the other hand, when the grade is to be written on a solution, it must be rounded off according to the problem statement requirements, or, in the absence of specific requirements, according to the guidelines presented above.

Rounding off is defined as the removal of unnecessary digits. Follow these three round off rules:

RULE 1. If the last digit to the right of the decimal to be dropped *is less than 5*, then the next digit to the left stays the same. For instance, 0.5813 rounded off to three decimal places is 0.581, because 3 (the last digit) is less than 5.

RULE 2. If the last digit to the right of the decimal to be dropped *is equal to or greater than 5*, then the next digit to the left is increased by 1. For instance, 0.5816 rounded off to three decimal places is 0.582 because 6 (the last digit) is greater than 5.

RULE 3. To round off several decimal places, round off each place, in order, from right to left. For instance, rounding off 0.52872848 to one decimal place yields in order 0.5287285, 0.528729, 0.52873, 0.5287, 0.529, 0.53 and finally 0.5.

A Word About Units of Measurement

In the United States, the standard unit of measurement for lineal distances is U.S. units. That is, inches, feet, yards and miles. In virtually all other parts of the world, units are expressed in S.I. units (S.I. units is the technical term for metric units). This workshop is based on U.S. units. Decimal feet and inches are the predominate units of measurement.

When registering for the exam, CLARB gives all examinees the choice of writing the exam in metric, or in U.S. units. If U.S. units are chosen, the entire exam will be in U.S. units; if S.I. units are chosen, the entire exam will be in S.I. units. “Mixing and matching” units is not permitted.

In the context of cartography (map making) and surveying, there are several conventions that apply to both U.S. and S.I. units. One convention that’s relevant to the LARE is the difference between horizontal and vertical measurements.

- Horizontal measurements — units of measurement (i.e., feet) will almost always be noted for horizontal measurements.

- Vertical measurements — units of measurement (i.e., feet) are not normally noted for vertical measurements, even though they are, in fact, in feet or meters — **it is universally assumed that the individual viewing the units knows that the units of measurement are in feet or meters.**

This convention is likely an outgrowth of cartographic convention. Note that contour line elevation callouts shown on topographical maps never note units of measurement in feet or meters. Only the number representing the elevation is noted — it is assumed that the elevation is in feet, or meters, above some datum, such as mean sea level. This is also true for individual elevation callouts identified on topographic maps. Similarly, units are generally not indicated on spot elevations on a grading plan or a survey, even though the elevations are, in actuality, feet above some datum.

One minor advantage of this convention is that it makes it easier to differentiate between horizontal and vertical measurements.

Summarizing the rule, units of measurement are shown for horizontal measurements; they are not shown for vertical measurements.

THE THREE BASIC GRADING FORMULAS

G **Grade — the slope or incline of a surface expressed as a percentage**
To calculate ***G***, the vertical difference in elevation **(*D*)** and the length **(*L*)** must be known, or be measurable by scaling.

The formula for determining Grade is $G = \frac{D}{L}$

A grade of 1% means that for each 100 feet horizontally, the vertical difference in elevation is one-foot, as shown in Figure 1.

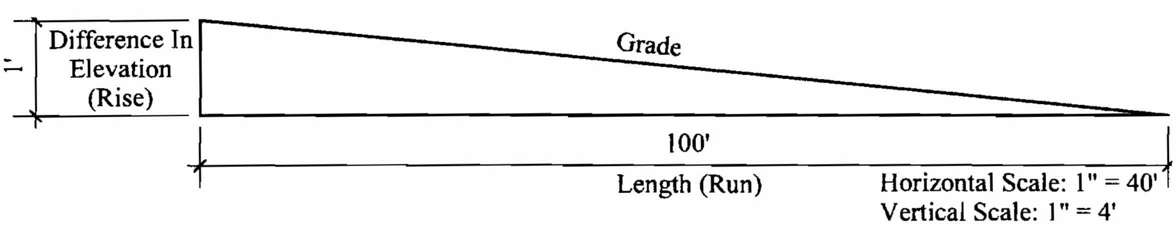


Figure 1. A 1% Grade

A grade of 2% means that for each 100 feet horizontally, the vertical difference in elevation is two-feet; for a 3% grade, the vertical difference in elevation is 3 feet, and so on.

D **Difference in elevation vertically**
When the elevations of *both points are known*, ***D*** may be found by simple subtraction. When the elevation *of only one point is known,* the formula shown below is used to find the difference in elevation between the known point and the unknown point. To calculate ***D***, the grade and the horizontal length between two points must be known, or be found by scaling. The formula for determining the vertical Difference in elevation is $D = G\,L$

L **Length — the horizontal measurement between two points**

(Note that both *difference* and *distance* begin with the letter ***D***. To avoid confusion, use the word *length* rather than *distance* to describe the horizontal measurement between two points.) To calculate ***L***, the difference in elevation (***D***) and the grade (***G***) must be known.

The formula for determining Length is $L = \frac{D}{G}$

The three grading formulas must be committed to memory. The memory aids shown in Figure 2 can be helpful in recalling these formulas while memorizing them:

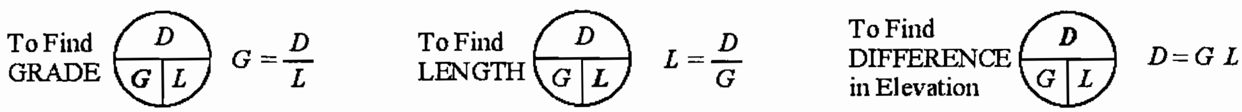


Figure 2. Grading Formula Memory Aid

HOW TO DETERMINE GRADE

Use the grading formula $G = \frac{D}{L}$ to find the grade of any plane surface when the difference in elevation between the low end and the high end can be determined, and the length between the two ends is given by dimension, or in the problem statement, or can be determined by scaling.

Relevancy to the exam: Determining the grade of a plane surface, or of a drainline, is the most basic of all grading skills. You will use this skill directly as part of solving grading problems where the grade is required as the end result (e.g., where the grade of a drainline is required); you'll also use it indirectly when finding the grade is the first step to solving one of the other grading formulas when the grade is not provided.

Summary of Steps:

Step 1. Determine the vertical difference in elevation between the two ends of the plane surface for which the grade is to be found by simply ***subtracting** the lower elevation from the higher.* If the elevations happen to be entered in reverse order, complete the subtraction and use the sign change key on your calculator to make the number positive before performing any additional calculations.

Step 2. Determine the horizontal length between the two ends. If the length is not given in the problem statement, or by a dimension, you must scale it.

Step 3. Using the *grade formula* $G = \frac{D}{L}$, substitute in the difference in elevation (D) from step 1, and the length (L) from step 2. Divide to find the grade (G).

Example: Determine the grade of the plane surface shown in Figure 3:

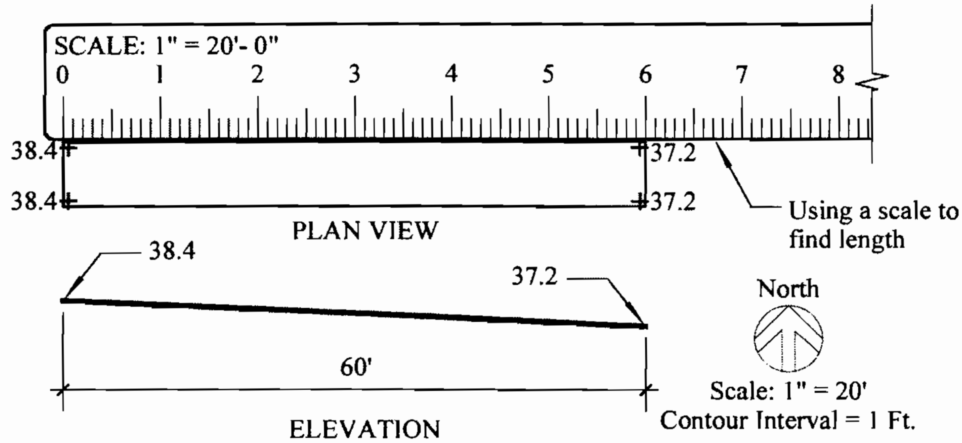


Figure 3. Finding the Grade of a Plane Surface

Step 1. Determine the vertical difference in elevation by subtracting (38.4 from 37.2 equals 1.2)

Step 2. Scale the length (it is 60 feet).

Step 3. Substitute in the difference in elevation and the length as follows:

$$D = 1.2 \quad L = 60 \text{ feet}$$

$G = \frac{D}{L} = \frac{1.2}{60} = .02$. Therefore, the grade of the plane surface is .02.

HOW TO DETERMINE DIFFERENCE IN ELEVATION

Use the *difference formula* $D = G\ L$ to find vertical difference in elevation between two points when the *grade is known, and the length between the two ends is given, or can be determined by scaling.*

Relevancy to the exam: Like the basic formula to find grade, finding the difference in elevation is part of many of the other calculations you will be required to perform to solve many kinds of grading problems, such as finding an unknown elevation when one elevation is known, or determining if cover over a drainline is sufficient.

Summary of Steps:

Step 1. Determine the horizontal length between the two ends. If the length is not given in the problem statement or by a dimension, scale it.

Step 2. Note the grade (it must be given).

Step 3. Use the *difference formula* $D = G\ L$
Substitute in the grade (G) from step 1, and the length (L) from step 2. Multiply to find the difference (D).

Example: Determine the difference in elevation between ends A and B of the plane surface shown in Figure 4:

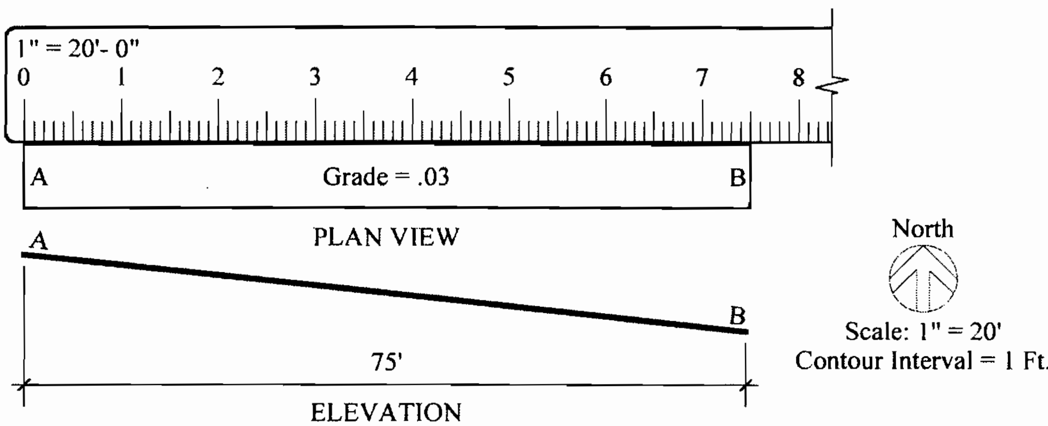


Figure 4. Finding the Difference in Elevation Between End A and End B

Step 1. Use scale to find length of plane surface.

Step 2. Note grade of .03.

Step 3. Substitute in the difference in elevation and the length as follows:

$G = .03 \quad L = 75$ feet

$D = G\ L = (.03)\,(75) = 2.25$. Round off to 2.3

HOW TO DETERMINE THE ELEVATION OF UNKNOWN POINT OR POINTS

When one elevation is known, use the *difference formula* $D = G\ L$ to find vertical difference in elevation between it and an unknown elevation or elevations.

Relevancy to the exam: Determining the elevation or elevations of unknown points is another basic skill frequently tested for. Problems utilizing this skill take many forms. One typical form is where the elevation of one corner of a plane surface has been given along with longitudinal and cross slope grades. You must then determine the elevations of the other three corners. Another common variant is where a drainline slope and an invert elevation of a drain inlet are provided. You are then required to determine the invert in or invert out of an adjacent drain inlet.

Summary of Steps:

Proceed as explained in "How to Determine Difference in Elevation" above. Once the difference in elevation is known, follow these steps:

Step 1. Identify and note the known elevation point.

Step 2. Determine direction pipe slopes. This information must be given. Look for slope arrows in conjunction with the slope of the pipe or, check to see if there is an endwall or some other outlet that indicates the direction of flow.

Step 3. If the unknown elevation is higher than the known elevation, add the difference in elevation to find the unknown elevation; if the unknown elevation is lower than the known elevation, subtract the difference in elevation to find the unknown elevation.

Determining the Unknown Invert Elevation at a Drain Inlet

Figure 5 shows a length of drainline and two drain inlets (abbreviated DI). The elevation is given at DI No. 2; the goal is to determine the invert elevation at DI No. 1.

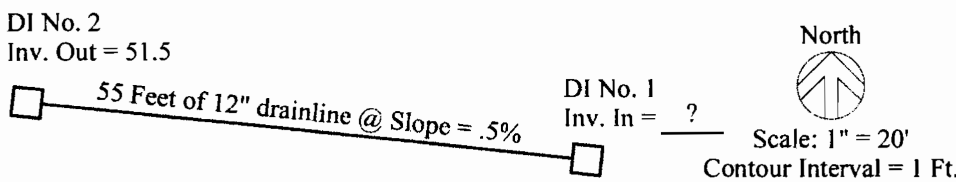


Figure 5. Finding an Unknown Elevation When One Elevation is Known

As noted on the pipe, the drainline is 55 feet long x 12-inches in diameter with a slope of .005 (.5%). The invert elevation *out* at DI No. 2 is 51.5. What is the invert elevation *in* at drain inlet Number 1? To find this elevation, the first step is to find the difference in elevation between the two drain inlets.

Step 1. Use the *difference formula* $D = G\,L$ to find the difference in elevation. Substitute in the grade and length as follows:

$G = .005 \quad L = 55$ feet

$D = G\,L = (.005)\,(55) = .275$. Therefore, the difference in elevation is .275

Step 2. Since the invert elevation in at D.I. No. 1 is lower than the invert elevation out at D.I. No. 2 (because water flows downhill), the difference in elevation will be subtracted from the known elevation at D.I. No. 2 as follows:

$51.5 - .28 = 51.225$. Therefore, the invert elevation in at D.I. No. 1 is 51.23

Finding Unknown Corner Elevations on a Plane Surface

The elevation at corner A of the plane surface shown in Figure 6 is 33.4. The goal is to find the unknown elevations corners B, C and D.

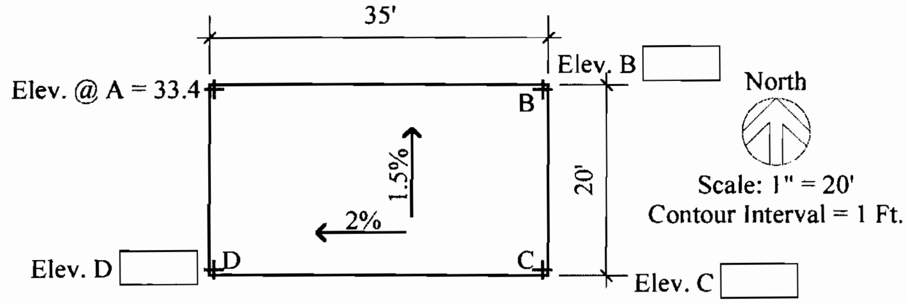


Figure 6. Finding Unknown Elevations at the Corners of a Plane Surface

Observe that the plane surface shown in Figure 6 is dimensioned and that both the longitudinal (long axis) and cross slope (short axis) grades are given. Also note that corner A is the *lowest* point on the plane surface as indicated by the flow arrows.

The process for finding the unknown elevations is identical to the process followed in the first example. In this case, three unknown elevations must be found. In addition, the elevation at corner C must be calculated based on one of the previously found corner elevations (corner B or corner D).

Step 1. Begin by finding the elevation at corner B as follows:

$G = .02 \quad L = 35$ feet

$D = G\,L = (.02)\,(35) = .7$. Therefore, the difference in elevation between corners A and B is .7.

Step 2. Since the grade arrow points uphill, the difference in elevation must be *added* to the elevation at corner A as follows:
$33.4 + .7 = 34.1$. Therefore, the elevation at corner B is 34.1.

Step 3. Find the elevation at corner D in the same manner:

$G = .015 \quad L = 20$ feet

$D = G\,L = (.015)\,(20) = .3$. Therefore, the difference in elevation between corner A and D is .3.

Step 4. Since the grade arrow points uphill, the difference in elevation must be *added* to the elevation at corner A as follows:

$33.4 + .3 = 33.7$. Therefore, the elevation at corner B is 33.7.

Step 5. Find the elevation at corner C. As noted above, corner C must be based on one of the two previously found elevations. In this example, the elevation at corner B will be used as the basis for corner C as follows. Note the difference in elevation from Step 1 is .7.

$$G = .015 \quad L = 20 \text{ feet}$$

$$D = G\,L = (.015)\,(20) = .3$$ This is the difference in elevation

Step 6. As in finding the previous corners, the grade arrow points uphill, so the difference in elevation will be *added* to the elevation at corner B as follows:

$34.1 + .3 = 34.4$. Therefore the elevation at corner C is 34.4.

Review the solution shown in Figure 7.

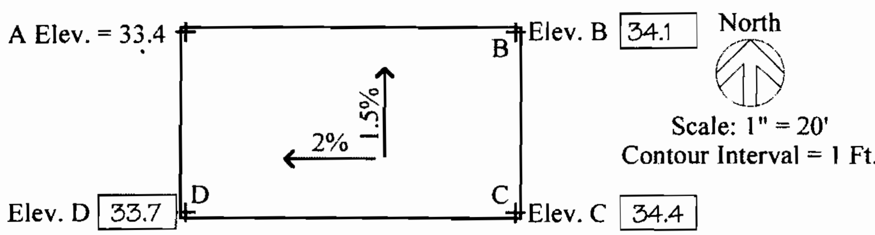


Figure 7. Solution

How To Determine Length

Use the *length formula* explained below to find horizontal length when the *grade and the difference in elevation are known.*

Relevancy to the exam: Determining the length between two points is the third of the basic skills you must grasp. Although length may, or may not, be tested for directly, it certainly will be tested for indirectly, particularly in plotting whole number contour lines (see next section).

Summary of Steps:

Step 1. Determine the vertical difference in elevation between two points *by subtracting the lower elevation from the higher.*

Step 2. Note the grade (it must be given).

Step 3. Using the *length formula* $L = \frac{D}{G}$, substitute in the difference in elevation (D) from step 1, and the grade as given. Divide to find the length in feet (L).

Example: Determine the length of the plane surface shown in Figure 8.

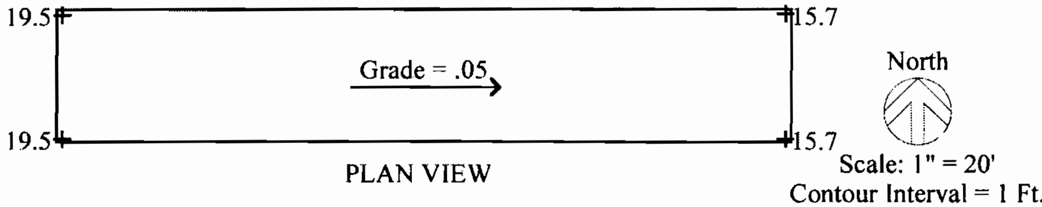


Figure 8. Finding the Length of a Plane Surface

Step 1. Determine the vertical difference in elevation by subtracting

$$19.5 - 15.7 = 3.8$$

Step 2. Note the grade of .05.

Step 3. Calculate the length as follows:

$$D = 3.8 \quad G = .05$$

$L = \frac{D}{G} = \frac{3.8}{.05} = 76$ feet. Therefore, the length of the plane surface shown in Figure 8 is *exactly* 76 feet.

HOW TO PLOT WHOLE NUMBER CONTOUR LINES

Relevancy to the exam: Plotting contours on a plane surface such as a walk, a terrace, or a sports field, or along the centerline of a road, or the flowline of a swale, is the one basic grading skill you can absolutely count on being tested for on the LARE — likely more than once, and probably in several different ways. Needless to say, being able to do this quickly and accurately is imperative. The following methodology directly addresses the twin issues of speed and accuracy.

Overview: Plane surfaces, centerlines, and flowlines usually do not begin or end with whole number elevations. This is true in the "real world" as well as the LARE. Because of this, the length to the first whole number contour line will be different, *and shorter,* than the length between the remaining contours. As a result, the process of plotting whole number contour lines will involve two separate length calculations:

- The first will be to find the first whole number contour line below the high end (see high end explanation below under Step 2).
- The second will be to find the length between the remaining whole number contour lines.

There are two possible whole number contour plotting situations you'll encounter. The simplest is where a grade *is* provided and contours must be plotted to reflect that grade. The second is where a grade *is not* provided, but sufficient information is available so that the grade can be determined. The following explanation and example will be based on the latter condition.

In order to plot whole number contour lines, the elevation at each end of the plane surface must be known and the overall length must be given or be measurable by scaling.

Summary of Steps:

Step 1. Find the difference in elevation between the two ends and calculate the longitudinal grade by using the *grade formula* $G=\frac{D}{L}$. If a length is not provided by dimension or in the problem statement, it must be scaled.

Step 2. Calculate the length to the *first whole number contour line from the* ***high end*** *of the plane surface* using the *length formula* $L=\frac{D}{G}$

Measure the length from the high end to eliminate the possibility of error and to save time. Starting at the high end reveals the difference in elevation without having to subtract — the digits to the right of the decimal point denote the difference in elevation (see Figure 9 and the following example).

Step 3. Find the length between the remaining whole number contour lines. Remember that the contour interval is 1 (almost always), so 1 will be substituted for *D*. Use tick marks to indicate the locations where all remaining contour lines cross.

Step 4. Draw and number whole number contour lines on the plane surface.

Example: Review the problem shown in Figure 9. The goal is to plot the contour lines on the plane surface. (Note that the contour interval is one foot. Although this is by far the most commonly used contour interval, always check the vignette. Be aware that CLARB doesn't state the contour interval on the plan — you have to look at the contour elevation callouts to determine the contour interval.)

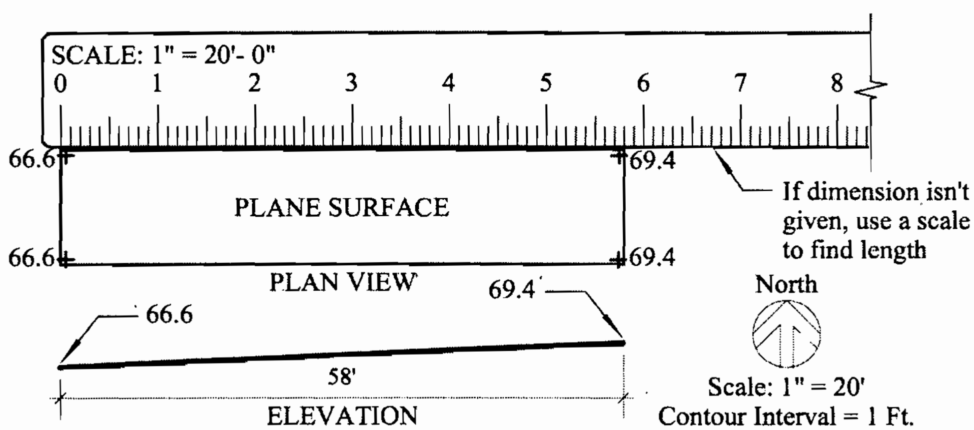


Figure 9. Plotting Whole Number Contour Lines — Finding Grade

Step 1. Begin by finding the grade.

Determine the difference in elevation between the two ends:

$$69.4 - 66.6 = 2.8$$

Observe that the overall length between the ends is 58 feet based on the dimension shown on the plan. Calculate grade by substituting in the difference in elevation and the length:

$D = 2.8 \quad L = 58$ feet   PRESS M+

$G = \frac{D}{L} = \frac{2.8}{58} = .048275862$. This is the grade. Place the entire number as displayed into calculator's memory.   PRESS MRC

Step 2. Place this number in your calculator's memory *in non-rounded form.* Doing so is critical. First, because this number will be used at least two-times: initially to find the length to the first whole number contour line, and then again to find the length the first contour and the remaining contours. (It may also be used a third time to find the cross slope if one is required — the process for doing this will be explained in class.) Second, as pointed out previously, rounding off can significantly compromise accuracy. Keep in mind that on the LARE, almost all plane surfaces are "precision" surfaces, meaning that the contours must be accurately plotted.

Step 3. Find the length to the first whole number contour line *below* elevation 69.4 at the *high end,* which will be contour 69. Note that the difference in elevation of .4 was revealed without having to subtract. Substitute in the difference in elevation and the grade as follows:

$D = .4 \quad G = .048275862$

$L = \frac{D}{G} = \frac{.4}{.048275862} = 8.285714286$ feet. Round off to 8.3 feet. Therefore, the length to the first whole number contour line is 8.3 feet

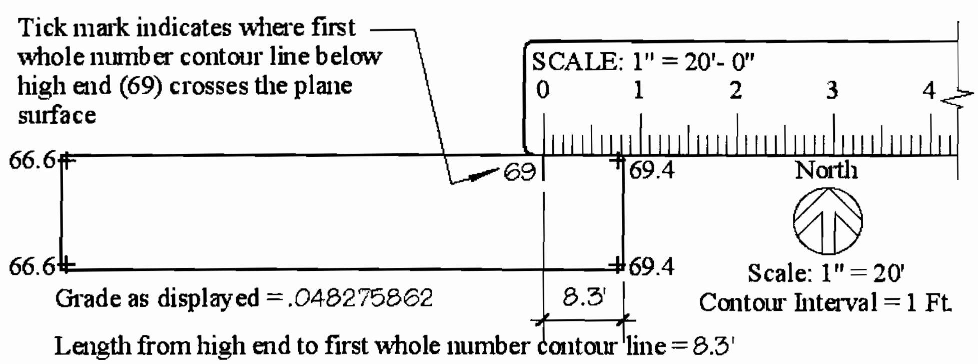


Figure 10. Scale to Locate First Whole Number Contour Line

Step 4. Scale 8.3 feet west from the high end (69.4) and place a tick mark at that point. Number it "69" to keep track of which contour it represents as shown in Figure 10.

Step 5. Find the length between all subsequent whole number contour lines. Note that the difference in elevation between 69 and 68 is one (1) foot, and that the grade remains .048275862. Substitute in the difference in elevation and the grade as follows:

$$D = 1 \quad G = .048275862$$

$$L = \frac{D}{G} = \frac{1}{.048275862} = 20.71428571 \text{ feet}$$. Round off to 20.7 feet. Therefore, the length between the remaining whole number contour lines is 20.7 feet

Step 6. Use a scale to measure 20.7 feet west from previously found contour 69 crossing point. Place a tick mark at that point and number "68" as shown in Figure 11.

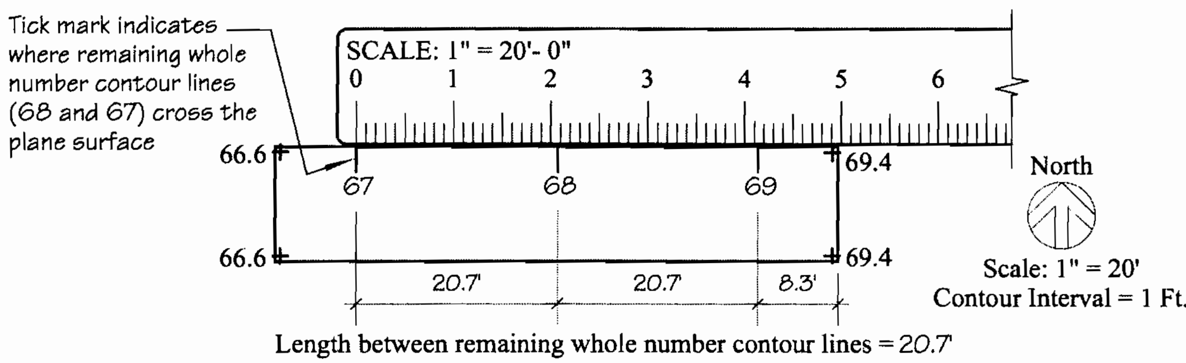


Figure 11. Scale to Locate Remaining Whole Number Contour Lines

Step 7. Draw and label contours as shown in Figure 12. This completes the process of plotting whole number contour lines on this simple plane surface.

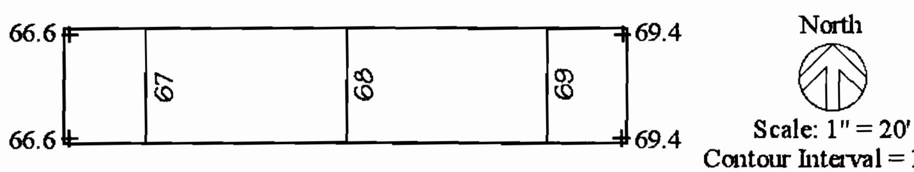


Figure 12. Draw and Label all Whole Number Contour Lines

The Case for not Rounding Off: To dispel any lingering doubt about why it is imperative that the calculated grade not be rounded off, review the next two examples. The problem for both examples is shown by Figure 13. (Note scale is 1" = 40'.)

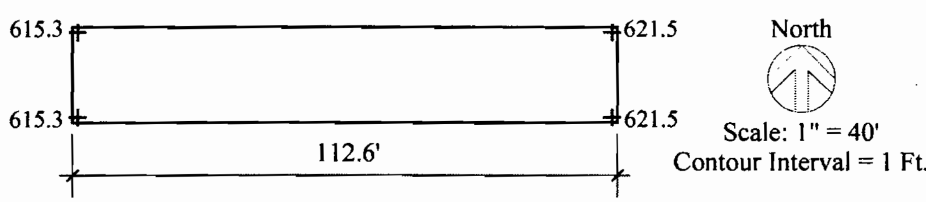


Figure 13. Example Problem — Plotting Whole Number Contour Lines

Example 1 — Correctly Done: Grade Not Rounded Off

Step 1. Begin by finding the grade.

Determine the difference in elevation between the two ends:

$621.5 - 615.3 = 6.2$

Observe that the overall length between the ends is 112.6 feet as shown by the dimension.

Calculate grade by substituting in the difference in elevation and the length:

$D = 6.2 \quad L = 112.6 \text{ feet}$

$G = \frac{D}{L} = \frac{6.2}{112.6} = .055062166$. This is the grade. Place the entire number as displayed into calculator's memory.

Step 2. Find the length to the first whole number contour line *below* elevation 621.5 at the high end, which will be contour 621. The difference between 621.5 and 621 is .5. (Again, starting from the high end made it unnecessary to subtract.) Substitute in the difference in elevation and the grade as follows:

$D = .5 \quad G = .055062166$

$L = \frac{D}{G} = \frac{.5}{.055062166} = 9.080645161 \text{ feet}$. Round off to 9.1 feet, the length to the first whole number contour line.

Step 3. Use a scale to measure 9.1 feet west from end 621.5. Place a tick mark at that point and number it "621" to keep track of which contour it represents as shown in Figure 14.

Step 4. Find the length between all subsequent whole number contour lines. Note that the difference in elevation between 621 and 620 is one-foot. Note that the grade remains .055062166. Substitute in the difference in elevation and the grade as follows:

$D = 1 \quad G = .055062166$

$L = \frac{D}{G} = \frac{1}{.055062166} = 18.16129032 \text{ feet}$. Round off to 18.2 feet, the length between the remaining whole number contour lines scaled from contour 621.

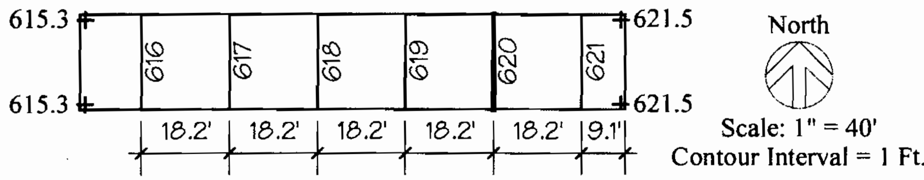


Figure 14. Example 1: Correct Solution with Grade *Not* Rounded Off

Step 5. Use a scale to measure 18.2 feet west from previously found contour 621, then 18.2 feet between the remaining contours as shown in Figure 14.

Example 2 — Incorrectly Done: Grade Rounded Off

Step 1. This example begins in the same way as in Example 1 by determining the grade of the plane surface, EXCEPT THAT THE GRADE HAS BEEN ROUNDED OFF FROM .055062166 TO .06.

Step 2. Find the length to the first whole number contour line *below* elevation 621.5 at the high end, which will be contour 621. The difference between 621.5 and 621 is .5. (Again, starting from the high end made it unnecessary to subtract.) Substitute in the difference in elevation and the grade as follows:

$$D = .5 \quad G = .06$$

$L = \frac{D}{G} = \frac{.5}{.06} = 8.3333$ feet. Round off to 8.3 feet, the length to the first whole number contour line.

Step 3. Use a scale to measure 8.3.1 feet west from the high end (621.5). Place a tick mark at that point and number it "621" to keep track of which contour it represents as shown in Figure 14.

Step 4. Find the length between all subsequent whole number contour lines. Note that the difference in elevation between 621 and 620 is one-foot. Note that the grade remains .055062166. Substitute in the difference in elevation and the grade as follows:

$$D = 1 \quad G = .06$$

$L = \frac{D}{G} = \frac{1}{.06} = 16.66667$ feet. Round off to 16.7 feet, the length between the remaining whole number contour lines scaled from contour 621.

Figure 15 on the next page shows the resulting incorrect solution. Remember, the calculations were done in exactly the same manner as in Example 1, except the grade was rounded off to .06 rather than the calculated grade of .055062166. Although at first glance, this solution may appear correct, a closer examination will reveal that *contour 615 is actually lower than the west end* of the plane surface, which has an elevation of 615.3. In other words, contour 615 is three tenths lower than the end, which is physically impossible. The moral of Example 2: Never round the grade off when plotting whole number contour lines.

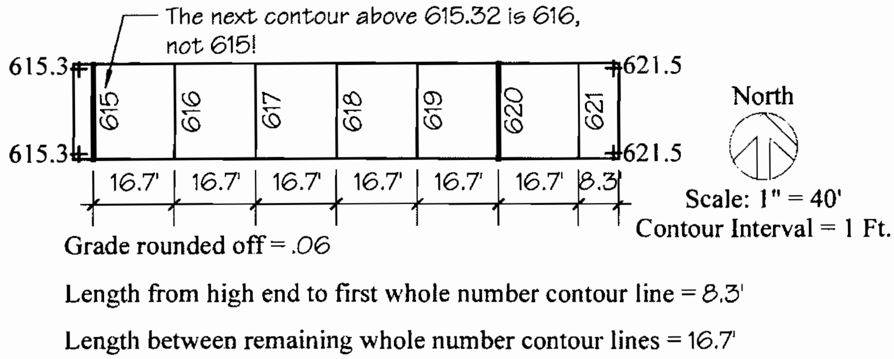


Figure 15. Example 2: Incorrect Solution Showing Consequences of Rounding Off the Grade

Review — Since the focus of the proceeding section was on plotting whole number contour lines, a brief review of the standard graphic conventions for drawing and numbering contour lines is in order. Remember them. They apply anytime you plot or draw whole number contour lines:

- Revised contours are to be drawn as solid lines, and drawn heavier than existing contours.
- Every 5th contour line is drawn heavier than the others.
- Elevation call-outs are to be placed on the high (uphill) side of the contour lines and are written without parentheses. (Inexplicably, CLARB ignores this standard graphic convention by omitting parenthesis on existing elevation callouts.)
- Where revised contour lines rejoin existing contour lines, a tick mark is required.
- Flow arrows — although optional, they're highly recommended — they not only help to convey the intent of your solution to the graders scoring your exam, but just as importantly, they provide you with a means for validating the orientation of the contours you've drawn.

CALCULATOR SHORTCUTS

Relevancy: It goes without saying that anything that can save time and reduce the potential for error is worthwhile. Most modern calculators have four features that help you do both. Here are the principal shortcut functions:

- Reciprocal
- Memory
- Sign change key
- Constant

Reciprocal Function

The reciprocal function can be used to find either grade or length when the contour interval is one-foot. The reciprocal function 1/X divides *one* by the value of X, which is the variable. Most scientific calculators have a dedicated reciprocal key *as a first function* (usually noted as 1/X on the keypad). Although most modern full-featured low-end calculators, such as those mentioned in the Introduction, have a reciprocal function, they lack a *dedicated* reciprocal key. Nevertheless, most do have a reciprocal function. It's invoked by entering the variable (X), pressing divide, then equals. Although this adds one keystroke, it still saves time and reduces the chance of error. Use of the reciprocal function is explained here for both types of calculators.

1. Using The Reciprocal Function to Find Grade:

The reciprocal function can be used to find *Grade* when the contour interval is one-foot. The procedure could not be simpler:

- For calculators *that have a dedicated reciprocal function,* scale the length between contour lines, enter the length in feet and press 1/X. The number displayed is the grade expressed in decimal form.

- For calculators *that do not have a dedicated reciprocal function,* scale the length between contour lines, enter the length in feet, press divide, then equals. The number displayed is the grade expressed in decimal form.

IMPORTANT DISTINCTION IN CALCULATING GRADE: Be aware that there is a fundamental difference between determining grade based on the length between contours on paved and non-paved surfaces. On paved (hardscape) surfaces, it is imperative that the *longitudinal grade be based on the length between contours scaled along the edge of the plane surface*, or *along a centerline if the plane surface is a road or other bilaterally symmetrical surface* as shown in Figure 16. It should not be scaled perpendicularly to the contours. The only exception to this rule is where the exam explicitly requires that the grade be calculated along a line perpendicular to the contour lines across a plane surface.

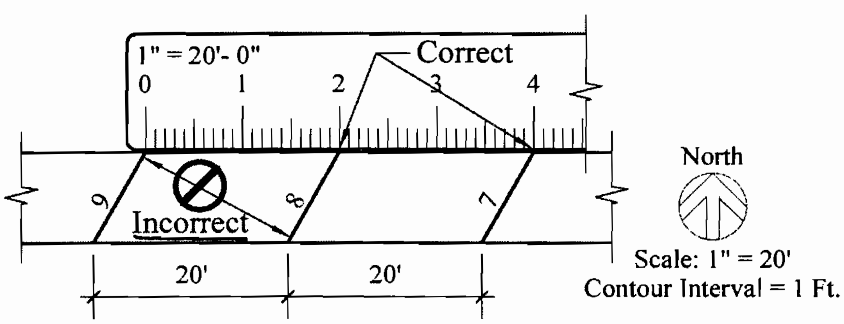


Figure 16. Correctly Scaling the Length Between Contours on a Walk Having Cross Slope

In the case of a road or a ditch, *scale along the centerline. "point-to-point,"* as shown in Figure 17.

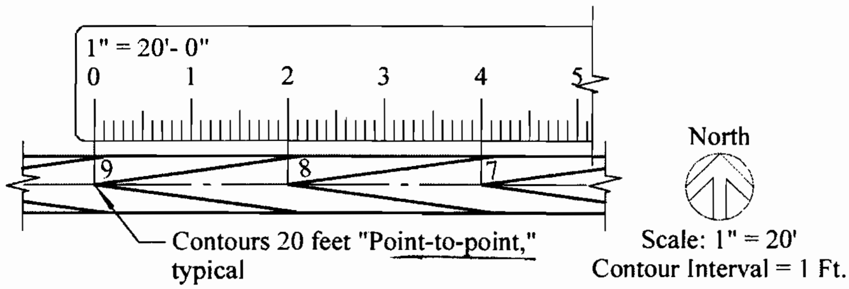


Figure 17. Correctly Scaling the Length Between Contours on a Ditch

On non-hardscape surfaces, since there is no point of reference, scaling can only be done by scaling *perpendicular to the contour lines* as shown in Figure 18.

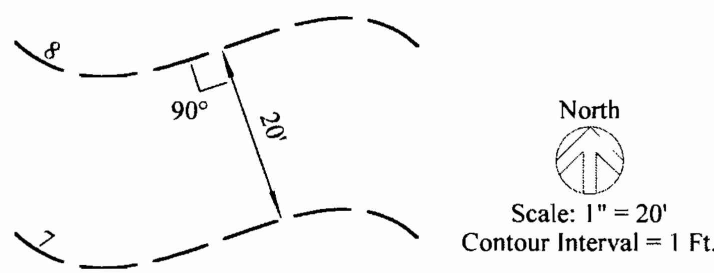


Figure 18. Correctly Scaling the Length Between Contour Lines on a Non-paved Surface

Swales present a special condition: in non-paved areas, the grade along the *flowline* is measured "point-to-point," in the same way that the ditch is in Figure 17. However, the *side slope* grade of a non-hardscape swale is measured perpendicular to the contour lines as shown in Figure 18.

The following example is based on Figures 13, 14, and 15. In all three figures, the scaled length between contour lines is 20 feet. (This example assumes a calculator with a "dedicated" reciprocal key.)

Enter 20 and press $1/X$. The display will read .05. Therefore, the longitudinal grade of all three figures is 5%.

2. Using The Reciprocal Function to Find Length:

The reciprocal function can be used to determine the *Length* between contour lines where the contour interval is one (1) foot and the grade is either known or can be determined. (Using the reciprocal function *to find the length between whole number contour lines* is a significant time-saver, particularly when plotting whole number contours.)

Summary of Steps:

Step 1. Determine the grade of the plane surface if it is not given. Once the grade has been determined, place it in memory. Remember, as explained above under "How to Plot Whole Number Contour Lines," the grade will be used at least two-times — first to find the length to the first whole number contour line, then to find the length between the remaining contours.

Step 2. Proceed as follows:

Example: Find the length between contours for Figure 19:

Step 1. In this example, the grade is not given, so it must be determined, as shown in Figure 19. Begin by finding the difference in elevation between the ends of the plane surface and then calculating its grade:

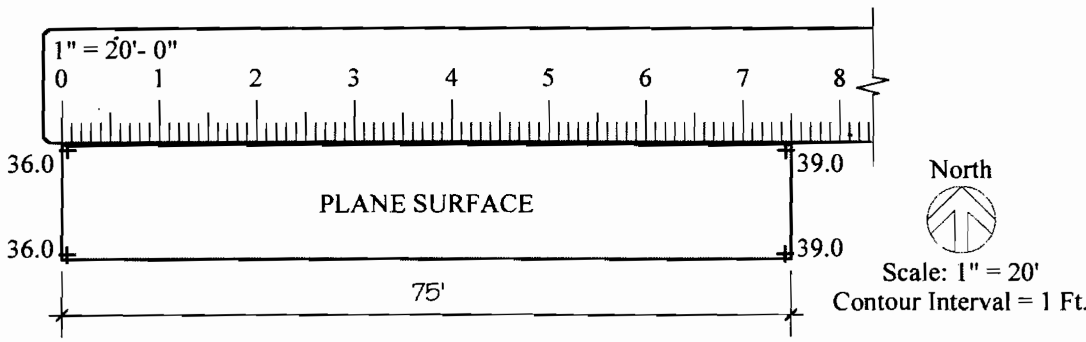


Figure 19. Reciprocal Function First Step — Finding Grade of Plane Surface

Find the difference in elevation: $39-36=3$

Scale the length of the plane surface (75 feet).

Find Grade:

$D=3 \quad L=75\text{ feet}$

$G=\frac{D}{L}=\frac{3}{75}=.04$. This is the grade. Place the number as displayed into calculator's memory.

Step 2. For calculators having a dedicated reciprocal function, press memory recall, then $1/X$. For calculators that do not have a dedicated reciprocal function, press memory recall, then divide, then equals. In either case, the result will be 25 feet. Plot the contour lines as shown in Figure 20.

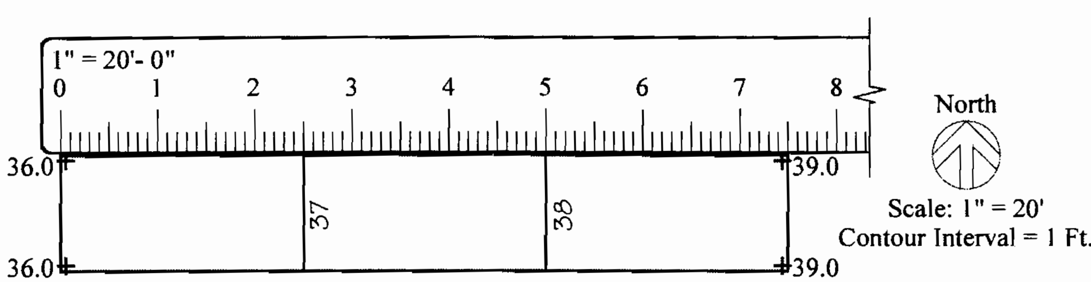


Figure 20. Example — Plotting Whole Number Contour Lines @ 25' OC on Plane Surface

WORKING WITH CONTOUR INTERVALS OTHER THAN ONE FOOT TO FIND GRADE OR LENGTH:

What if the contour interval is something other than one-foot? Using the reciprocal function may still be an advantage, although it adds one additional keystroke compared to simply using either the *grade formula* $G=\frac{D}{L}$ or the *length formula* $L=\frac{D}{G}$. You may still find it simpler to use the reciprocal function. (Using the reciprocal function is not recommended for calculators *not having* a dedicated reciprocal key because it adds *two* keystrokes.) Here is how to proceed.

To Find Grade:

- For calculators having a dedicated reciprocal key, enter the length, press $1/X$, then multiply the result by the contour interval.

  Example One: Assume a contour interval of two-feet, and a scaled length between contour lines of 100 feet. Enter 100, press the reciprocal key, then multiply the result by two. The result is a grade of 2%.

  Example Two: Assume a contour interval of five-feet, and a scaled length between contour lines of 500 feet. Enter 500, press the reciprocal key, then multiply the result by five. The result is a grade of 1%.

To Find Length:

- For calculators having a dedicated reciprocal function, enter the grade, press $1/X$, then multiply the result by the contour interval.

MAXIMIZING SPEED WHEN PLOTTING CONTOUR LINES

This Section revisits the process of plotting whole number contour lines, but with an emphasis on maximizing speed. The process shown below should be memorized. (Important: To avoid confusion, it is strongly recommended that you be thoroughly familiar with the underlying principles of plotting whole number contour lines as explained above before attempting to utilize this method.) To effectively utilize this shortcut method, it is also imperative that you be completely familiar with the operation of your calculator — especially the use of memory, the reciprocal function and the constant function (where available). With practice, the method demonstrated in this section has the potential of reducing the time takes to plot contours by up to 50%! Ideally, with complete familiarity, plotting contours will become virtually automatic. Optimally, you should strive to attain this level.

In the following example, whole number contour lines are to be plotted on the plane surface shown in Figure 21.

Assumptions:

- The longitudinal grade *is not* given, so it must be calculated.
- The plane surface is to be straight graded.
- The plane surface *does not* have cross slope.
- The elevations at the ends of the plane surface *are not* whole numbers.
- The calculator used will have a *single* full memory, a *reciprocal function* (**without a dedicated reciprocal key**), and a *constant function.*

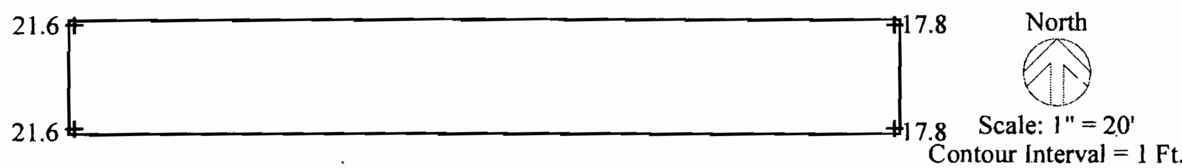


Figure 21. Example — Plane Surface

Step 1. Find grade of the plane surface shown in Figure 21.

Find difference in elevation: $21.6 - 17.8 = 3.8$. Use scale to find the length of the plane surface (75 feet).

Find the Grade as shown in Figure 22:

$D = 3.8 \quad L = 85.7$ feet

$G = \frac{D}{L} = \frac{3.8}{85.7} = .044340723$. This is the grade. Place the entire number as displayed into calculator's memory.

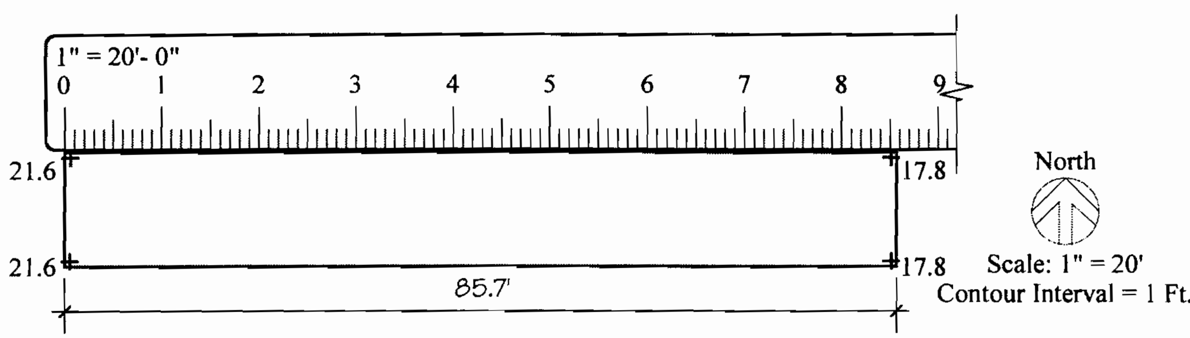


Figure 22. Example — Determining Grade

Step 2. Find the length to the first contour as follows:

√ Enter .6 (the difference between elevation 21.6 and contour 21)

√ press divide (operand)

√ press recall (recalls grade stored in memory) (MIRC)

√ press equals (completes calculation). The result displayed will be 13.53157895. Round off to 13.5 feet

√ scale 13.5 feet from west (high) end and place a tick mark at the edge of the plane surface to indicate the location of contour 21.

It is necessary to place a tick mark rather than attempting to draw in the contour when 1) you're using the constant function (because the scale is not moved, it prevents drawing the contour lines after each measurement); 2) if the plane surface is to have cross slope, the deflection of the contour line from perpendicular must be calculated first. This process, along with calculating cross slopes, will be explained in class.

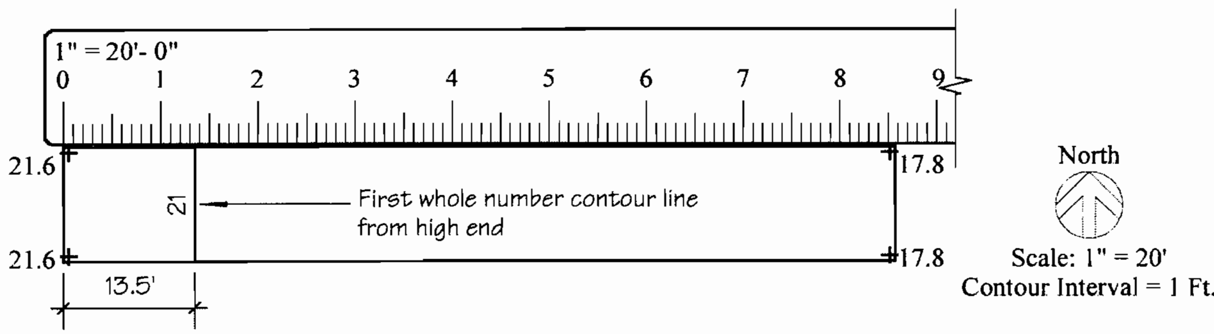


Figure 23. Example — Finding Length to First Whole Number Contour Line

On complex plane surfaces, it is a good idea to number the tick marks to keep track of their elevations to avoid possible confusion later when drawing the contours.

$$D = .6 \quad G = .044340723$$

$$L = \frac{D}{G} = \frac{.6}{.044340723} = 13.53 \text{ feet. Round off to 13.5 feet.}$$

Step 3. Find the length between the remaining contours as follows:

Because the contour interval is one-foot, the reciprocal function can be used to find the length between contour 21 and the remaining contours.

√ Press recall (recalls grade stored in memory) (MIRC)

√ press divide (operand to invoke the reciprocal function)

√ press equals (completes calculation)

√ the result displayed will be 22.55263158. Round off to 22.6 feet

√ scale 22.6 feet from previously plotted contour line 21 and place a tick mark at that point.

$$D = 1 \quad G = .044340723$$

$$L = \frac{D}{G} = \frac{1}{.044340723} = 22.55 \text{ feet. Round off to 22.6 feet.}$$

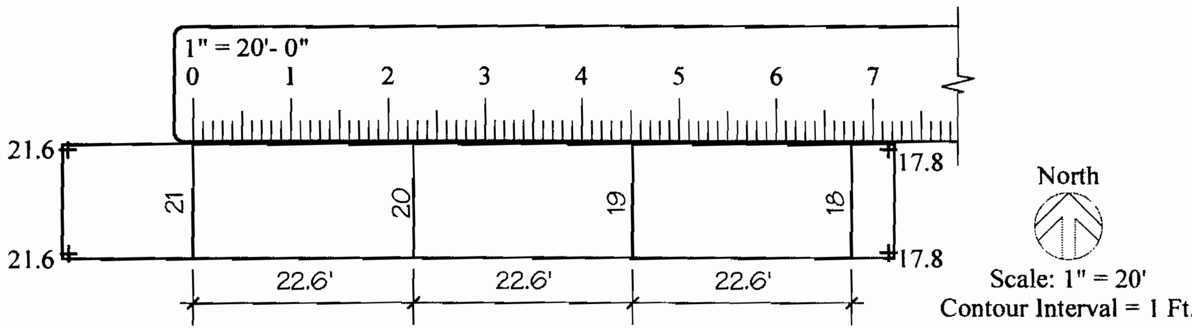


Figure 24. Example — Finding Length Between Remaining Whole Number Contour Lines

At this point, you have two choices: you can plot the contour lines in the conventional way by scaling from point-to-point, moving the scale each time. On this particular problem, that's probably the most efficient way to proceed. However, where there are more than four or five contour lines to be plotted, you can save additional time and improve accuracy by using your calculator's constant function. Here's how to proceed based on the most common type of constant function:

√ leave the entire length as displayed (22.55263158) in the calculator

√ place the zero point of the scale on contour line 21 — the scale will remain in this position throughout as shown in Figure 24

√ scale 22.6 feet east to contour line 20 and make a tick mark

√ on the calculator, press the plus sign (+), then equals (=) — note that the plus sign will pressed *only* this one time

√ the display will now read 45.10526316, which rounds off to 45.1 feet

√ find this length on the scale and make a second tick mark to indicate contour 19

√ press equals again and the display now reads 67.65789474, which rounds off to 67.7 feet

√ find this length on the scale and make a tick mark to indicate contour 18

This process is repeated until all contour lines have been plotted. Notice that each time the equal key is pressed, the number displayed increments by 22.55263158, which is the constant. Some calculators do not support this function — if the number displayed does not increment, it is possible that the calculator being used does not have a constant function. However, be aware that some calculators require that a dedicated key (often a key identified with the letter "K") be pressed to invoke the constant function — check the instructions that came with the calculator.

In addition to saving time, the accuracy of the plot is also improved because it eliminates the cumulative error that arises when the scale is moved for each measurement. And, because the length is being is being added to itself in *its non-rounded off form* each time equals is pressed, the calculator automatically rounds up or down. That being said, the level of accuracy obtained without using the constant function is perfectly adequate. Although the proceeding process for plotting whole number contour lines may appear, because of the number of steps, complicated, it is not. Once you've used this procedure a dozen times or so, it becomes automatic.

* CALCULATING HEIGHT OR DEPTH OF A FEATURE

Relevancy to the exam: This section demonstrates how to design to a specified height or depth. Typical examples of site features that have height or depth are concrete curbs, retaining walls, the crown of a road, or the depth of a ditch or swale. Note that on the exam, retaining walls and curbs almost always have vertical faces, as shown in Figure 25.

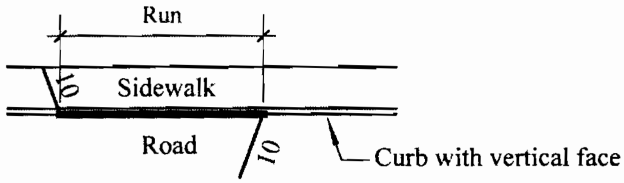


Figure 25. Example — Run on a Curb

In contrast, roads having crowned or depressed centers, ditches, and swales have sloping "faces," as shown in Figure 26.

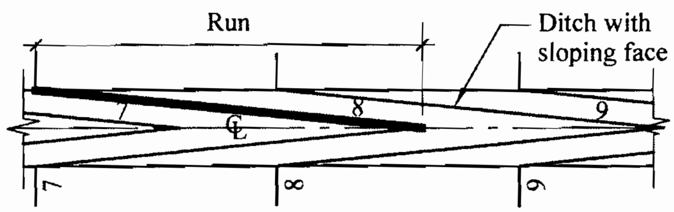


Figure 26. Example — Contour Run in Ditch

Calculating height or depth relies on the concept of the contour line "running" on the vertical or sloping surface of the feature. Both figures demonstrate this concept. In calculating the height or depth of site features, the goal is to find the *length* the contour line must run horizontally. Since length must be found, the *length formula* $L = \frac{D}{G}$ is used.

Summary of Steps:

Step 1. If the longitudinal grade is not given, find it using the *grade formula* $G = \frac{D}{L}$.

Step 2. In most cases, the height or depth of the site feature is given. When it is not given, assume that it is a design decision. If the required height or depth of the feature is given in feet and inches, the inches must be converted to tenths of a foot by dividing the number of inches by 12. For instance, if the height of a wall is given as being 3'-4" high, four inches is divided by 12, equals .33 ($\frac{4}{12}=.33$). Adding the 3-feet to .33 equals 3.33. Therefore, in this example the height of the wall is 3.33 feet.

Step 3. Using the formula $L=\frac{D}{G}$, substitute in the *grade* found in Step 1, and the *difference in elevation* found in Step 2. The resulting answer is the run of the contour line in feet.

Example 1 — Retaining Wall

Figure 27 shows a retaining wall with contour lines located on the high side of the wall. The object is to find the point where contour line 60 will appear on the low (south) side of the retaining wall which is 2'-6" high (note the scale change from 1" = 20' to 1" = 40').

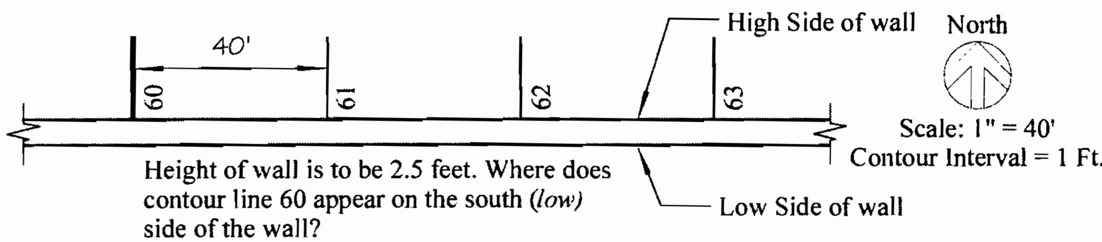


Figure 27. Example 1 — Correctly Show Contours on South Side of Wall

Step 1. Find the longitudinal grade based on the horizontal length between contour lines at the top face of the wall:

$D=1 \quad L=40$ feet

$G=\frac{D}{L}=\frac{1}{40}=.025$. This is the grade. Place the number as displayed into calculator's memory.

Or use the reciprocal function. For calculators with a dedicated reciprocal key, enter 40, press $1/X$); for calculators without a dedicated reciprocal key, enter 40, press divide then equals.

Step 2. Take note of the height of the retaining wall. If it is not given in the problem statement, it will be a "design decision," based on the overall grading design. In this example, the height is given. Since it is in decimal feet, it is not necessary to convert.

Step 3. Calculate the run of contour line 60 on the wall. Substitute in the difference in elevation determined in step 2 by the grade found in step 1 as follows:

$D=2.5 \quad G=.025$

$L = \frac{D}{G} = \frac{2.5}{.025} = 100$ feet. Therefore, contour line 60 must "offset" 100 feet to correctly show the contour lines at the retaining wall as shown in Figure 28.

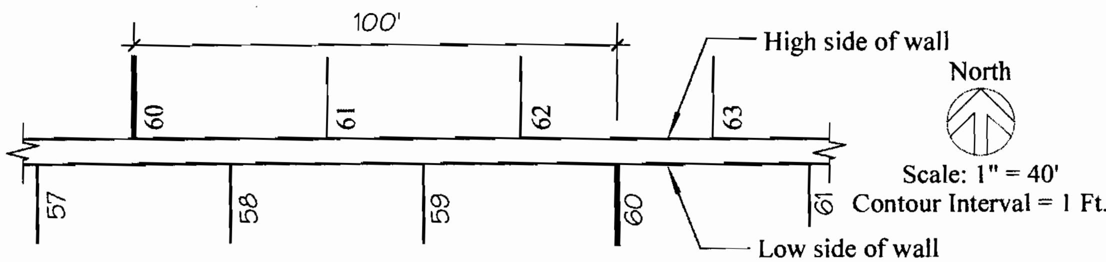


Figure 28. Example 1 — Solution Showing Contour 60 on South Side of Wall

Example 2 — Depth of a Ditch

Figure 29 shows a ditch without the contour lines plotted in the ditch itself. The problem statement requires that the ditch be 14 inches deep. (Note that the scale is 1" = 20'.)

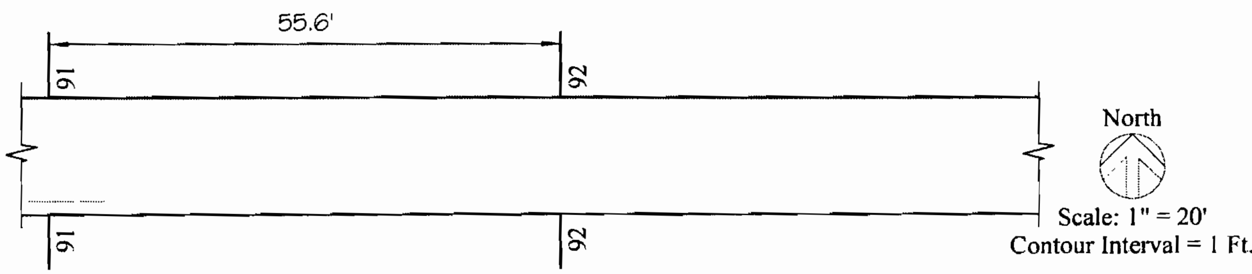


Figure 29. Example 2 — Correctly Show Contour Signature for Ditch that is 14 Inches Deep

The goal in this example is to determine how far the contour lines on the wall of the ditch must deflect to correctly indicate a depth of 14 inches.

Step 1. Note the required depth of the ditch is 14 inches. Since the depth is given in inches, it must be converted to tenths of a foot as follows: $14 \div 12 = 1.16666667$

Step 2. Find the longitudinal grade based on the length between the contour lines at the top face of the wall:

$D = 1 \quad L = 56.6$ feet

$G = \frac{D}{L} = \frac{1}{55.6} = .017667844$. This is the grade. Place the entire number as displayed into calculator's memory.

Or use the reciprocal function: For calculators with a dedicated reciprocal key, enter 56.6, press $1/X$), or, for those without a dedicated reciprocal key, enter 55.6, press divide then equals.

Step 3. Calculate the run of contour line 91 on the wall of the ditch. Substitute in the difference in elevation determined in step 2 and the grade found in step 1 as follows:

$$D = 1.17 \quad G = .017985611$$

$$L = \frac{D}{G} = \frac{1.17}{.0179985611} = 65.052 \text{ feet, which rounds off to 65 feet.}$$

Therefore, the contour lines must "offset" 65 feet on the wall of the ditch to correctly indicate the ditch signature shown in Figure 30. (The above result is based on both the grade and the difference in elevation *not being* rounded off; if one or both are rounded, the result will be slightly different than that shown.)

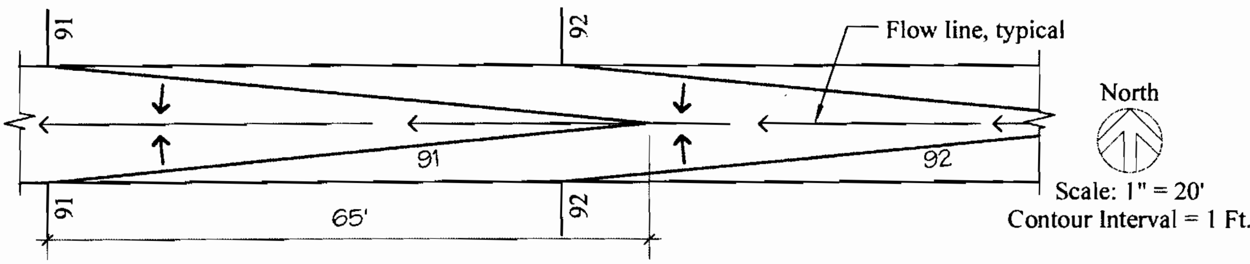


Figure 30. Example 2 — Solution Showing Contour Signature for Ditch that is 14 Inches Deep

Example 3 — Crown of a Road

Figure 31 shows a road without the contour lines plotted on the road surface itself. The problem statement requires that the road have a seven-inch crown. The goal in this example is to determine how far the contour lines on the road surface must deflect to correctly indicate a seven-inch crown.

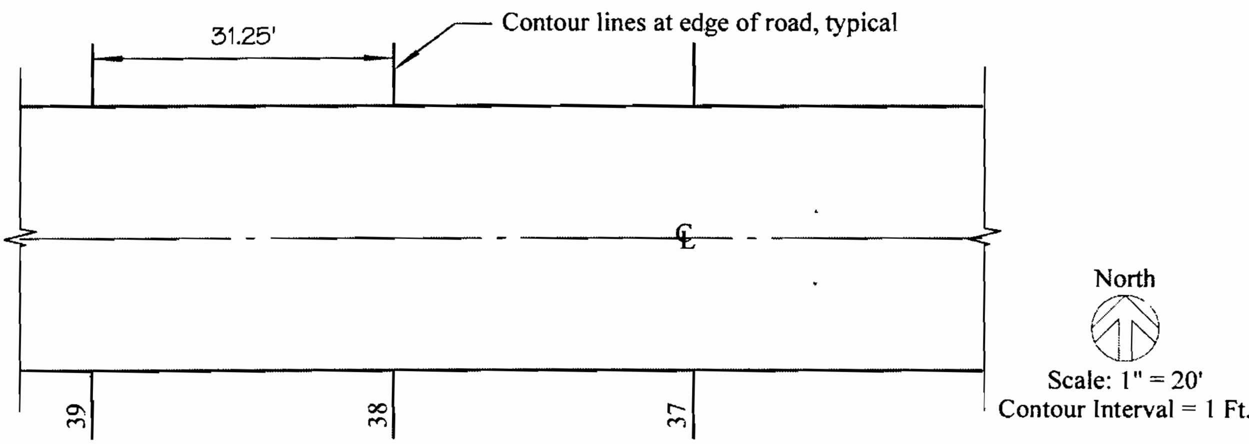


Figure 31. Example 3 — Correctly Show Contour Signature on Road for a Seven-Inch Crown

Step 1. Find the longitudinal grade based on the length between the contour lines at the edge of the road:

$$D = 1 \quad L = 31.25 \text{ feet}$$

$G = \frac{D}{L} = \frac{1}{31.25} = .032$. This is the grade. Place the number as displayed into calculator's memory.

Or use the reciprocal key: For calculators with a dedicated reciprocal key, enter 31.25, press $1/X$), or, for those without a dedicated reciprocal key, enter 31.25, press divide then equals.

Step 2. Since the height of the required crown in given in inches, it must be converted to tenths of a foot as follows: $7 \div 12 = .58333333$

Step 3. Calculate the run of the contour lines on the road surface. Substitute in the difference in elevation determined in step 2 and the grade found in step 1 as follows:

$$D = .58 \quad G = .032$$

$L = \frac{D}{G} = \frac{.58}{.032} = 18.2$ feet Therefore, the contour lines must "offset" 18.2 feet to correctly depict the contour lines on the surface of the road as shown in Figure 32.

Notice that this contour signature appears identical in appearance to the cross slope signature of a road. In fact, it is a cross slope, but with a difference: it is based on a crown height given in inches, rather than a grade, as in the case of a cross slope. Calculating cross slopes based on a specific grade will be explained in class.

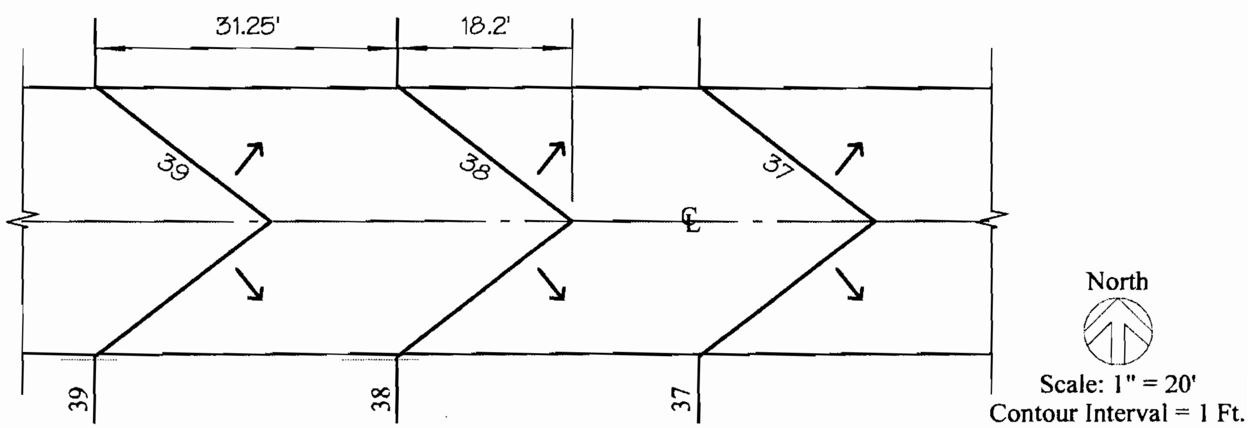


Figure 32. Example — Solution Showing Contour Signature on Road for Seven-Inch Crown

HOW TO DETERMINE HEIGHT OR DEPTH OF SITE FEATURE

Relevancy to the exam: Whenever possible, you should design to the required height or depth requirements from the outset. Nevertheless, it is not always possible to do so. Therefore, in such cases, you must be able to verify compliance with height or depth requirements. For example, it has become increasingly common on the exam for the problem statement to require that swales have a minimum depth of six-inches (see *Designing a Swale to a Required Depth* below).

The *difference formula* $D = G\ L$ is used to find out how high or deep a site feature is. The grade and length of run must be known, or be determinable. See the following example and Figure 35.

Summary of Steps to Find the Height of a Curb:

Step 1. If the longitudinal grade is not given, find it using the *grade formula* $G = \frac{D}{L}$.

Step 2. Scale the "run" along the surface for which the height or depth is being determined. In this case, that is the length of the contour line on the road surface from where it first touches the face of the curb to where it mounts the curb.

Step 3. Using the formula $D = G \times L$, substitute in the *grade* found in Step 1, and the *length* or run found in Step 2. The resulting answer is the height or depth of the surface given in *tenths of a foot.*

Step 4. To convert the height to inches, *multiply* the tenths of a foot by 12.

Figure 33: Find the height of the curb.

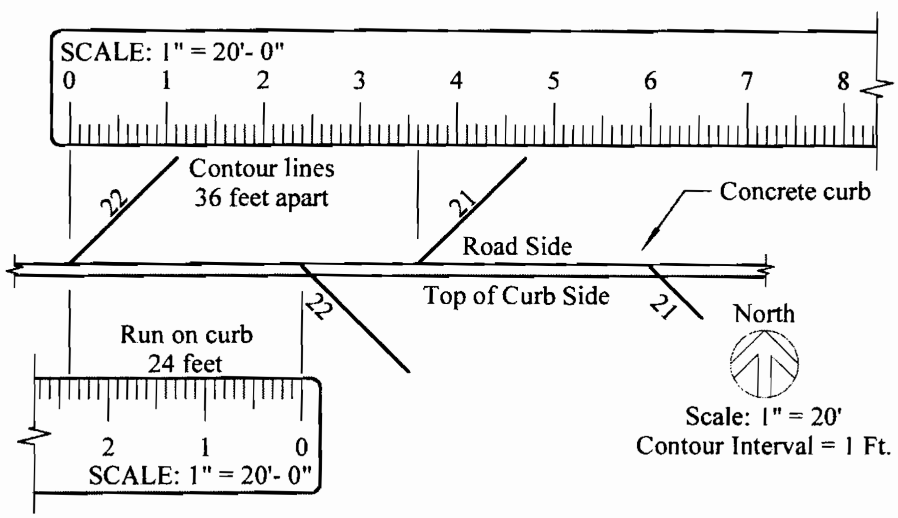


Figure 33. Example — Finding Height of Curb

Step 1. Find the longitudinal grade: Scale the length between contour lines on the road surface. Remember that the difference in elevation vertically between whole number contour lines is 1-foot.

$D = 1 \quad L = 36$ feet

$G = \frac{D}{L} = \frac{1}{36} = .028$. This is the grade. Place the number as displayed into calculator's memory.

Alternate shortcut method for finding grade: Since the contour interval is 1 foot, the reciprocal function may be used. For calculators having a dedicated reciprocal key, Enter 36, press 1/*X*; for calculators without a dedicated reciprocal key, enter 36, press divide, then press equals.

Step 2. Scale run of contour line on face of curb. This is the length from the point on the road surface where the contour line first touches the bottom face of the curb to the point where it "mounts" the top of the curb. The scaled length of the curb run in Figure 33 is 24 feet.

Step 3. Using the *difference formula* $D = G\,L$, find the height of the curb by substituting in the grade and the length and multiplying as shown:

$G = .028 \quad L = 24$ feet

$D = G\,L = (.028)(24) = .67$. This is the difference in elevation between the top and bottom of the curb.

Step 4. This step is optional, and depends on the desired final form of the number. The number, as calculated, is expressed in decimal feet. If it is to be expressed in inches rather than decimal feet, multiply .67 times 12. Therefore, the height expressed in inches is 8-inches.

DESIGNING A SWALE TO A REQUIRED DEPTH

Relevancy to the exam: On most exam administrations, a minimum swale depth of six-inches is required. All swales you design must meet or exceed that requirement.

There are two swale conditions that may be encountered: Swales having *defined boundaries*, and swales *not having defined boundaries* (the latter is more commonly encountered).

Swales Having Defined Boundaries

Example: Figure 34 depicts a swale having a defined boundary. Having a defined boundary, or edge, to work to, makes it easy to establish the depth of the swale based on the *run of the contour line* from the point where it touches one boundary, or the other, to where it crosses the flowline.

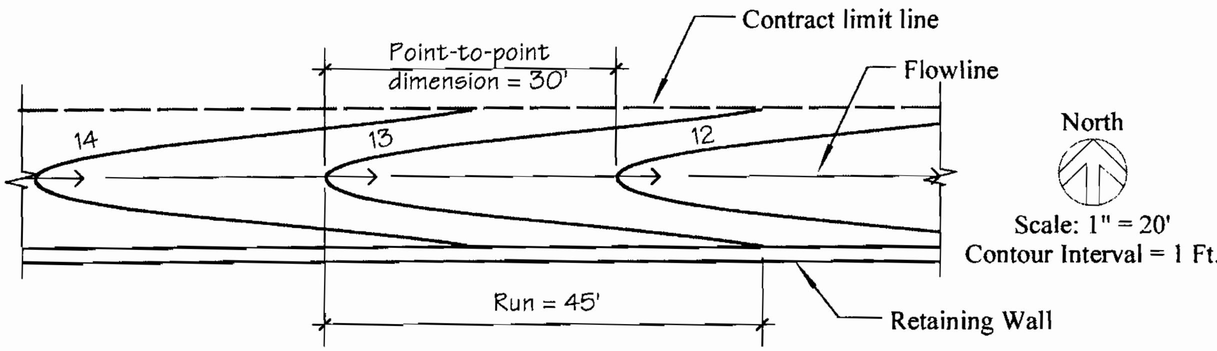


Figure 34. Example — Designing a Swale to a Specified Depth for a Swale Having Defined Boundaries

Step 1. Find the longitudinal grade based on the point-to-point length between the contour lines:

$D = 1 \quad L = 30$ feet

$G = \frac{D}{L} = \frac{1}{30} = .03$. This is the grade. Place the number as displayed into calculator's memory.

Or use the reciprocal function. For calculators with a dedicated reciprocal key, enter 30, press $1/X$); for calculators without a dedicated reciprocal key, enter 30, press divide then equals.

Step 2. Scale run of contour line in swale. As mentioned above, this will be an approximation. In the second example, the run is about 45 feet as shown in Figure 33.

Step 3. Using the *difference formula* $D = G\ L$, find the depth of the swale by substituting in the grade and the length and multiplying as shown:

?

$G = .03 \quad L = 45$ feet

$D = G\ L = (.03)\,(45) = 1.35$ * Therefore, this swale is 16.2 inches deep which comfortably exceeds the 6-inch requirement.

CONVERT TO INCHES * MULTIPLE 1.35 × 12 = 16.2

Swales Having Undefined Boundaries

Figure 35 shows a swale that *has an undefined boundary.* This is typical of horseshoe swales and swales located away from hardscape or other built site features. In this case, it is more difficult to establish the run because the edges are amorphous. That is, they do not provide a defined point of reference to scale to. Nonetheless, by identifying the point where the contour lines change direction, or where they rejoin existing contour lines, it is possible to establish a "nominal" boundary or edge upon which to scale the run.

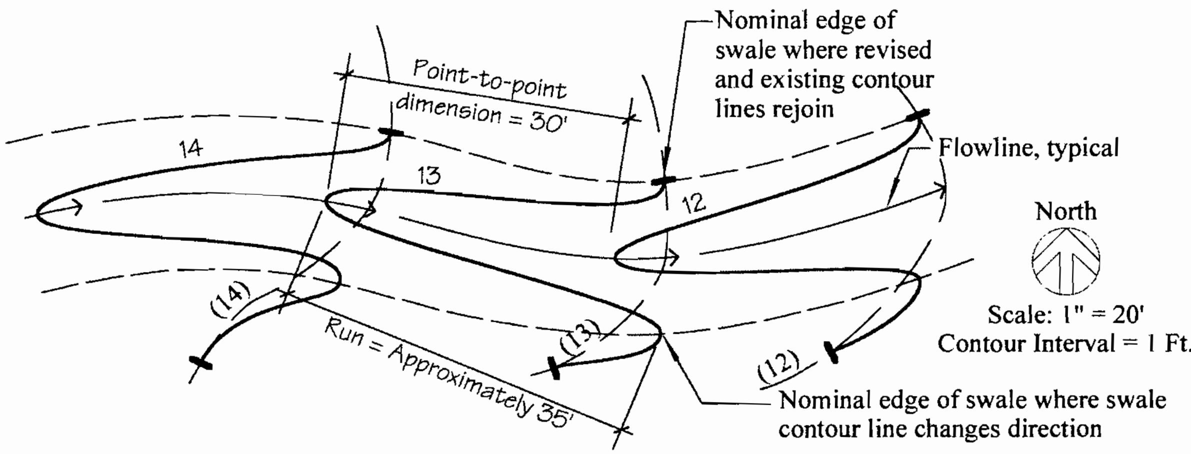


Figure 35. Example — Designing a Swale to a Specified Depth for a Swale Having Undefined Boundaries

Step 1. Find the longitudinal grade based on the point-to-point length between the contour lines. In this example, the point-to-point dimension is identical to that shown in the previous example (30 feet), so the grade is .03.

$D = 1 \quad L = 30$ feet

$G = \frac{D}{L} = \frac{1}{30} = .03$. This is the grade. Place the number as displayed into calculator's memory.

Step 2. Scale run of the contour line in swale. As mentioned above, this will be an approximation. The assumed approximate run here is 35 feet as shown in Figure 35.

Step 3. Using the *difference formula* $D = G\,L$, find the depth of the swale by substituting in the grade and the length and multiplying as shown:

$G = .03 \quad L = 35$ feet

$D = G\,L = (.03)(35) = 1.2$ Therefore, the swale is just over one-foot deep (14.4 inches), which exceeds the 6-inch requirement.

Appendix B—Instructor Biography

Jerry Hastings, A.S.L.A.

- Bachelor of Science degree in Landscape Architecture from California Polytechnic State University, Pomona, 1970.

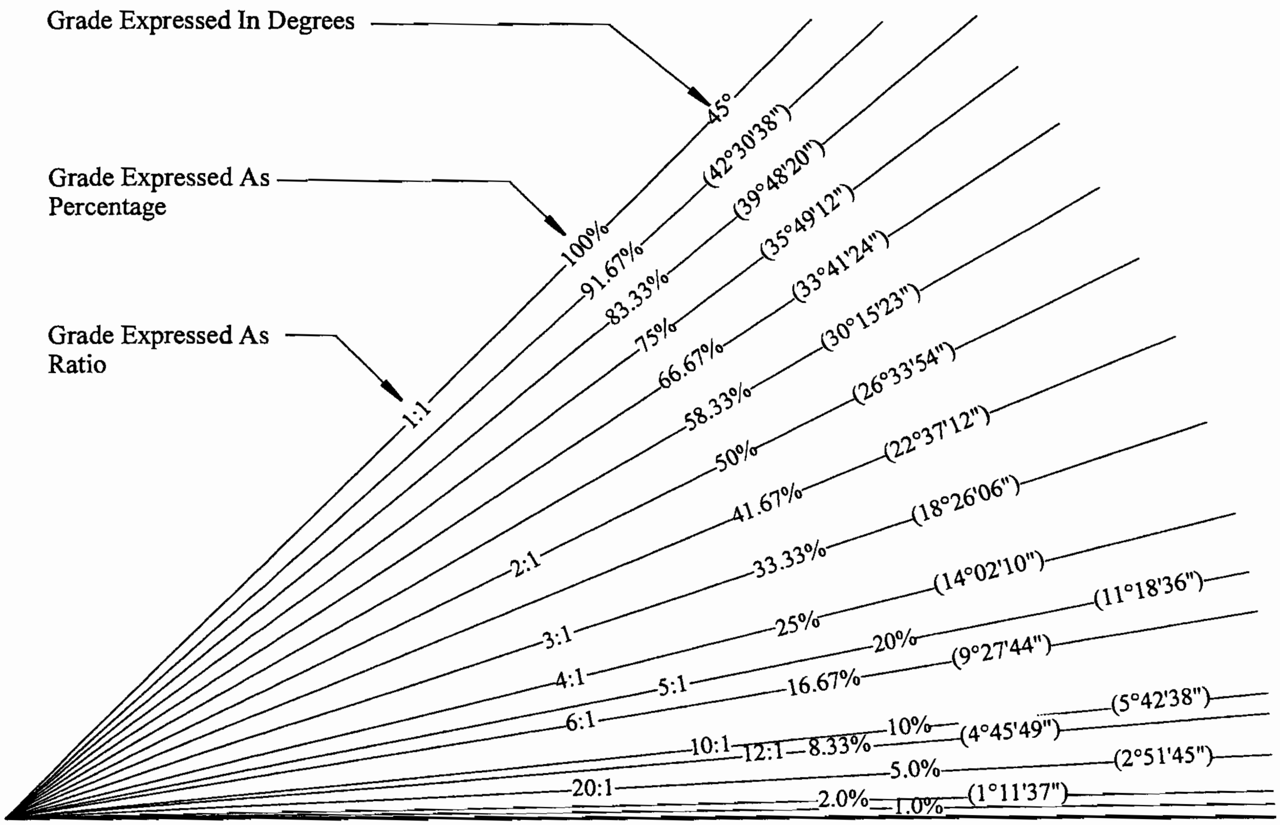
- Registered Landscape Architect (No. 1577) in the State of California.

- Retired 2002 from City of Los Angeles, Department of Recreation and Parks. Last position held: Director of Design. Now pursuing active consulting practice and expanded teaching activities; writing exam related textbooks for Professional Publications, Inc (PPI).

  - Worked in the private sector for eight years, and then began career with the City of Los Angeles in 1976.
  - Began teaching, UCLA Extension Landscape Architecture program in 1979. Classes taught include Grading and Drainage: an Intensive Review since 1984; Grading and Drainage (since 1980); the Design Implementation Workshop (predecessor of the LARE Review, since 1982); Irrigation Practices, Introduction to the Profession, Professional Practices, and various computer aided design courses. Senior Extension Instructor since 1985.
  - Department Head from 1986 to 1987.
  - Faculty Chair from 1992 to 1994.
  - Faculty Liaison to the Guidance Committee from 1994 through 2003.
  - California State University, Northridge, Extension Landscape Design Program (1994 through 1995)
  - University of Southern California Master's Program 1991 through 1993.
  - *LARE Review Section E Vignettes*, published 2005; *LARE Review: Mastering Section E*, is scheduled for publication in 2007.

- Member of the American Society of Landscape Architects since 1972.
  - Chapter President (1978 and 1979).
  - Co-founder of the Los Angeles Section of the Southern California Chapter; served as that Section's first President.
  - Chairman ASLA National Council of Presidents (1979).
  - California State Board of Landscape Architects Enforcement Committee, Member, 1986 through 1989.
  - California State Board of Landscape Architectural Examiners, Member, 1988 through 1991.

Appendix B
Slope Visualization Diagram



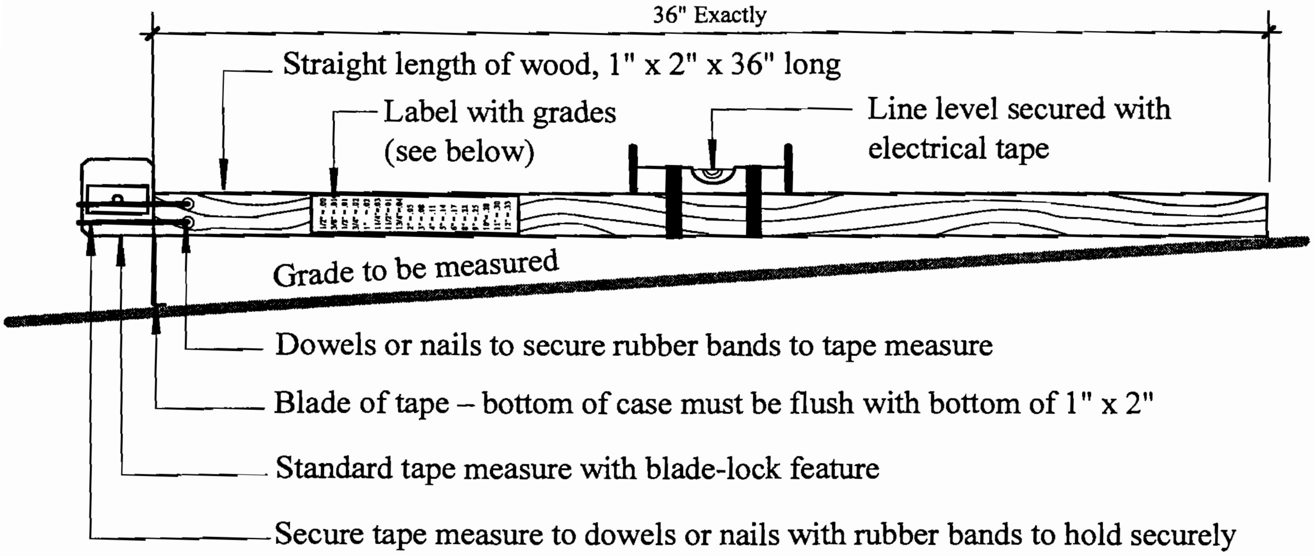
LARE "MILESTONE" GRADES TO KNOW*

.5%	Minimum slope (grade) for drainlines.
1%	Contours 100-feet apart (100:1). May, in some cases, be the permissible minimum grade on hardscape surfaces (always refer to the problem statement).
2%	Contours 50-feet apart (50:1). Optimum cross slope grade; minimum grade on swale flowlines, usually the minimum grade on hardscape; the minimum grade on non-paved surfaces.
5%	Contours spaced 20-feet apart (5:1). Maximum grade for walks and parking lot surfaces. Any grade greater than 5% on a pedestrian path of travel is considered a ramp.
8.3%	Contours spaced 12-feet apart (12:1). Maximum permissable grade for handicap ramp.
10%	Contours spaced 10-feet apart (10:1). Maximum flowline grade for swale.
33%	Contours spaced 3-feet apart (3:1). Usually the maximum permissable grade on non-paved surfaces.

* Always read the problem statement carefully for given minimum and maximum grades.

Appendix A
Grade Measurer

The Grade Measurer is simple to construct from inexpensive, easy to find, off-the-shelf items. Simply follow the plan below. Use the device in the field to find the grade of any surface. The design shown is a good compromise between accuracy and convenience. If you need more accuracy, increase the length of the 1" x 2". If you do, remember to recalculate the grade table (see the method shown below).



Grade Table for 36 inch Grade Measurer:

1/4" = .007	1" = .028	2" = .056	6" = .17	11" = .30
3/8" = .01	1 1/4" = .03	3" = .08	8" = .22	12" = .33
1/2" = .014	1 1/2" = .014	4" = .11	9" = .25	
3/4" = .02	1 3/4" = .049	5" = .14	10" = .28	

How to calculate your own grade table: Grade table is based on the formula $G = \frac{D}{L}$
(Keep in mind that the calculation is in inches and fractions of an inch. Remember to convert inches and fractions of an inch to decimal inches — see examples below)

Where:

G = Grade
D = Difference in elevation (measured in inches)
L = Length (in this case = 36 inches)

Examples: For 1": $G = \frac{1"}{36"} = .028$; For 1 3/4": $G = \frac{1.75"}{36"} = .049$

How to use your Grade Measurer:

1. Place end of 1" x 2" on high side of slope to be measured.
2. Level the 1" x 2" by observing the level.
3. Pull blade of tape measure out until it just contacts the finish surface (set blade lock so there is just enough friction to prevent the blade from retracting). Keep measurer level.
4. Lift the measurer carefully so tape doesn't retract and read the tape at point where it comes out of the c
5. The number you read will be in inches and fractions of an inch. Find the corresponding inches and fractions of an inch on the Grade Table and read the grade directly.

Appendix C—LARE Reference Manual

Following is a partial copy of the current *LARE Reference Manual* (as of January 2006). It contains that portion of the manual that pertains to Section E. It is provided here as a study resource only for this review. To avoid possible confusion, you should discard this copy after you have received your "official" copy from your local licensing authority.

Closing Words of Wisdom

Anyone who has taken any part of the exam, and particularly Section E, will attest to the fact that the most challenging aspect of the experience is the extreme time pressure the examinee is placed under. I constantly hear from those who have unsuccessfully taken the exam: "if only I had more time…" In fact, the issue of time is, intentionally, a key component of the exam process. It's an excepted fact in testing that constraint of time is a valid way to reveal depth of understanding and familiarity with the specific knowledge, skills and abilities being tested.

That said I strongly believe that your best preparation for dealing with time pressure is *thoughtful repetition, as opposed to rote repetition.* This is in accord with the cliché, *practice makes perfect.* Be sure your repetition is sharply focused on the knowledge, skills and abilities for which you'll be tested. Mindless, rote repetition, can actually be counterproductive.

Whether it is plotting whole number contour lines or designing a horseshoe swale, the fact is that the more experience you have in each of the core skill areas being tested, the faster you'll be able to produce a correct solution.

I sincerely wish you profound clarity of mind and purpose on your journey toward passing Section E.

The *LARE Reference Manual* follows on the colored pages; page numbering of the *LARE Reference Manual* corresponds to CLARB's numbering.

LARE Section E: An Intensive Review

Section E – Grading, Drainage And Stormwater Management

Spring 2008

Instructors: Angela Woodward, ASLA and John Tikotsky, ASLA
Course Author: Jerry Hastings, ASLA

University of California at Los Angeles Extension
Department of The Arts, Landscape Architecture Program

Technical: Workbook and vignettes prepared on Apple Power Macintosh G5 computer. Output: 8-1/2 x 11, Brother HL 1670N laser printer at 600 dpi; 11 x 17 vignettes, Epson 1270 ink jet printer. Text type face Times New Roman Regular (PS); title type face Times New Roman Bold (PS); display typeface Bradley Hand ITC (TrueType). Software: Word processor—Microsoft Word, Office version 2004; graphics—PowerCADD 7, graphic files saved in TIFF image format and imported into Word as pictures.

Chapter 1 — Preface

ABOUT THE WORKSHOP

LARE Section E: An Intensive Review (henceforth referred to as "review") is crafted to enhance your possibility of passing Section E, Grading, Drainage and Stormwater Management. Three key areas of preparedness are emphasized: *core subject matter mastery*, *test-taking experience* and *stamina.* In order to maximize your expectation of passing Section E, a thorough knowledge of grading and drainage, *as a subject,* is crucial. To address this need, this workshop has a strong focus on core grading skills. However, the test-taking and stamina aspects of the exam are arguably just as important. For this reason, practice exam materials, comparable in scope and rigor to the actual exam, have always been a central feature of these workshops.

It is assumed that you've read the Introduction document that was part of the pre-mailing you received prior to the workshop. If you haven't read it through all the way, you should do so sometime during the next three days. It contains important information on such topics as the new exam, suggested readings, and suggested Web resources. It also contains a schedule for the weekend and information on lunch during the mock exam on Sunday.

This workbook contains all instructional materials required for the workshop, including exercises with solutions. Practice and mock exam vignettes, which are printed on 11" x 17" bond paper, will be handed out separately.

EXERCISES, VIGNETTES, SOLUTIONS, AND THE MOCK EXAM

Over the next three days, you will have an opportunity to practice on exercises and vignettes that become progressively more rigorous as the review progresses. The review will culminate, beginning on Saturday, and continuing on Sunday, in a mock exam. Consider this a dress rehearsal of the exam that features facsimiles of actual vignettes from recent exam administrations.

Two types of vignettes will be used in the Review.

- Invented Vignettes — I devised these vignettes to attempt to simulate CLARB vignettes.

- CLARB Facsimile Vignettes — These vignettes are based on actual CLARB vignettes tested between 2002 and December 2005. The facsimile vignettes are numbered in the 30s, through the 70s. They are referred to as *facsimile Vignettes* because they are, for all intents and purposes, identical to the actual vignettes tested by CLARB. To avoid potential legal problems from copyright infringement, these vignettes have been intentionally modified in various ways to "disassociate" them from the originals.

  We respectfully request that you be circumspect and exercise good judgment in your treatment of these vignettes and solutions; doing so will help preserve this valuable resource for the future.

  For both classes of vignette, use the provided hard-copy solutions to self-evaluate your solutions.

  Beginning at approximately 3:00 on Sunday, the remaining time will be dedicated to discussing approach, suggested test-taking strategies, and pitfalls to avoid.

EXTRA EXERCISES AND VIGNETTES

There are more vignettes and exercises than can be completed within 23-hours of class time. This has been done intentionally to provide a study resource that you can turn to during the exam preparation period before the exam. Bear in mind that you retain all "invented vignettes" with solutions, and all exercises with solutions. Those you don't complete during the workshop weekend can be completed and self-evaluated at a later time.

As you look at the provided solutions, particularly those for vignettes that approach, or match, the rigor of the actual exam, bear in mind that for most vignettes there are often multiple ways to solve any given problem. The provided solution can only reveal one of these ways. So keep in mind that although your solution may be different, it may be equally correct. Also, be aware that for the sake of completeness, the provided solutions *usually go beyond what is minimally required to achieve a passing score.*

An Important Note About Graphic Quality: Note well that graphics, beyond being legible, are not a factor in scoring the exam. If your solution is correct and legible, you pass, *regardless of its graphic quality.* The point is that you need to concentrate your efforts on correctly solving the problems, and not be concerned, beyond basic legibility, with graphic quality.

ROLE OF THE *REFERENCE MANUAL*

The *LARE Reference Manual* is the sole source of all technical information you'll be required to apply to solving problems. Consider this manual the equivalent of a local code. In fact, the standards are derived directly from recognized national and international codes. *Note well that the standards contained within the* LARE Reference Manual *take precedence over any other local codes or ordinances you may be familiar with. Exam evaluation will be based only on the standards set forth in the Manual.* Obviously, the *LARE Reference Manual* is central to your success. Here are some suggestions on how you can most effectively turn this resource to your advantage.

1. Optimally, memorize the *intent* of the entire manual. This doesn't mean you need to memorize it word-for-word, but rather the concepts articulated in it. For example, you would know how long a handicap ramp may run horizontally or how many feet of elevation change may occur vertically before a landing is required (it's 30-feet horizontally and 2.5-feet vertically), or that a landing is required at both ends of a ramp. For Section E it is particularly important that you be totally familiar with all accessibility requirements, particularly those that apply to the design of ramps, ramp landings and handrails, steps, step handrails, and guardrails. Keep in mind that public safety is a major focus of the exam.

2. Although you don't need to memorize the manual per se, at minimum your level of familiarity with the Manual's contents should be such that you know exactly where to find needed information *without having to search for it.*

3. It is imperative that you understand even the subtlest nuances of the requirements set forth in the Manual. This is not as simple as it sounds! For example, read the following wording from the *LARE Reference Manual* that addresses the issue of the spacing between handrails on steps: "Intermediate handrails are required so that all portions of the required width of stairs are within 2.5' of a handrail." Do you really understand what is required? Read it over several times to be sure, and then make a plan-view sketch to see if you've it got it right. If you do, you're on your way to mastering the subtleties of the *LARE Reference Manual.* In reading any other part of the manual, if there is ever any doubt about any statement, make a sketch, draw a plan, section, or elevation to clarify the statement before going on.

A study copy of the current *LARE Reference Manual* is provided for your use during the review. The part included pertains to Section E. It is included in Appendix C of this workbook. You may also download a current pdf version of the *LARE Reference Manual* by entering: http://www.clarb.org/documents/refman012006.pdf

About a month prior to the exam, your licensing authority will send you an official copy of the manual. Treat this manual as a study reference: highlight, underline, or annotate to attain an appropriate level of familiarity with it. Be sure to discard the study copy from Appendix A when you receive your official copy to avoid the risk of any changes made subsequent to the printing of the appendix copy. You will be given a clean copy of the manual at the beginning of each section of the exam; you will not be permitted to take your copy of the manual into the test.

Emphasis on Following Instructions
One exam trend that should be noted is an increasing emphasis on following instructions. In fact, recent exams have emphasized the examinee's ability to understand and carry out requirements to the letter. Keep in mind that all textual information, regardless of whether it's part of the requirements or within the graphic portion of the vignette has significance — CLARB does not gratuitously place anything on any part of a vignette that isn't relevant to the problem.

Emphasis on Attention to Detail
Attention to detail is another important exam trend that is being increasingly emphasized.

EXPLICIT VERSUS IMPLICIT INSTRUCTIONS

CLARB makes a distinction between explicit and implicit instructions.

Explicit instructions are those that are given directly in the problem statement. These are the written instructions that you must respond to.

Implicit instructions are *implied instructions* that must also be addressed in solving the problem.

Discussion: **A minimally competent landscape architect is expected to provide a solution that not only responds to the explicit instructions given in the problem statement, but also to factors affecting the practice of landscape architecture, such as safety (especially safety), efficiency and code regulations.** For example, although you are not told in the problem statement to provide a safe design, it is expected that a minimally competent landscape architect would automatically provide such a design. If a client were to give you a project, that client would expect you to follow codes, provide a safe design and not waste money by over-designing the project.

In a testing situation, you're expected to perform in the same manner as a practicing, minimally competent, landscape architect. That is, you must consider the LARE equivalent of codes, the *LARE Reference Manual,* even if the problem statement does not specifically tell you to do so. Explicit and implicit instructions are weighted equally in grading your exam.

LARE SCORING

(CLARB's procedure for scoring the exam has recently changed. Read the following information carefully to understand these changes.)

Footnote Explanation
When a candidate for licensure receives a failing score on any section of the exam, the resulting score report includes footnotes that can help the candidate identify areas where improvement is needed.

Each graphic section of the LARE is divided into several competency areas. The footnotes in parentheses after a failing score indicate the candidate's performance on each of the competency areas within that section of the exam.

Footnote 1. At or above the level required to pass. These are the content areas in which the candidate's performance was at or above the level required to pass this subsection.

Footnote 2. Slightly below the level required to pass. These are the content areas in which the candidate's performance was slightly below the level required to pass this subsection.

Footnote 3. Well below the level required to pass. These are the content areas in which the candidate's performance was well below the level required to pass this subsection.

Competency Areas for Section E — Grading, Drainage and Stormwater Management

1. Synthesize and make connections between aspects of landscape architecture and disciplines outside of landscape architecture including consultant studies.

2. Design for protection and management of land resources (e.g. land forms, grading, drainage, vegetation, habitat, erosion and sedimentation control).

3. Design for protection and management of water resources (e.g. storm water, water supply, and ground water.

For example, a score report for Section E may appear as F(1,3,1). In this case, the candidate's performance was at or above the level required to pass in Competency Areas 1 and 3, and well below the level required to pass in Competency Area 2.

CLARB preliminarily reports candidate scores online at http://www.CLARB.org before sending out the "official" scores from the various registration boards. This is important to the candidate because links are available that provide helpful information such as common mistakes made on various problem types and reference resources that can help the candidate better prepare for the next administration of the exam.

How Graphic Solutions are Scored

The vignette problems are evaluated by graders who are licensed landscape architects who have at least five-years of experience. These professionals may work in academic, private or public practice. Representatives from each jurisdiction administering the examination are invited to serve as graders. The evaluation itself takes place at a single grading session conducted by CLARB where all of the examinations are scored one time.

After the exam administration, the Master Graders Committee reviews the problems and evaluation criteria. Master Graders typically are individuals with extensive experience in evaluating graphic response problems. The Master Graders are not given any information about the intent of the problems, and therefore they approach the problems as if they were candidates. If they feel that there are items in the problem statement that are ambiguous or unclear, they have the authority to modify the evaluation criteria as necessary to compensate for the ambiguity or lack of clarity. The Master Graders then review a number of actual exam solutions to ensure that the criteria fairly evaluates all possible responses. Finally, the Master Graders conduct a training session to explain the grading process and the evaluation criteria to the exam graders. The Master Graders are present at the grading session to resolve any questions that the graders might have about unique solutions.

During the grading sessions, two different graders independently evaluate each exam solution. Exam booklets are given to graders randomly. The jurisdiction from which the exam originated, or the identity of the candidate, are not revealed to the grader. In addition, the scores assigned by the first grader are concealed from the second grader. This process ensures that no grader will be biased by marks recorded by another grader. Each grader applies the evaluation criteria to assign the appropriate score for each competency area tested on the exam. If the scores of the first two graders are not the same for any competency area, a Master Grader rescores the vignette.

The graders complete a computer-scanned score sheet for each exam booklet, using the evaluation criteria for each problem. The completed score sheet is removed from the test booklet and sent through a computer scanner to record the grader's score as a backup.

Candidate Reviews

Reviews of failed graphic performance sections are administered through individual state licensing authorities. There are two types of reviews available: Standard and Red-Line. With both types, the candidate will review their failed vignettes and the evaluation criteria that the graders used to grade the exams. Note that the exams remain the property of CLARB and will not be released to the candidate. A Standard and Red-Line review of the same section is not permitted.

Standard Review — If a Standard Review is requested, the candidate will have the opportunity to review their actual failing exam solutions against the evaluation criteria that was used to grade the exams. The candidate should not expect to see any marks on their solutions, nor should they expect to receive the specific reason as to why the problem was failed. The candidate must review the evaluation criteria and determine which of the specific items was lacking in their solution. The Standard Review is an effective process for many candidates. Most of the errors on the problems can be easily identified upon review of the evaluation criteria. However, if the candidate does not possess sufficient knowledge about the subject, the Red-lined review may be better able to pinpoint weaknesses.

Red-line Review — If a Redline Review is requested, the candidate will have the opportunity to review a marked-up copy of their failing graphic solutions. The Red Line process is completed outside of the grading process to eliminate any bias during the grading of exams. To avoid bias, graders are not permitted to mark on the exams since different graders independently evaluate each exam. The candidate will receive general comments on the weakness exhibited on each problem. For example, a grading design may have a comment near it that reads: "The candidate does not understand how contour lines are to be treated at curbs." The comments are intended to define areas of weakness so that the candidate can better prepare for the next administration of the exam. The specific criteria that caused the resulting score will not be outlined.

Review Procedures — With either review process, the candidate will be required to adhere to the following procedures: The candidate will not be allowed to bring any materials into the review*. The candidate must sign in for the review procedure. The candidate may not make notes or remove any information that may compromise the security of the problem. Standard Review procedures are permitted for a period of nine (9) months from the date of exam administration. The candidate will have a maximum of one-hour to review Section E problems (for Section C, the maximum time is one and half-hours.)

*The licensing authority in some states may allow the candidate to being non-programmable calculators, scales and the score report. Candidates should check with their particular licensing authority to learn what is, and is not, permitted.

Feedback

We have a strong commitment to your success! We would very much appreciate hearing from you after you've taken the exam. Your candid comments, both complementary and critical, are always welcome. These have always been enormously helpful in improving the quality of these licensing reviews. The easiest, most direct way to communicate with us is via email at:

Angela Woodward's email:
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Chapter 2
Test-Taking Strategies and Approaches

EXAM DOS AND DON'TS

The following dos and don'ts apply to the exam you'll be taking in a month or two. In order to maximize the value of the practice vignettes and the mock exam, *apply these same guidelines now.* Think of the workshop as your dress rehearsal for the actual exam!

1. Do be time conscious, but do not become preoccupied with time to the point of distraction.

2. Do keep in mind that the test you're taking is *not* a real-life grading problem. Understand the difference between the exam and what you do in real-world landscape architectural practice.

3. Do keep your solution as simple and straightforward as possible. Don't embellish your drawings with information or graphics that are not specifically required. The evaluation of your solution is based only on the required elements and how you put them together. Adding superfluous information wastes time that could be spent completing other vignettes.

4. Do only what is required, no more.

5. Do not try to achieve an optimum solution. Solve the problem completely.

6. Do finish all four vignettes. A blank vignette **diminishes your chances of passing Section E.** If a vignette temporarily stumps you, put it aside and do another. Often, your ability to envision a solution will improve after you've worked through several vignettes. Keep in mind that a vignette with a partially correct solution is much better than a blank sheet.

7. Resist the temptation of slipping into any one of the undesirable "office-practice" modes described under Work Habits below.

8. Don't try to achieve *Absolute* precision for parts of the problem that don't require it. In fact, trying to achieve more precision than is called for not only wastes valuable time, but could penalize you for non compliance. To be sure you're on track, verify precision in the problem statement and then concentrate on maintaining that level of precision throughout the problem solving process. (It is important to differentiate between precision required for elevations and grades that are to be shown as part of your solution versus the precision applied when performing calculations; in the latter case, you must maintain a sufficient level of precision, particularly when plotting whole number contour lines — more on this in Chapter 4) Most recent exams have required the precision of spot elevations to be to the nearest 1/10 (one place to the right of the decimal point), and grades, either to the nearest 1/10 or 1/100 (one or two places to the right of the decimal point respectively). Grades may be expressed in decimal or percentage form unless a percentage sign is present in the grade fill-in box, then it must be in percentage form. Contour lines drawn on non-paved should always be drawn freehand. Contours drawn on paved or precision non-paved surfaces should be drawn with a straight edge of some type. A glide (hand-held rolling parallel) is ideal for this task.

WORK HABITS

Work habits are a good predictor of how well you'll do on the exam. Following is a discussion of some typical work habit issues. Some of these may apply, or apply partially, or may not apply at all to you. This workshop presents the perfect opportunity to analyze your own work habits, critically and objectively, to see if there's need for improvement.

1. **"Perfectionist."** Perfectionist tendencies can be a desirable quality in the work place if they aren't obsessive. Unfortunately, in

the context of the exam, perfectionism, especially when it comes to graphics and lettering, can be a serious handicap. For example, if you're in the habit of using a straightedge to keep your vertical strokes vertical when lettering, you're probably wasting time — even if you think you're fast, you'll be faster without using a straightedge. To save even more time when lettering, omit drawing guidelines. They aren't necessary. In fact, if your cursive handwriting is legible, consider using *handwriting* instead of *hand lettering* for plan notes. Keep this one point in mind: beyond legibility, graphically impressive drafting and lettering have absolutely no bearing on your score. You're not being tested for appearance, but rather for content. Focus on the bottom line, which is to produce a correct and legible solution in the shortest time possible.

2. **"Embellisher."** The embellisher has a proclivity for adding graphics or information that are not specifically required. Embellishment is especially destructive if it becomes a substitute for confronting the challenging aspects of solving a problem. The best remedy for avoiding the temptation to embellish is to stay focused on what is required. Keep in mind that your solution is evaluated *solely* on what is specifically required.

3. **"Plodder."** This work habit is all too easy to slip into. It is often a carry-over from the more relaxed atmosphere of the workplace. If you're a thoughtful, conscientious, worker who likes to contemplate things before moving ahead, you'll need to temper this work habit when taking the exam. If you believe you have plodder tendencies, use the practice vignettes to consciously work toward overcoming them.

4. **"Thinker."** This is an examinee that spends a disproportionate amount of time *thinking* rather than *doing*. Similar to the embellisher, the Thinker puts off trying to solve the problem for one of several possible reasons: One is lack of confidence. Another is not knowing how to approach the problem, or not knowing what to do next. The test-taking emphasis of this workshop will help you gain confidence and a better sense for how to approach a variety of problem types. Beyond this, consciously budgeting your time during each step of the vignette completion process, including reading instructions, analyzing the site, etc., will help overcome the excessive "thinking" handicap. Practice adhering to your time budget on the practice vignettes. Note that some of the vignettes include a time target. Try to use these targets as your own personal time goal.

5. **"Insufficient Calculator Skills."** There's no excuse for this self-destructive shortcoming. If you spend more than a few seconds doing a simple multiplication or division calculation, you're guilty of this indiscretion, and you're severely hurting your chances of passing Section E. Fortunately, the cure is simple: **Practice.** Your goal, well *before the exam,* is to become so completely familiar with all of your calculator's functions that it essentially becomes a transparent extension of your mind.

THE TEN GENERAL STEPS OF SUCCESSFUL TEST-TAKING

For most examinees, knowing how to approach any given vignette is the bottom line of test taking. This Section discusses both approach and test-taking strategies at a general level, and suggests a sequence of steps that can be applied to completing any vignette. Beyond these general steps, it is useful to know the specific problem types you're likely to encounter. The end of this Chapter describes in detail the primary vignette types. In the course of solving the practice vignettes, you will have been exposed to all the *known* vignette types. Near the end of the workshop, solutions will be projected for most of the vignettes you worked on. The focus of this review will be on approach and test-taking strategies.

The process of approaching any given vignette can be broken down into ten sequential steps.

Important: As you read through these steps, keep the exam in perspective: Understand that the problems are contrived. Even though they may superficially appear to resemble "real world" grading problems, they are not. Rather, they are designed to test for specific areas of knowledge. The subject matter experts who create the exams use a wide variety of testing techniques to accomplish this goal, some of which may at first appear to be beyond the sphere of landscape architecture. For example, to test basic grading principles, they may use something that might seem better suited to the skill set of a civil engineer, such as a road intersection or a plan and profile problem. Don't be intimidated. Instead, break the problem down to see what is really being tested. Invariably, you'll find that, in spite of initial appearances, you have the knowledge, skills and abilities necessary to solve the problem. Often, to test your depth of knowledge, the subject matter experts will use obstacles such as trees or other unexpected elements to challenge you.

Step 1. Prepare yourself for the exam
Optimally, this process has already begun, preferably months ago. If you've been preparing, either alone, or as part of a study group, congratulations. You're obviously serious about passing. This workshop is also part of your preparation process.

The 24 hours immediately prior to the exam is a particularly critical period where what you do can impact your performance on the exam. Follow these simple rules to be at your best:

- Go easy on additional studying — assume that you've already done all that you can.

- Get a good night's sleep — this is absolutely not the time to party!

- Eat and drink what you normally eat and drink. Avoid excess caffeine, alcoholic beverages, spicy foods, any food in excess, or any food, beverage or substance you don't customarily consume.

- Allow extra time to get to the testing venue — having to rush at the last minute is *not* a good way to begin the exam. Under no circumstances can you afford to arrive late; doing so is usually disastrous.

- By all means, talk to friends and acquaintances. But make an effort to avoid negativity and discussion of the impending exam — doing so is usually counterproductive, and it could even have a detrimental impact on your attitude and ability to perform at full efficiency.

Step 2. Read the Problem Statement — This is the most important step of all. **Fact: Not reading the problem statement carefully enough is the NUMBER ONE reason for failure.** Read, and then re-read the problem statement. Doing this step conscientiously is critical.

Suggested Problem Statement Reading Regimen:

1. Read the problem statement through once carefully with an emphasis on comprehension.

2. Read the problem statement through a second time to highlight or underline all *explicit* requirements that must be addressed in solving the problem.

It is imperative that you completely understand the problem and what is required before you begin work. As part of the reading process, be sure to note maximum and minimum grade limits.

In addition to reading the instructions, note these points as well:

- The problem statement will usually describe the context of the problem and the specific requirements you must consider when completing your solution.

- As you read the problem statement, ask yourself what code or safety standards from the *LARE Reference Manual* might apply to the problem you're solving (e.g., landings and handrails on ramps, handrails on steps, etc.). The surest way to avoid omitting anything that might be required is to have a thorough working knowledge of the *LARE Reference Manual.* Keep in mind that most of the information contained within the *LARE Reference Manual* has to do with public safety, and that failure to address a safety issue will likely result in a failing score. **Fact: To put the importance of Reference Manual familiarity in perspective, know that lack of familiarity is the number two reason for failure.**

Step 3. Verify scale, contour interval, and orientation of north — Check for the following:

- Drawing scale — it can be anything from 1" = 10' up to 1" = 500' or beyond for large-scale problems. 1" = 20' is most common. Drawings at 1/4" or 1/8" scale are highly unlikely, but do bring an architect's scale as a precaution.

- Contour interval — it is typically one foot, but other intervals, such as two feet, are also used. Large-scale problems — for example watershed area problems — typically have a contour interval of 5 or 10 feet. Be prepared for any interval. Again, check the drawing to verify interval. Also, be aware that CLARB does not state the interval on the plan — you must determine the interval by looking at the elevation callouts on the contours.

- North is most typically up, but sometimes it is left or right. Verify before beginning.

Step 4. Do a quick but *disciplined* analysis of the site: Begin by studying the existing contour lines. Note high and low points and natural directions of flow. Carefully read — and comprehend — elevation call-outs on existing contour lines so that you know what is high and what is low — if you make the mistake of reversing high and low at the outset, you'll end up fighting your instincts as you attempt to solve the problem!

Try to identify existing natural contour signatures. Check to see if a condition exists where water flows *toward a structure or some other site amenity.* On a large percentage of vignettes, controlling runoff will need to be part of the solution — think horseshoe swale in such cases.

It is almost always in your best interest to know the prevailing grades, and particularly the grade of any existing plane surfaces, paved or unpaved. Therefore, if sufficient information is available to determine the grade, it's recommended that you do so. When dimensions are not provided, you must scale the length. Here is a simple rule to keep in mind:

"Always be Curious About the Grade."

When *to know* that you need to know the grade is a matter of experience. If you're not sure, calculate the grade. Chances are knowing the grade will be advantageous.

Step 5. Scan the problem sheet for critical information — Most, but not all information critical to the solution to the problem will be given in the Requirements. At this point, you are already familiar with the requirements. Information beyond that shown in the requirements will often be given on the plan itself. Following are specific things to look for on the plan:

- Elevations — Frequently, an existing elevation, or elevations, will be shown on the plan. Look carefully for this information. Be sure to include drainage structures in this search (drain inlets, manholes, pipes, and so on). Elevation information is almost always critical in solving the problem.

- Grade Criteria — Grade criteria are usually given in the requirements, but can also be given on the plan portion of the vignette.

- Cross Slopes — If cross slope is not specifically called for in the requirements, assume nonetheless that it should be provided unless it is explicitly prohibited. Providing cross slope is one of those things that is expected of a minimally competent practicing landscape architect — i.e., view cross slope as an implicit requirement. Assume a cross slope grade of 2% unless another cross slope grade is noted in the problem statement. In some cases, cross slopes may be prohibited indirectly, for example where a pair of identical spot elevations are provided on either side of a walk. In such cases, do not provided cross slope. Where one spot elevation is shown in the center of a walk, it could go either way — decide based on other plan criteria. For instance, since building entrances are level across the width of the threshold, assume that where a walk adjoins the finish floor, cross slope is not intended.

- Buildings, Pools and Water Features — For a building, pool or water feature, an elevation or elevations must be provided. For buildings where you may be expected to provide a finish floor elevation, a box or a line for you to enter the elevation is typically provided. For pools and water features, coping elevations are required. Be aware that on the LARE, finish floors, pools and water features are always level, meaning that all corner points will have the same elevation. Read the problem statement very carefully in regard to setting finish floor and pool coping elevations. If the problem statement provides a criterion that establishes a maximum or minimum elevation, write the permissible range directly on your vignette or overlay as a reference.

- Think of all hardscape plane surfaces, and most unpaved plane surfaces, as "precision surfaces," meaning that the contour lines crossing such surfaces must be accurately plotted. In scoring the exam, clear Mylar templates with the correct contours drawn on them are frequently used to verify placement of contours plotted by the examinee. Although these templates have built-in tolerance for slight scaling variations, use reasonable care in plotting whole number contour lines.

Step 6. Identify "red flag" areas
Red flag areas are those areas where the test designers have intentionally placed some sort of constraint or object to challenge your grading skills or test your depth of knowledge. Identify these as part of your plan analysis. Here are some typical places and things to look for:

- Restricted areas where room to manipulate contours is limited — especially areas near contract limit or property lines.

- Areas where structures, paved surfaces, and most especially trees, are located close to property or contract limit lines.

- Pay close attention to a "Lone Tree" or to a group of trees that appears to be randomly placed. Such trees are usually anything but random. Nonetheless, keep in mind that all problems are solvable.

- Elevations you cannot change. For example, off site contour lines, contour lines within the drip lines of trees, etc.

Step 7. Envision a solution
As you look at a vignette, try to mentally envision an overall solution. If it doesn't come, try to envision parts of the solution — perhaps contour lines on a walk, a road, or a parking lot.

The experience gained in doing the practice vignettes will help you become increasingly more proficient at quickly doing this. Being able to envision most of a solution, or part of a solution, can be a pivotal point in the solution finding process. Of course, regardless of how much of the solution you visualize, you'll still need to work out the details. For example, if there's a parking lot, you should be able to form an approximate mental image of what the contour lines will look like on the surface of the lot, but you'll still need to calculate their exact position and cross slope angle, and probably provide spot elevations as well. As you might expect, your ability to envision a solution at any level is largely a matter of experience.

Step 8. Decide what must be done <u>first</u> and do it

Once you've scoped the problem out — meaning you've done all the things mentioned in steps 2 through 7 — it's time to implement your solution. Problems that focus on grading issues (as opposed to stormwater management issues) will almost always feature at least one plane surface. It may be paved or unpaved.

Note Well: Before doing any other site grading, it is imperative that you <u>first</u> <u>grade all plane surfaces</u>, paved or unpaved.

This means deferring the design of swales or any other non-plane surface contour revisions until all plane surfaces have been graded.

Here are some typical examples of hardscape plane surfaces to look for: parking lots, driveways, patios, ramps, game courts, pool decks, and walks. Note that not all plane surfaces are paved. Examples of some non-paved plane surfaces: Play fields, terraces, dirt paths, etc.

Discussion of block grading

Block grading is a method for "proofing" the workability of a potential solution before committing to it. Using this technique can save you from making a false start, which usually means erasing and redrawing. Block grading doesn't work for every problem type, but for those types where it's appropriate, it can save considerable time.

Here's the concept behind block grading: The diagram shown in Figure 2-1 shows a parking lot and a tennis court connected by a walk.

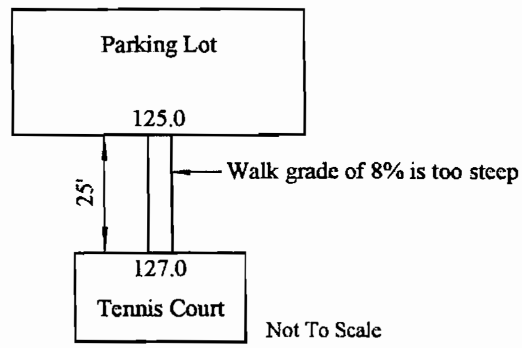


Figure 2-1. Conceptual Example of Block Grading

The maximum and minimum allowable grades on the walk are 5% and 2% respectively. For this example, assume that solving the problem includes setting the elevations of both the tennis court and the parking lot, plus establishing the grade of the walk.

To use the block grading technique, *establish an approximate mid-point elevation* for both the parking lot and the tennis court that works with the surrounding finish grades, or with spot elevations supplied on either or both surfaces. Now verify that the grade of the connecting walk doesn't exceeding the maximum 5% grade, or fall below the minimum grade of 2%. If the grade of the walks falls within the proscribed range, go ahead and plot the contour lines. You can be sure that your solution will work. If on the other hand, the grade falls outside the grade parameters, adjust the mid-point elevation of the parking lot or the tennis court, or both, until the grade of the walk is within range. This process should take only a minute or two, compared to whatever time you would expend if you made a false start and then had to erase and start over.

Which is Better? Working Directly on the Vignette, or on Trace? Or a combination of the two? This is an important question that needs to be resolved well before you sit for the exam. If you haven't made a decision, this workshop is an excellent place to experiment to find out what works best for you. Here are some of the pros and cons of each approach.

Working Directly on Exam

The main advantage of working directly on the exam is that doing so could ultimately save you time. Hard lining is easier, hence faster, because the information you placed on the vellum is highly visible, making it easy to discern. The disadvantage of working directly on the exam vellum is that if you do a lot of "thinking with your pencil," your drawing will tend to become cluttered with information that you'll have to sort out when it's time to hard line. In working directly on the exam, you have several pencil choices. A non-print pencil is one. These are good because nothing you write will appear on the final Ozlid print CLARB uses to grade your vignette. Another is a conventional pencil with a medium-hard lead, such as a 2H or 3H, or a light touch with a softer lead.

Working on Trace

The advantage of working on an overlay is that you can sketch and calculate to your heart's content without having to worry about it being on the exam material. The disadvantage of working on trace and then tracing is that it's more difficult to discriminate between the information you want to transfer and that which you don't. Therefore, overall, tracing tends to take more time. In using trace, it's important to maximize contrast in order to facilitate tracing. Use a black felt tip pen or a soft pencil, such as a B, HB, or Berol Draughting 314. You may have to "harden" some of the line work on your trace to facilitate tracing. Be aware that the transparency of the vellum the exam is printed on can be variable, and that you'll have to trace without benefit of a light table or backlighting.

Important — Do not place the trace on your drawing at the outset. Once you place the trace over your problem, printed information you need to be aware of tends to be somewhat obscured. It's surprising how much you stand to miss when the drawing area is covered with trace. Therefore, to insure complete comprehension of the information presented on the plan, defer placing the trace over the vignette until you've completed step 7. Once you reach Step 8, you can tape the trace to your vellum and proceed with solving the problem.

Ultimately, a common-sense combination of the two techniques may make the most sense for most examinees. The idea is to begin on trace, but doing only the most preliminary design work, then transfer the solution directly onto the exam as soon as you believe you know how you're going to precede. For many, this is the most expeditious approach. The majority of examinees tend to prefer this method over the all on-the-vellum or mostly on trace approaches. Try using the hybrid approach on the practice vignettes to see if it's right for you.

Step 9. Hard-line your solution

One issue that's common to each of the three approaches is knowing when to begin hard lining your final solution. Once your preliminary solution has been developed to the point where you're confident that you have conceptually solved the problem, it's time to hard-line. Experience will help you know when it's time to hard-line. Work on minimizing your preliminary solution phase on the practice vignettes. One last point — keep in mind that either tracing or hard-lining has a way of taking longer than you think it will, so budget enough time for this critical step. Remember, only the exam page that CLARB provided will be handed in — **overlays or attachments will not be not accepted.**

Step 10. Completion and checking

Here's a recommended procedure for doing a final check of your exam solution. Begin with the first item of the requirements. Read it through carefully, and then check your solution to verify that you have complied completely.

Once you're sure that you have, place an "X" through the bullet to keep track of those you've already checked. (Note that on the vignettes provided for this workshop, to facilitate identification of specific requirements, numbers have been used in place of the bullets used on the exam.)

Next, check your solution carefully to be sure that all boxes and spaces provided for spot elevations or grades have been filled in. Check the following specific areas for completeness.

Drainage

a. Look at all drainage structures and pipes. Check to make sure you provided rim elevations if they were required. Likewise invert elevations, both in and out if required, and slope (grade) of drainline? Spaces are usually provided on the plan to accept these numbers.

b. Drainlines usually terminate at an endwall. If this is the case, check to be sure you provided an invert out and top of endwall elevation. Note that in some cases, a finish grade elevation at the back of the endwall may also be required.

c. Cover over drainlines — it's usually 24-inches, but sometimes 18-inches or even 12-inches. Verify that you have complied with the coverage requirement. CLARB will often test the examinee's ability to provide sufficient cover, so check the cover over the drainline for at least one contour line that crosses the drainline. Remember that cover is measured from the invert elevation at a given point, and that the cover over the drainline is the sum of the drainline size *plus* the required cover. For example, if the pipe size is 12-inches, and the cover requirement is 24-inches, the difference in elevation between the invert elevation and the surface elevation must be 36-inches or greater (see "Cover over Drainlines," Chapter 5). If you find that cover is insufficient, move the offending contour line, or contour lines, *down slope*, toward the endwall. This will have the effect of forming a ridge over the drainline. Although this is an inelegant solution in terms of aesthetics, it is quick and highly effective — quicker than playing with invert elevations. Nonetheless, it is sometimes necessary to lower the invert elevations at one or both ends of a drainline to gain additional cover. At an endwall, be careful not to set the invert out elevation *lower* than the contour line immediately below the endwall, which would form an undesirable water-retaining pocket, and be sure the slope of the drainline doesn't fall below .5% (usually the minimum permissible slope for a drainline.)

Contour lines

Check carefully for the following.

a. Are they continuous? Verify by tracing along each line from where they depart from an existing contour to where they rejoin it.

b. Are they all numbered?

c. Did you place a tick mark at the point where each rejoins the existing contour?

d. Is every 5^{th} contour line drawn heavier? (Every 5^{th} contour will end in a zero or a five.)

e. Did you skip or omit any contours? Verify by confirming that the elevation call-outs are sequential.

f. Check pairs of spot elevations for contour omissions. Remember that a whole number contour line must pass between any two spot elevations having a difference in elevation of one foot or more (e.g., contour line 25 must pass between spot elevations 24.5 and 25.5; contour line 25, 26, and 27 must pass between spot elevations 24.5 and 27.5.).

g. If there is a retaining wall or endwall, contours must be revised to accommodate the wall. Check to see that the number of contours going into and coming out of the wall match the difference in elevation as indicated by top and bottom of wall elevations (or in the case of an endwall or headwall, the number of contour must match the top of wall and invert in or out elevations). Verify that the same number of contour lines that go into the wall come out of it — this is almost always the case. For example, if three contours go into the wall three should come out.

h. Verify that you did not omit contour lines in other areas where they are required. There are three common areas where contour omission errors tend to occur:

- As noted above, where drain lines enter at a headwall, or daylight at an endwall. Contour lines at both of these features must be revised — think of them as retaining walls.

- At back slopes and front slopes of swales — that is, the area above and below where the swale signature nominally begins or ends.

- Points of site access — look for an existing contour line where a curb cut occurs at a driveway, or at a parking lot entrance. Also, wherever new work, such as a walk, adjoins existing work, write the word "JOIN" on the *new work side* of the line to denote the new work meets both line and grade to the existing.

This completes the ten steps. Once you've completed a vignette, go immediately on to the next one. If you've just completed the fourth and last vignette, use whatever time remains to go over each solution one more time. Go over the problem requirements to make sure that you've responded to all program requirements and site conditions, and make one last check that all boxes that require elevations or other information have been filled in. Again, if you take the time at the beginning to thoroughly read and highlight the problem statement, you will save time in the long run. It can cost precious time — and perhaps even a passing score — if you have to go back and make corrections.

Summary of the Ten Steps:

1. Prepare for exam
2. Read Problem Statement
3. Verify scale, contour interval, and orientation of north
4. Perform an analysis of site
5. Search the problem for critical information
6. Identify "red flags"
7. Envision a solution; block grading
8. Decide what must be done first and do it
9. Hard-line solution
10. Complete drawing and check

COMMON CAUSES OF ERRORS

a. Time pressure. Time is your number-one enemy. Few of us customarily work at the frenetic pace the exam demands. This pace forces us out of our comfort zone. One of the negative penalties of time-pressure is an increased likelihood of erring. Practice will go a long way toward minimizing the likelihood of erring due to time pressure.

b. Luck (as in bad luck). Obviously, you should do all you can to minimize the luck factor. It's probably impossible to completely eliminate it from the equation, but be assured that the better prepared you are, the less luck will play a role.

c. Vignette types you haven't been exposed to before, or a "different look" for a vignette type you have been exposed to before (the latter is the more likely). Of course, there's always the possibility of encountering a new vignette type that hasn't been tested before. Although it's impossible to prepare specifically for the unknown, a strong foundation in grading and drainage skills will improve your chances of surmounting the challenges a new vignette type present.

Being aware of potential pitfalls can help you guard against them. Listed below are some typical pitfalls and errors you must strive to avoid.

- First and foremost, you must avoid health, safety, and welfare errors or omissions. Of these, public safety errors are the most critical. Missing any health, safety, or welfare requirement usually results in failure. Examples: Ramps — omitting handrails; omitting landings on handicap ramps, or not placing the landings in the correct places (at the beginning and end of all handicap ramps, plus every 30-feet of run or 2.5-feet of elevation change); handicap ramp grades that exceed 12:1 (8.3%). Steps — omitting handrails; omitting center handrail or handrails (handrails must be within 2.5-feet of each other); incorrectly drawing (graphically) the handrails (remember that the handrail projects 12-inches beyond the top riser, and 12-inch plus one tread width beyond the bottom riser — become accustomed to this appearance). The bottom line is that you must be totally familiar with the *LARE Reference Manual.*

- Errors that violate explicit instructions must be avoided at all costs. The explicit instructions are those given in the Requirements. Reading the Requirements carefully and completely will go a long way toward avoiding these kinds of errors. To put it the other way, errors of this type are almost always the result of *not reading* the problem statement carefully enough. There is no excuse for this.

- Errors that violate implicit instructions. Errors of this type are usually the result of insufficient familiarity with the *LARE Reference Manual*, but can also be the result of a lack of practical experience (there is no substitute for having broad-based landscape architectural experience).
- Runoff errors —runoff must not be permitted to run onto paved surfaces (think freezing water and ice). If the problem requires the development of any kind of functional or decorative mound, all runoff generated on the mound must be intercepted with a swale or swales and diverted away from adjacent paved surfaces or site improvements that would be harmed by such runoff. Sometimes, a drain inlet, or inlets, will be provided. Treat these drainage structures as suggestive of part of your solution.

- One frequently made potentially fatal error that's actually easy to spot once you know what to look for is neglecting to solve part of the problem. Examine the entire graphic portion of the problem, starting with the area within the contract limit line, to verify that you've addressed everything. Then check the problem beyond the contract limit line.

Should you correct an error if one is detected? Absolutely — the only limitations are time and your ability to make the required correction. However, be certain that what you believe to be an error is, in fact, an error — the last thing you want to do is to "correct" a correct solution. Small errors, particularly errors of omission, are always easier to remedy than errors where something has been graphically committed to because of the additional time it takes to erase. Obviously, the best solution is to avoid making errors in the first place.

WHERE TO LOOK FOR ERRORS

Look at spot elevations you're expected to provide — Although graphic "boxes" are provided for you to write in spot elevations, in addition there are several other places where you are expected to provide spot elevations:

1. **High Point Swale**
   It must be identified on the plan, meaning that both a specific point must be graphically indicated on the plan and its elevation. The accepted abbreviation for High Point Swale is HPS. Bear in mind that the high point swale is high only relative to the swale itself — it must always be set at an elevation lower than the site feature it is to protect. In accordance with current exam standards, this ideally means setting the high point swale elevation six-inches below the exterior elevations of the site feature to be protected. The reason for this strategy is to insure that your swale has a minimum depth of at least six-inches at the outset. See Chapter 4 for information on designing or determining swale depth. Chapter 4 also presents a design methodology for designing horseshoe swales.

2. **Any other high or low points**
   If, in the course of solving the problem, either a high point, or a low point is established as part of your solution, it must be called out with a spot elevation. Include the abbreviation suffix HP or LP as apropos to your elevation.

3. **Spot Elevations at Flights of Steps**
   Place spot elevations at the tops and bottoms of flights of steps. If the walks adjoining steps have cross slope, the steps should too, even if the instructions don't explicitly require it. Place one spot elevation at both sides of the top and bottom step for a total of four spot elevations for each flight. If cross slope is explicitly excluded, place a single spot elevation in the center of the flight of steps at the top and bottom for a total of two for each flight. Do not place spot elevations on each individual riser. Note that the *LARE Reference Manual* also requires a 2% wash, back to front, on all steps to facilitate drainage. See Chapter 4 for specific information on how to calculate the difference in elevation as the result of 2% wash. If a space is provided to indicate the number of risers, do so. If not, place a note adjacent to the flight of steps indicating the number of risers. Express the number of risers, the riser height, the tread length in inches and note the 2% wash — for example, your note could read: 3 Risers @ R = 6", T = 12" with 2% wash.

4. **Spot Elevations at Handicap Ramps and Landings**
   As you would expect, the design of handicap ramps gets a lot of emphasis in Section E. Because ramps have cross slope in addition to their longitudinal slope, spot elevations must be placed at all four corners (two at the top and two at the bottom). Cross slope on ramps is a *LARE Reference Manual* requirement — provide it unless it is explicitly excluded. On landings, place spot elevations at all four corners. On ramps cut into curbs, provide spot elevations at the top center and bottom center of the ramp.

WHAT TO DO IF YOU'RE RUNNING SHORT OF TIME

The obvious answer is "don't run short of time in the first place." Running short of time is usually caused by one of two things: 1) you didn't manage your time correctly or, 2) you were stumped by one or more of the vignettes, perhaps because it was of a type you hadn't encountered before, or you just found very difficult to solve.

As for the time management problem, use this workshop to gain experience in improving your time management skills. The best way to do this is to break down each phase of the problem-solving process and allot an approximate amount of time to each. For example, allot 5 minutes ± to read and highlight the problem statement; 10 minutes ± to analyze the problem; another 10 minutes ± to complete your preliminary design, and so forth. Obviously, the time allotted to each step will vary depending on the specific problem, but your total time to completion should be approximately 1¼ hours. In practice, some vignettes will take less time than this, while others will take more time, so you'll need to be flexible.

Often an examinee is stumped by one vignette. As expected, better preparation makes this less likely. But still, in spite of best efforts, it can happen. There are several things to be done. One is to put off completing a difficult vignette until later, the idea being that you're more likely to have insights and a level of focus that will guide you in finding a solution. Another is to reread the problem statement looking for a different angel. Also, try to look at the problem in different ways. Sometimes, your first instincts can be wrong so you'll benefit by trying to see the problem differently.

It is vital that you not leave any vignette blank — a blank vignette will, in all likelihood, result in failing Section E. One thing that is on your side is that exam scoring is not punitive. In other words, if you commit an error, points are not subtracted — they just aren't earned. Therefore, it's better to have something down on the vignette, even though you're pretty sure it isn't correct, than to leave the vignette blank.

If, in spite of your best efforts, you find yourself in the position of running short of time, there are a couple of things you can do to "expedite" your solution.

First, resist the tendency to panic. Understand that a partial solution, even if it isn't entirely correct, is better than a blank vignette. Obviously, the closer you come to a correct solution, the better.

Try to visualize a possible solution. In this situation, hard-line directly on the test materials from the start (do not work on trace). Keep your solution as simple as possible. Once you've set a course, stay with it. Remember that your first instincts are more likely than not to be correct.

Begin by identifying any plane surfaces that will require grading. Concentrate on completing them first. If you are required to set spot elevations, take your best guess, but try to stay close to adjacent existing elevations. If there's a 6-inch concrete curb, be sure to take it into account. If possible, keep your approach as "contour-centric" as possible. On precision plane surfaces, you'll need to take the time to calculate the correct locations of the whole number contour lines. Being able to plot whole number contour lines quickly can really pay dividends in this situation.

In some cases, you can "guesstimate" spot elevations. Most examinees are amazed at how close they can come just by interpolating between contour lines — if time is very short, you won't have a choice. The trend in accuracy requirement has been increasingly to the nearest 1/10 of a foot. Check the instructions to verify.

Once all spot elevations and contours have been placed on hardscape surfaces, quickly draw in all remaining contours and meet existing contour lines. Pay attention to any required slope ratios, but don't worry about how the contours look. If some are close together, while others further apart, ignore it. If time permits, number your revised contour lines and place tick marks where they meet existing contour lines. If not, omit the numbers and tick marks — placing contour lines correctly is the highest priority.

Lastly, budget a minute or two to look at your solution one last time to be sure all spot elevation boxes have spot elevations in them. If not, quickly "guesstimate" any missing elevations. Next, check your contour lines to make certain they're continuous, and that you haven't skipped any. Use any remaining time to make your solution as correct as possible.

VIGNETTE TYPES

The best specific approach for any given vignette depends on problem type. You will be exposed to a wide range of problem types. For these, approach will be a major focus. This section describes most of the common vignette types and discusses ways to approach each. Although there are an infinite number of possible problem variations, most tend to fall into one of the several broad problem categories described below.

Swale or Horseshoe Swale Vignettes — Expect at least one vignette that requires the design of a swale or a horseshoe swale. Horseshoe swale vignettes come in an infinite variety of forms. The key to correctly solving these problems is to first recognize that a swale is needed. In analyzing a site, always look to see if the existing contour lines direct runoff toward any site element that would be adversely affected runoff. Often, the problem statement will include instructions that either state directly, or by implication, that runoff is not to be permitted to run onto a given site element (i.e., a building). Once you have identified the need for a swale, design it so that it intercepts and diverts all runoff away from and around the site improvement. See Chapter 4 for more on the design of horseshoe swales.

In designing the swale flowline, look for a specific collection point for disposal of the runoff, and then make sure the flowline terminates at that point. CLARB typically provides a point of disposal, such as a drain inlet, a body of water, or even an existing swale. The advantage of such a collection point to the examinee is that it suggests part of your solution, but be aware that it also obliges you to utilize that point of collection in your solution.

Swale Temptations — Resist the temptation to design swales where they are not absolutely necessary. Keep in mind that the construction of a swale requires additional site grading which results in more of the site being disturbed — something you want to steer clear of to avoid being penalized for an excessive solution. Moreover, remember that swales concentrate the flow of runoff, which can be undesirable when a collection point for disposal of the collected runoff isn't available. Indeed, one indication that a swale may not be needed is the absence of a collection point. In designing the flowline of a swale, avoid directing runoff across walks or onto other paved surfaces. And, it is especially important that you do not concentrate the flow of runoff across a property or contract limit line unless the problem statement specifically permits it.

Topographic and/or Watershed Vignettes — Recent exam administrations have seen an increased focus on watershed areas. See Figure 2-2. Virtually all watershed problems require you to identify the watershed areas by defining their enclosing ridgelines.

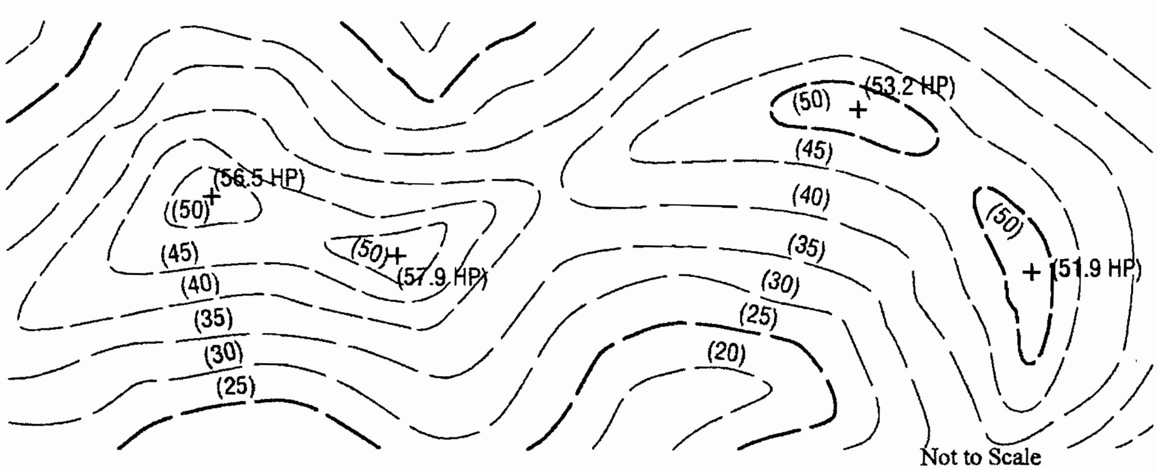


Figure 2-2. Contour lines revealing a ridge signature

The dictionary defines a watershed as "a ridge or stretch of high land dividing the area drained by different rivers or river systems." To restate this definition in the context of the LARE, it can be said that a watershed area is a unit of land enclosed by a ridgeline that contributes runoff to a single point of discharge — usually a watercourse or body of water, such as a lake or the ocean. The boundary of a watershed is defined by ridgelines, high points and saddles depicted by contour signatures, which you are required to delineate with a continuous line. Figure 2-2 portrays a unit of land with a series of high points, ridges, and saddles. Figure 2-3 shows this same unit of land with the watersheds defined.

Try to picture how this landform would appear as an actual site. Notice that there are a series of high points with descending ridgelines that "bottom out" in saddles. Or, in some cases, saddles are defined with elevations. In either case, shed. Continue working in this manner until the entire watershed area has been graphically de you'll trace along this path to define the water lineated. Read the requirements carefully in regard to which watersheds are to be delineated. In many cases, it will be only the primary watershed, while in others, it will be the watersheds of specific lakes or stream systems. Complete the watershed portion of the problem by applying the stipulated graphic convention (usually a continuous solid line with arrows drawn perpendicular to pointing away from it as illustrated in Figure 2-3). In nature, most watersheds are "open," meaning that water flows out of them. However, on several recent exams, the watersheds have been "closed," meaning that there is no outflow. In nature, this is the exception rather than the rule. Be prepared for this possibility.

If the watershed is closed, make sure the watershed boundary line closes to form a continuous line. If the system is open, continue the watershed boundary line to *its absolute end* — that is, to a watercourse or water-body, or to a contract limit or property line.

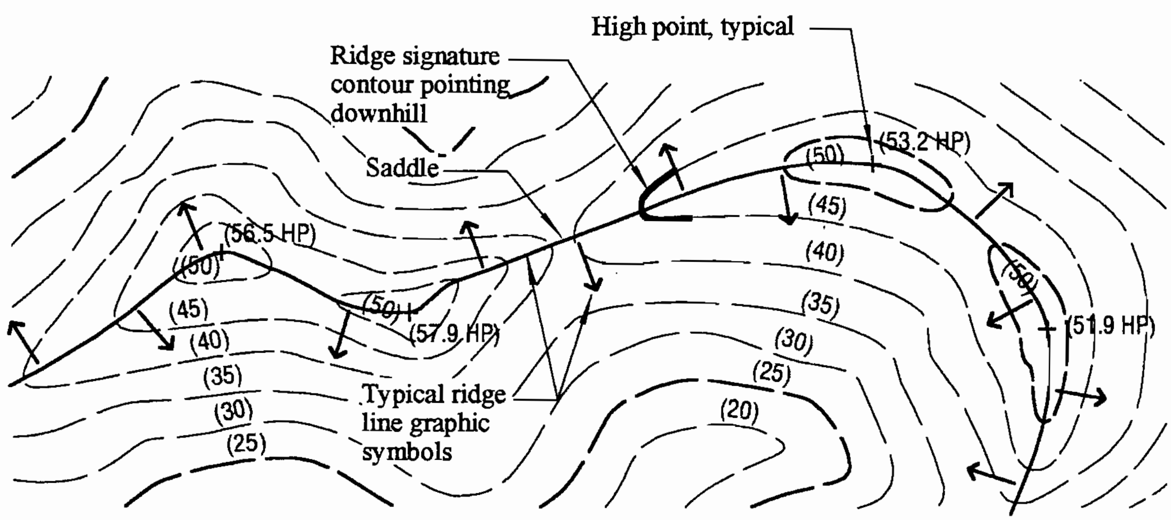


Figure 2-3. Ridge line indicated with typical graphic symbol

In addition to defining watershed areas, vignettes of this type also frequently require you to site some kind of development that will most likely include an access road. As always, instructions must be followed to the letter, including strict adherence to whatever graphic conventions are shown. If a heavy dashed line with arrowheads at either end is specified to indicate a road, within the limits imposed by using a pencil, do your best to replicate that graphic symbol.

Keep in mind that the contour interval on large-scale watershed vignettes is usually 5-feet or 10-feet. If something is to be sited within the watershed, there will customarily be slope limits that must be complied with. Consequently, to comply with those limits, you'll need to calculate the minimum allowable spacing between contour lines based on the specified contour interval. For example, if the contour interval is 5-feet, and the maximum allowable grade is 10%, you'll use the length formula to determine that minimum spacing as follows.

$D = 5\text{-feet} \quad G = .10$

$$L = \frac{D}{G} = \frac{5}{.10} = 50\text{-feet}$$

Therefore, the contour lines must be at least 50-feet apart. For more information on use of the length formula, see Chapter 4.

Approach: Read the problem statement carefully. You need to know exactly what is required. For example, as mentioned above, check the requirements to see if *all* watershed areas are to be identified, or certain specific watershed areas, or *only one specific* watershed area. Next, attempt to visualize the entire watershed by stepping back, so to speak, and viewing the "big picture." With experience, you'll be able to readily pick out watershed areas (see Study Tip below). This step is important because being able to discriminate between a main ridgeline, or ridgelines, and secondary ridgelines can be challenging. Once you have a grasp of the watershed areas, begin to delineate them. Start at any convenient high point and work downhill along the natural ridgeline toward a saddle, then back up again to the next high point. See Figure 2-3 for an example of this process.

Study Tip: Familiarity with topographic maps can greatly improve your proficiency at solving watershed problems. A good way to quickly gain map experience is to purchase a 7.5-minute series United States Geological Survey (U.S.G.S.) topographical map. Such maps are available online from various sources including the United States Geological Survey (USGS), from map shops, and from stores that sell outdoor recreational equipment. The map you choose should include hilly or mountainous terrain to insure that there are a variety of landforms to study and identify. Try tracing along ridgelines. Attempt to define watershed areas. Try identifying other existing contour signatures such as swales, summit signatures, various road signatures, steep slopes, flat areas, promontories, saddles, and so on.

Mounding to Visually Screen an Objectionable View — Although not every administration of the exam features a mounding problem, they are frequent enough that you should know what they are and what is needed to solve them. The key problem elements are a viewpoint, or view area, that is typically delimited by a vision cone, and the object or site feature that is to be screened by mounding. Contours and spot elevations on the plan provide ground-level points of reference, while the viewing height — typically 5 ft — and the height of the feature to be screened are given in the problem statement, or on the plan itself.

To construct a screen, earth must be mounded to some minimum height. The height required may be given in the problem statement, or you may have to determine the minimum height necessary to affect the screen. Some of the contours that that form the mound will close on themselves within the contract limit area.

You can also count on having to draw more contours than for other problem types. As always, all contours should be drawn freehand, but with care. You should strive to do your best to maintain the required slope ratio. However, CLARB understands that you're drawing the contours freehand, and consequently does not require absolute exactness. In other words, don't worry if some of the contours you've drawn end up closer than the stipulated slope ratio. The standard has been to permit up to 10% of the examinees contours to be out of compliance. Use of a tick sheet created for the required slope ratio and scale can improve the precision of your contour placement.

Order of work: Begin by establishing the minimum height necessary to accomplish the screen. One technique that usually works is to note the elevation of the viewing area, then add the five-feet eye height to it. For example, if the ground elevation at the viewpoint is 16.5, adding 5-feet equals an elevation of 21.5. Test that elevation as the top of the mound elevation. Most often this simple procedure works. Unfortunately, the only way to know for sure if the assumed elevation is sufficient is to draw a simple diagrammatic freehand section. The section shown in Figure 2-4 is a formalized version of this concept and is shown here as such for demonstration purposes.

In this example, the viewing level elevation is 16.5, and eyelevel height is 5 ft, which equals an eyelevel elevation of 21.5. The object to be screened is 8 ft high, and the slope requirement is 3:1. The sightline drawn from the eyelevel elevation to the top of the 8 ft object reveals that the mound must be at an elevation of at least 20.5, as shown in the figure. However, it is recommended that you be conservative in establishing this elevation by providing a mound elevation that is slightly higher — in this example, 6-inches higher — than the minimum necessary to affect the screen. Note that as a function of the slope ratio, the maximum elevation needed to create the screen *diminishes* as the high point is shifted away from the viewing level. Be careful in shifting this point more than necessary — remember that the prescribed slope ratio must be maintained, and all revised contours must "daylight," or catch up to, existing contours within the project limits.

There are two other important point to keep in mind when solving a screen-by-mounding problem:

- The minimum elevation necessary to provide the screen must be maintained *across the entire width of the vision cone.*
- Screen-by-mounding problems almost always require some kind of swale. This is due to the fact that the mound itself generates runoff. If part of that runoff can flow onto adjacent paving, regardless of whether it's within the contract limit line or not, it must be diverted with a swale. The same goes for any other site amenity that should be protected. Be proactive in looking for this condition.

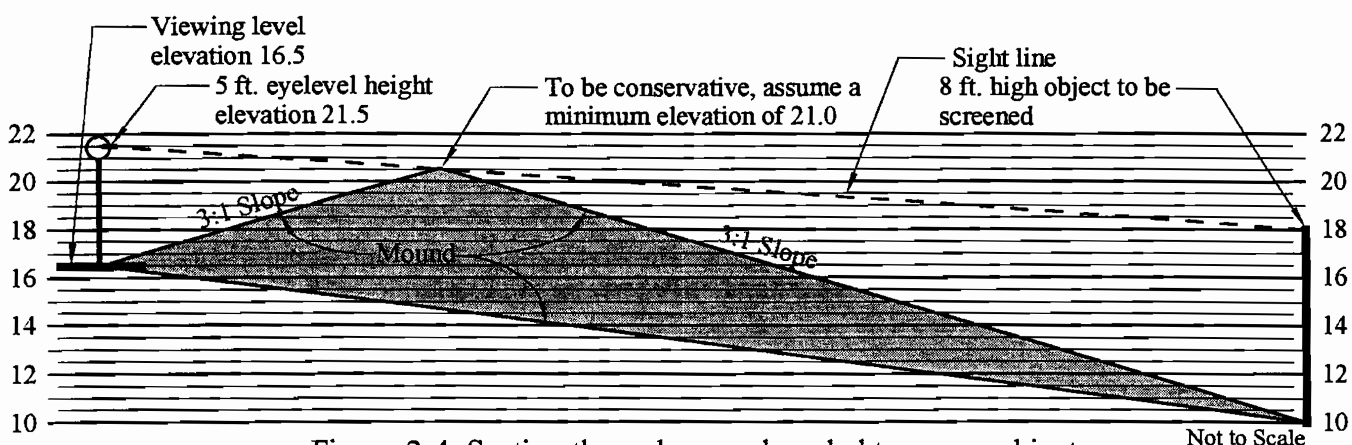


Figure 2-4. Section through mound graded to screen object

Plan and Profile Vignettes — Another vignette type is the plan and profile style problem shown in Figure 2-5. Plan and profile vignettes always feature a road, and may also add some other lineal design element, such as a swale. The road may be symmetrical about its centerline, or it may be asymmetrical, such as when there's a six-inch curb and sidewalk on one side, and no curb but a shoulder on the other side. Regardless of the configuration, the profile determines the elevations along the centerline or centerlines. The key to solving a plan and profile vignette *is to project the points where the centerline on the profile cross the elevation lines down onto the centerline (or centerlines) on the plan.* Understand that the whole number contour line crossing points along the centerline are driven solely by the profile. Using a profile to establish elevations on a road surface represents a simplified means for providing a vertical curve as is evidenced on the plan shown in Figure 2-5 where the contour spacing near the summit becomes longer (compare the greater length between contour lines 12 and 13 with the lengths between contour lines 10, 11 and 12). Be sure to search the plan view portion of the plan thoroughly for any information that may be relevant to the solution, such as paving material, e.g., asphalt concrete (AC), or portland cement concrete (PCC). Remember, all plan text is has relevancy to the problem.
Cross Section — See Figure 2-6. *The cross section* is a critical component of all plan and profile problems, and it is virtually always provided. The information contained in the cross-section normally includes such vital information as required cross slope grades and the width dimensions of road surfaces, sidewalks, shoulders, and so on. Be sure to also note any features

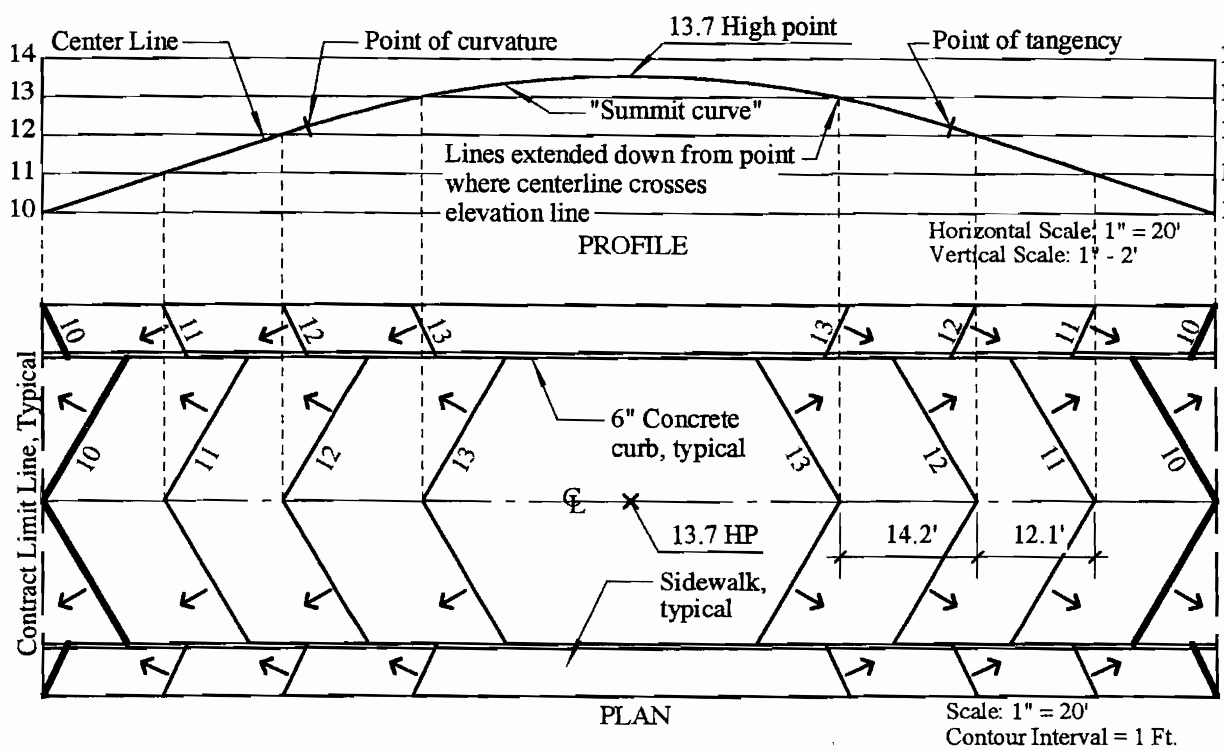


Figure 2-5. Example of plan and profile for road

Cross Section — See Figure 2-6. *The cross section* is a critical component of all plan and profile problems, and it is virtually always provided. The information contained in the cross-section normally includes such vital information as required cross slope grades and the width dimensions of road surfaces, sidewalks, shoulders, and so on. Be sure to also note any features

Df = CROSS SLOPE X WIDTH / LONGITUDINAL GRADE

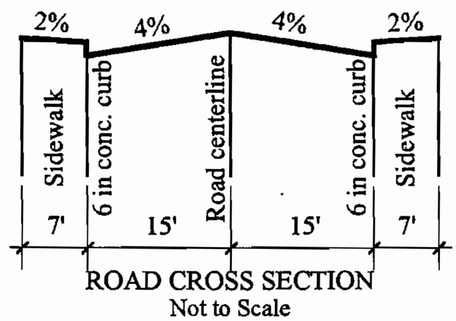


Figure 2-6. Example of road cross section for plan and profile

"Pure" Grading Problem — This class of vignette can assume one of many guises. Some shown in section, such as curbs, shoulders or swales that are part of the problem. Sometimes the fact that's it's a grading problem won't be immediately evident. For example, a recent vignette consisted of a road T-intersection. The requirements included several sections having different cross slopes and cross slope configurations (e.g., crowned center vs. sloping in one plane) at various points, along with a longitudinal section along the road's centerline.

At first glance, this vignette looked like something a civil engineer would be expected to design. However, upon closer inspection, the astute examinee would have noticed several things: First, that simply calculating and plotting a cross slope wouldn't solve the problem because, in this particular case, the points where the contour lines crossed the road surface were not at the points where the sections were drawn — they were part way between two sections having cross slopes of 1% and 2%, meaning that the cross slope grade was neither 1% or 2%, but something in between. Second, based on this fact, it would become clear that it was necessary to find spot elevations at various points, then the grades between those spot elevations, then finally, the points on the road surface where the whole number contour lines met the curb face based on those grades. Once these points were established, it was simply a matter of drawing contour lines from point-to-point to complete the solution. In other words, what at first look appeared to be a very complex problem was, in fact, actually a relatively simple grading problem.

Rational Method — The Rational Method is no longer part of Section E — it has been moved to Section D.

Summary — The five basic vignettes types described above are not the only possibilities. Although vignettes generally test for one or two skill areas, it is also possible that one or more additional skill areas could be added to the mix on one vignette. The simple fact is that you must be ready for virtually anything. As you might expect, the best preparation is a strong foundation in core grading skills along with a reasonable amount of test-taking experience — these are the two areas this class is specifically designed to address.

Chapter 3
Introduction to Contour Lines

Contour lines, along with spot elevations, are the primary means by which landforms, both existing and proposed, are communicated on a LARE vignette. This Chapter concentrates on contour lines while Chapter 4 focuses on the arithmetic aspect of grading — working with elevations, grades, lengths, and cross slopes.

Contour lines, and the signatures they form, are the foundation of grading and drainage and the exam. Consequently, you must have a thorough understanding of both contours and working with elevations, grades and lengths to pass Section E. This chapter is dedicated to attaining a thorough understanding of contour lines. Along the way, there will be tips for working with contour lines with an emphasis on correctly drawing contour signatures along with a simple, foolproof technique for correctly depicting contour lines at curbs.

CONTOUR LINES DEFINED

There are six so-called rules of contour lines that govern their use (see also Six Rules of Contour Lines below). The first two rules define the unique qualities of contour lines.

Rule 1 states that a contour line has a specific unchanging whole number elevation along its entire length. Existing contour line 10, depicted in Figure 3-1, demonstrates this fact.

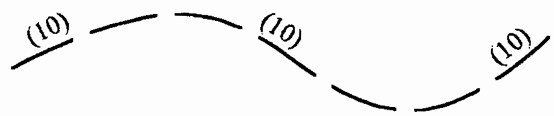


Figure 3-1. Existing Contour Line 10

Rule 2 states that *contour lines have equal vertical separation*, meaning that if the contour interval is one foot, all contour lines on a given plan are one foot apart vertically as shown in Figure 3-2.

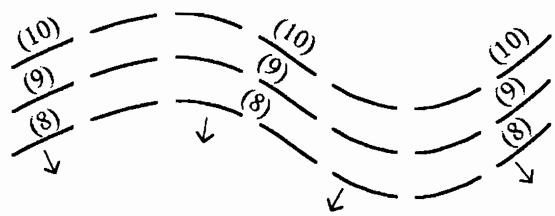


Figure 3-2. Existing Contours Having Equal Vertical Separation

A VOCABULARY OF CONTOUR TERMS TO KNOW

- **Contour Line** — Figure 3-2 above shows typical *existing contour lines,* drawn as dashed lines; Figure 3 below shows a typical *revised contour line* drawn as a solid line.

Figure 3-3. Revised Contour Line

- **Contour Signature** — Multiple contour lines which, when viewed together, depict a natural or man-made topographical feature, such as a swale, a ridge, a plane surface, a local depression, etc.

Figure 3-4 depicts a natural swale signature.

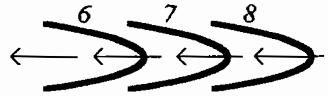


Figure 3-4. Contour Signature
Depicting a Swale

- **Plane Surface** — Any surface having a definable area described by points of known elevation at. Figure 3-5 shows a typical sloping plane surface with elevation callouts at the corners.

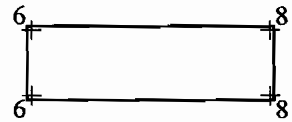


Figure 3-5. Plane Surface

- **Longitudinal Slope** — Slope *along* the long axis of a plane surface. Figure 3-6 shows a plane surface that has longitudinal slope only—no cross slope. Notice its characteristic ladder-like appearance with the contour lines crossing the plane surface perpendicular to its long axis.

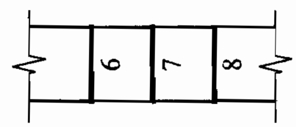


Figure 3-6. Longitudinal Slope

- **Cross Slope** — Slope *across* the short axis of a plane surface. Figure 3-7 shows a plane surface that has cross slope and longitudinal slope. Notice that the contour lines cross the plane surface diagonally. Most plane surfaces have both longitudinal and cross slope grade. Important point: On plane surfaces, the longitudinal slope is measured along the long axis, while the cross slope is measured across the short axis.

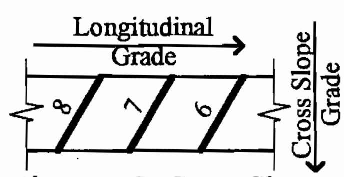


Figure 3-7. Cross Slope

- **Run** — The horizontal length of a contour line that "runs" along any vertical face, such as a wall or a curb, as shown in Figure 3-8. Run is that portion of the contour line which is actually on the face of the vertical surface, in this case, the curb face. Although it is not normally shown graphically on the face of the curb, it is here to illustrate the concept of run. The contour elevation callout, in this example contour 7, defines the fact that the contour line runs on the face of the curb.

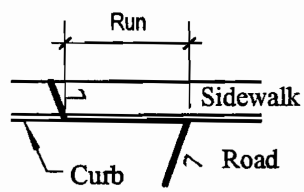


Figure 3-8. Run

- **Straight Grade** — A surface having a constant slope. A straight grade contour signature is characterized by contour lines that are evenly spaced, as shown in figure 3-9.

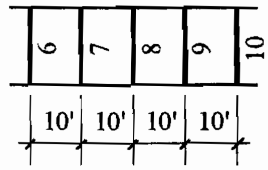


Figure 3-9. Straight Grade

- **Precision Surface** —Any surface where the placement of contours must be exactly correct. Figure 3-10 shows contour lines spaced exactly 50-feet apart which indicates a grade of exactly 2%. Any time the problem statement specifies a specific grade, consider it to be a precision surface. Count on being tested on your ability to place contours precisely on a plane surface.

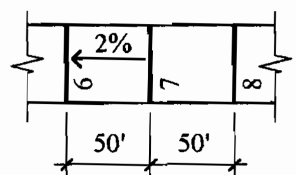


Figure 3-10. Precision Surface

GRAPHIC CONVENTIONS FOR DRAWING CONTOUR LINES

On Section E vignettes, existing contour lines are always shown as part of the problem. Your task is to provide a solution to the grading problem, which will require the revision of the existing contours. Specific graphic conventions for rendering revised contour lines should be followed. Study Figure 3-11.

Summary of contour line graphic conventions required on the exam:

1. Revised contour lines are drawn as solid lines (existing contour lines are drawn dashed).

2. Revised contour lines are drawn somewhat heavier than existing contour lines.

3. Revised contour lines on non-paved surfaces should be drawn freehand; those on hardscape surfaces can be drawn freehand or hard line. If they are drawn freehand, care should be taken to make them as accurate as possible.

4. Every fifth contour line is to be drawn heavier than the others (e.g., 90 and 95 are drawn heavier than 91, 92, and so on).

5. Contour lines are to have elevation call-outs to identify their elevations. There are two correct ways to write elevation call-outs:

   - Place the call-out on the *uphill side* of the contour line, as shown in Figure 11.

   - Place the call-out in a break in the contour line.

Discussion: Placing the number on the uphill side of the contour line is the quicker of the two because it does not require preplanning where to place breaks in contour lines for the callouts. Placing the number on the uphill side also has the benefit of telling you at a glance which direction terrain is sloping without needing to actually read the numbers. (Having said this, it's important to stress that beyond a preliminary or first look at a plan, the elevation callouts must be read and the elevations they represent must be mentally processed.)

- Call-outs on revised contour lines are customarily written without parentheses, while call-outs on existing contour lines are written within parentheses. CLARB vignettes will always portray existing contour lines as dashed, but may, or may not, write elevation callouts within parentheses.
- Flow arrows are optional but highly recommend if used correctly and in moderation. First, they help convey the intent of the grading plan to the scorer, and second, and more importantly, they provide you with a secondary check. Make sure that the flow arrows are drawn perpendicular to the contour lines, and, remember that runoff flows down hill only (not a joke — I've seen more than a few examinees become disoriented and indicate runoff flowing parallel to contour lines, or worse, flowing uphill).
- Where revised contour lines meet existing contour lines, place a small "tick mark" to graphically reinforce the join point.

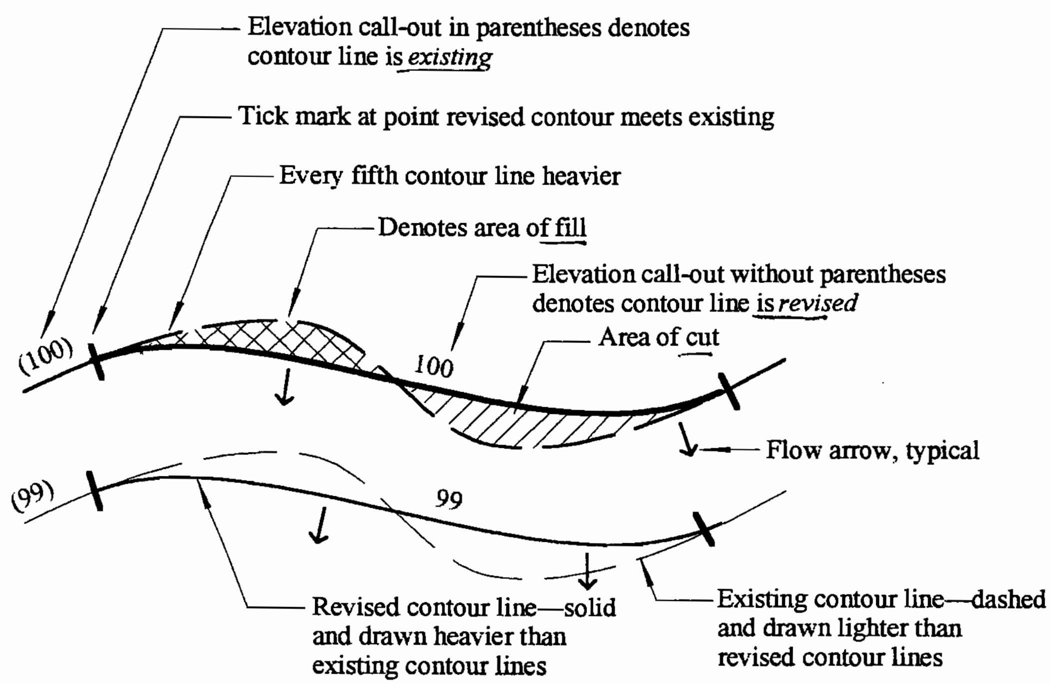


Figure 3-11. Graphic Conventions for Drawing Contour Lines

THE SIX RULES OF CONTOUR LINES

These rules form the graphic conventions governing the use of contour lines. It is important to know them and understand the underlying concepts of what they mean. Notice, again, that the first two rules define the essence of contour lines.

Rule One Contour lines have the same elevation along their entire length as shown on existing contour line 10 in Figure 12. That is, a contour line never varies in elevation; it has exactly the same elevation along its entire length. It is worth noting that this first rule is probably the most broken rule of all. For example, if you draw a contour across a curb or a wall without offsetting it, the first rule of contours has been soundly broken!

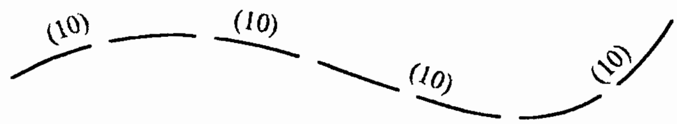


Figure 3-12. Rule One

Rule Two Contour lines have equal vertical separation, as shown in Figure 3-13. A contour interval of one foot is most common on the LARE

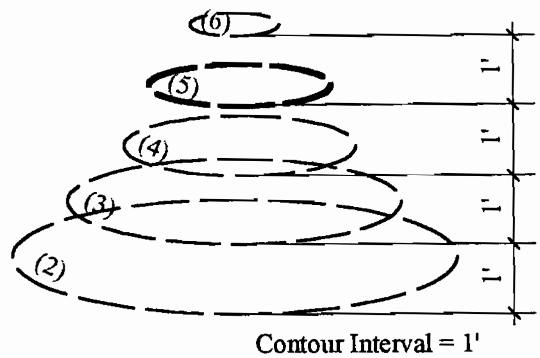


Figure 3-13. Rule Two

Rule Three The steepest slope is a line perpendicular to the contour lines. This principle is illustrated in Figure 3-14.

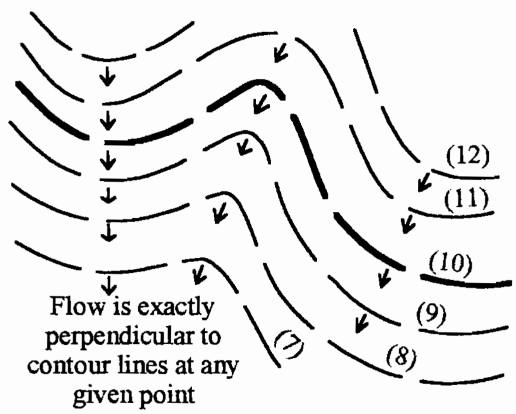


Figure 3-14. Rule Three

Rule Four All contour lines close on themselves at some point on the face of the earth, although they *may not* do so on an individual map or plan as shown in Figure 3-15. In some cases, a contour line can run for hundreds, even thousands of miles before closing on itself.

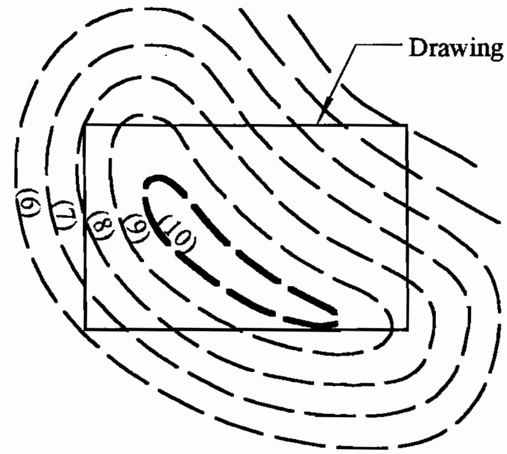


Figure 3-15. Rule Four

Rule Five Contour lines never merge — because they always occur in pairs, they cannot merge. In Figure 3-16, the left contours are correct; the right contours are not.

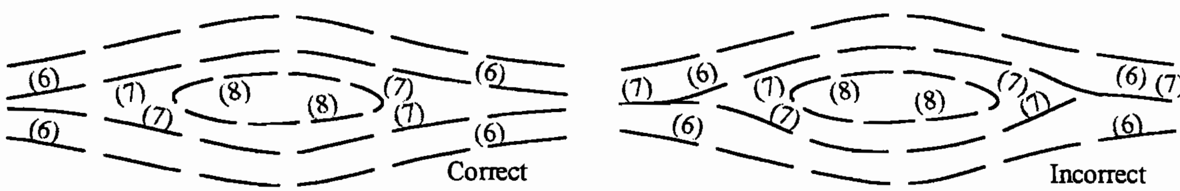


Figure 3-16. Rule Five

Rule Six Contour lines never cross each other (at least they do not on the LARE). In Figure 3-17, the left contours are correct; the right contours are not.

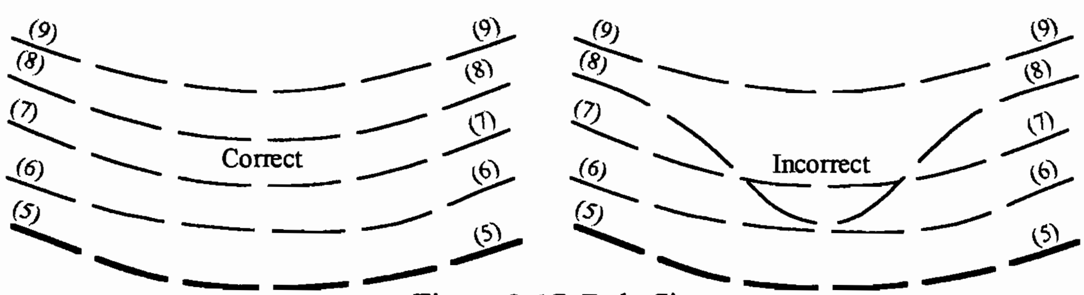


Figure 3-17. Rule Six

ALL ABOUT CONTOUR SIGNATURES

The Importance of Being Totally Familiar With Contour Signatures — As pointed out at the beginning of this Chapter, being well versed in contour signatures can make an enormous difference in how well you do on the exam. Being able to "read" terrain features by observing contour signatures facilitates site analysis. But even more importantly, it improves your probability of quickly visualizing a solution, or at least part of one. Obviously, having this ability is a tremendous asset. Study the following contour signatures carefully, then do the exercises at the end of the chapter.

The following three signatures demonstrate several basic contour line concepts. Figure 3-18 shows a so-called straight graded slope. Notice that the contour lines are evenly spaced. Figures 3-19 and 3-20 are slopes that are not straight graded—the contour line spacing is variable. On the LARE, all plane surfaces will be straight graded, with one exception: In road design, where a vertical curve is required, contour placement is precisely governed by a profile. See Chapter Five for a discussion of this problem type.

Slopes on *non-paved surfaces* may or may not be straight graded. Swales in particular will often have variable flow line grades. This is acceptable and even desirable from a design standpoint, as long as the flow line grade stays within the requirements—usually a minimum of 2% (contour lines not spaced more than 50 feet apart) and a maximum of 10% (contour lines not spaced closer than 10 feet apart).

A second concept that these figures demonstrate is the use of a section as a means of plotting the location of contour lines in plan view. Recent administrations of the exam have seen an increase in so-called *plan and profile problems.* These are discussed further in Chapter 5. For now, observe how the points where the line on the section (usually a centerline in road design) that crosses each elevation are extended onto the plan to establish the whole number contour line crossing points.

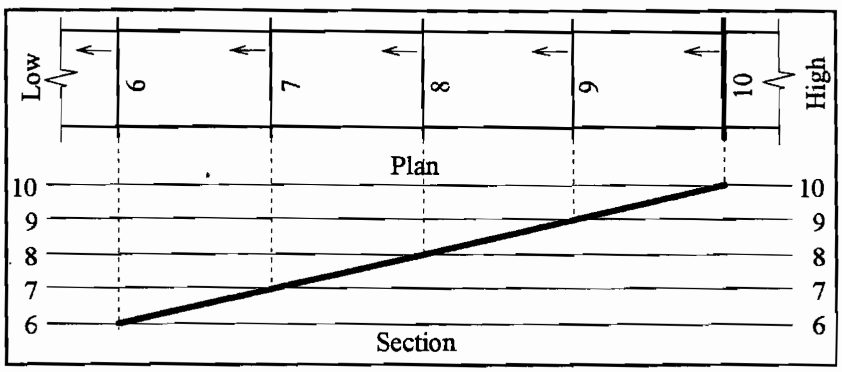


Figure 3-18. Contour Signature Representing a Straight Grade

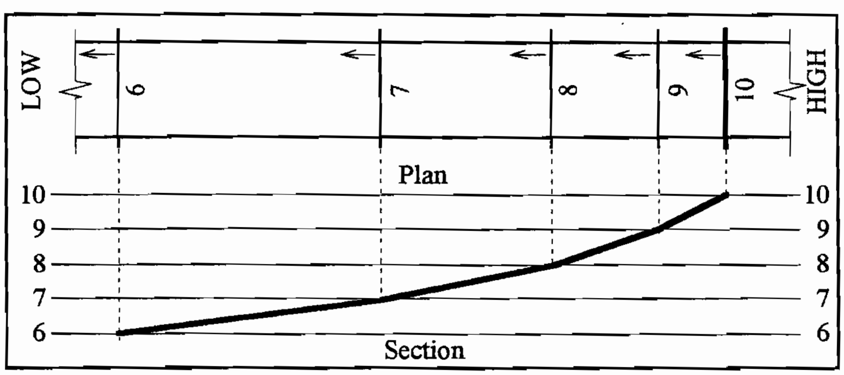


Figure 3-19. Contour Signature Representing a Concave Slope

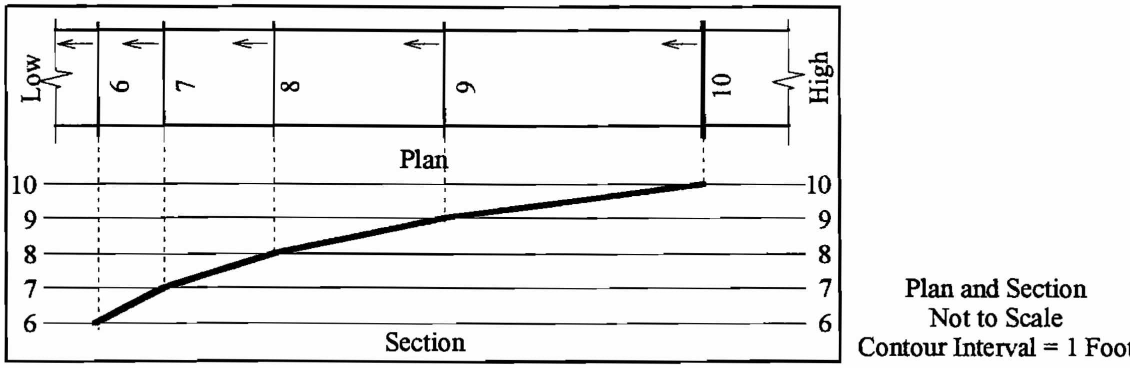


Figure 3-20. Contour Signature Representing a Convex Slope

The next group of signatures represents *natural* and *man-made landforms* you're likely to encounter.

Contour Signatures Representing Swales

Figure 3-21 shows two types of swale signatures. The illustration on the left could be either an existing natural swale signature, or a man-made *non-paved swale,* graded in earth, rather than constructed of a man-made material such as concrete. The illustration on the right shows a non-natural man-made swale. Swales are commonly used for "passive" drainage—there are no catch basins or other drainage structures needed. Swales provide positive, minimal maintenance, surface drainage. On the down side, they also require considerable space on a site to execute. Memorize this signature—virtually every administration of the LARE features at least one problem requiring the design of a swale of some kind.

Memorization Tip: In a swale signature, the contour lines always *point uphill* at the point they cross the flowline.

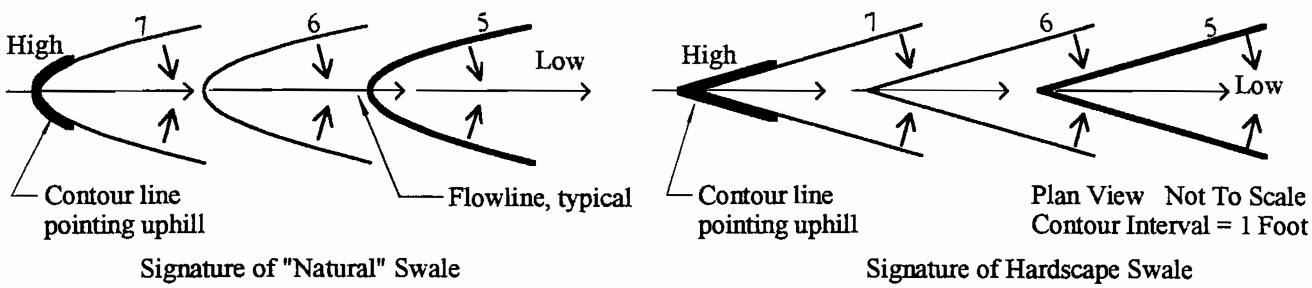


Figure 3-21. Swale Signature

Figure 3-22 shows a man-made ditch, which is simply a variation of the swale signature shown above in Figure 3-21—contour lines are still pointing uphill. See Chapter Three for a method of determining the depth of an existing ditch, or a method for correctly designing a proposed ditch.

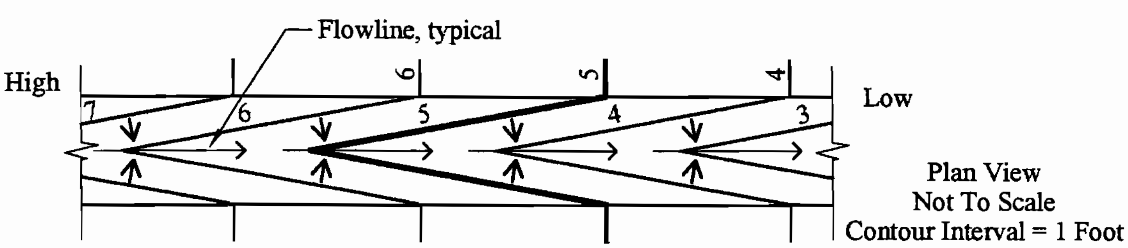


Figure 3-22. Ditch (Swale) Signature

Avoid These Incorrect Swale Signatures

Notice that in a correctly drawn swale signature, the contour lines "flare" or "veer" away from the flowline—contour lines maintain the same elevation while the flowline us descending. Contrast the correct signature shown in Figure 3-21 to the "test-tube" like shape of the signature shown in Figure 3-23. This signature is incorrect because along the segment of the swale where the contour lines run parallel to the flowline, the *flowline would have to be dead level.*

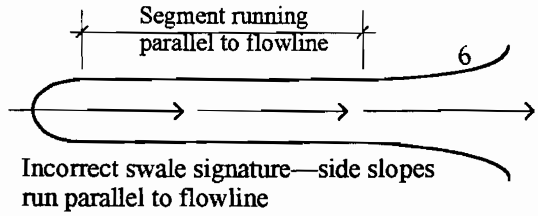


Figure 3-23. Incorrect "Test Tube" Swale Signature

A second incorrect signature is shown in Figure 3-24. Recent exams have required that swales be at least six-inches deep. Figure 3-24 does not comply with this requirement.

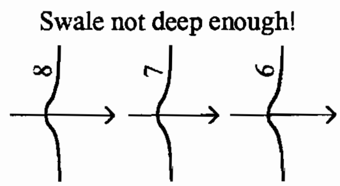


Figure 3-24. Incorrect Swale "Too Shallow" Signature

Ridge Signature—Think of a ridge as a swale turned inside out. Study Figure 3-25. Notice the similarity to a swale. In fact, the only thing that differentiates a ridge from a swale, when viewed in plan view, are the elevation callouts. Remove those, and they cannot be distinguished from one another. The illustration on the left of Figure 3-25 shows what could be a natural or a man-made ridge signature, while the illustration on the right shows a man-made-only ridge signature.

Memorization Tip: In a ridge signature, contour lines always *point downhill.*

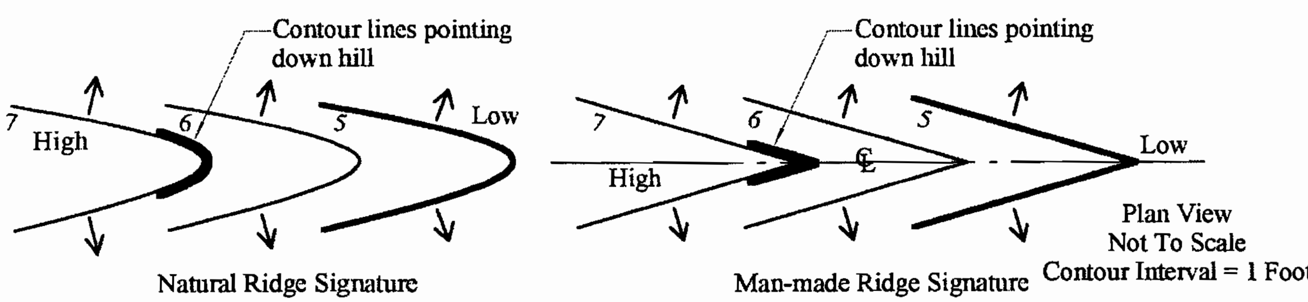


Figure 3-25. Ridge Signature

Contour Signatures Representing Summits and Depressions

Figure 3-26 shows a "summit" signature on the left, and a depression signature on the right. Notice that, like the swale and ridge signatures, these too signatures appear identical until the elevation callouts are read. The summit signature is directly applicable to problems where mounding is used to screen an objectionable view.

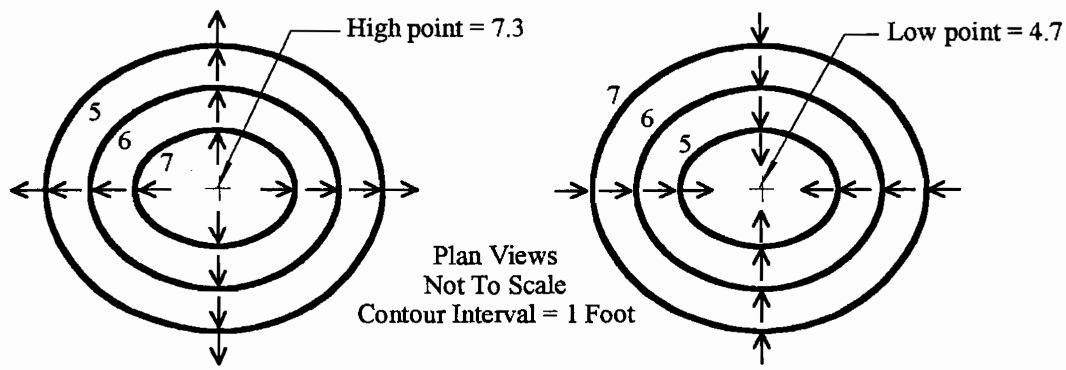


Figure 3-26. Summit and Depression Signatures

The depression signature comes into play on the exam when the problem requires that a watershed area be defined by tracing along ridgelines. The depression signature in its pure form describes the condition that exists when a watershed is "closed," meaning that there is no outflow from it. If a watershed is "open," meaning that there is outflow, which is far more prevalent in nature, the signature that correlates most closely is the swale signature.

Walks and Lineal Plane Surfaces

Figure 3-27 shows a simple walk or lineal plane surface that has longitudinal (long axis grade) slope but no cross slope (short axis grade). Notice the characteristic ladder-like appearance of the contour lines. Because it does not have cross slope, this signature is confined to limited applications on the LARE, such as tennis or other game courts.

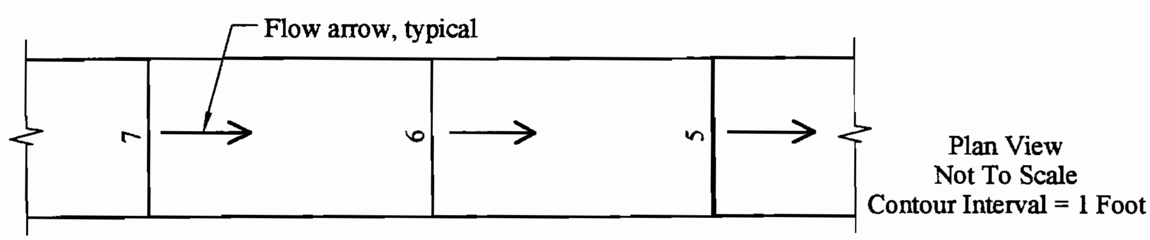


Figure 3-27. Plane Surface Having No Cross Slope

Figure 3-28 shows a standard walk or plane surface that has both longitudinal grade and cross slope grade. Notice the characteristic diagonal orientation of the contour lines. The reason for providing cross slope is that it is desirable to shed runoff as quickly as possible, but without compromising the safety or appearance of the surface. A cross slope of 2% is specified in the *LARE Reference Manual* and it is the correct default value to use if a cross slope is not specified in the problem statement (if it is not, it becomes an implicit instruction, meaning that unless otherwise specified, cross slopes should always be provided on walks and plane surfaces other than some game courts).

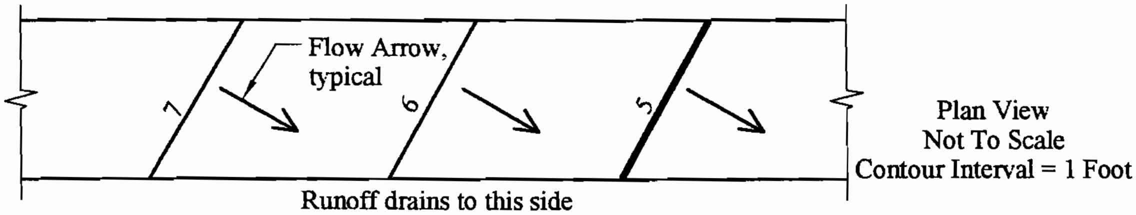


Figure 3-28. Plane Surface Having Longitudinal and Cross Slope

Figure 3-29 shows a curvilinear walk with cross slope. In this example, it is shown with a centerline. On the exam, centerlines are normally not provided, but if spot elevations are provided in the center of a walk, adding a centerline will facilitate plotting whole number contour lines with cross slope.

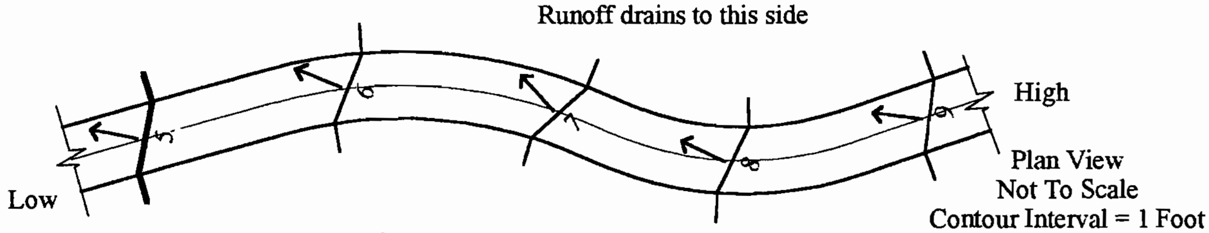


Figure 3-29. Curvilinear Walk

Parking Lot and Road Signatures

Parking lots have always been a popular test element on the LARE. Roads of various types have also been featured, increasingly so in recent administrations. Roads and parking lots come in many configurations. Surfacing can be concrete or asphalt, or a even a modular paving material. Where concrete is specified, it may be noted as Concrete, or as Portland Cement Concrete, or as PCC. Where asphalt is specified, it may be noted as Asphalt, or as Asphalt Concrete, or as AC. Both roads and parking lots can have curbs and adjacent sidewalks; roads may have shoulders, and so on. Beyond this, an infinite number of variations are possible by simply combining two or more signature attributes.

Basic Road Signatures — Below are four basic "prototype" signatures for roads. Most other road signature configurations are variations of these. Most road signatures are "bilaterally symmetrical," meaning that the signature is mirrored across the centerline — all of the examples shown below fall into this category. However, on the LARE, some road signatures are asymmetrical. For example, a road may have a six-inch concrete curb on one side, but a shoulder or a ditch on the other. These variations have all been featured on recent exams.

Figure 3-30 shows a simple portland cement concrete (PCC) road with a crown (raised center), but without curbs, sidewalks or shoulders. Note the pronounced *chevron shape* of the contour lines on this

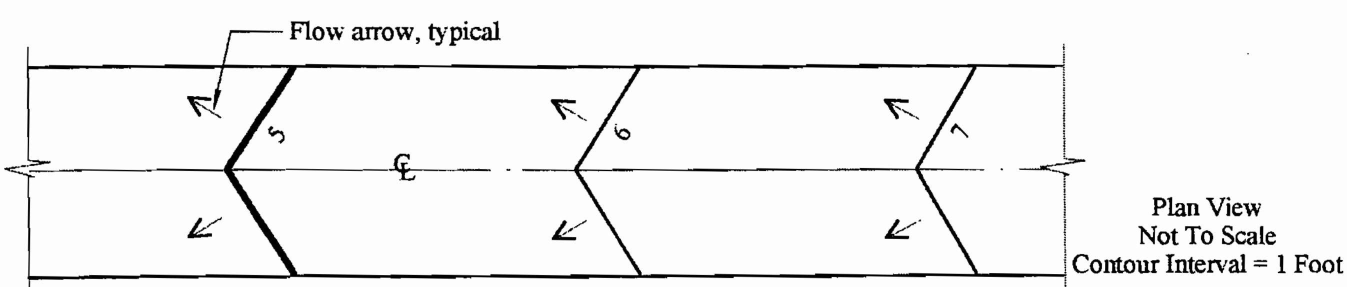


Figure 3-30. Concrete Road Without Curbs Signature

road signature. This is the characteristic signature for a portland cement concrete road. In this example run-off flows off the road at its edges.

Figure 3-31 shows a portland cement concrete (PCC) road with crown, six-inch concrete curbs and adjacent sidewalks. In this example, all run-off generated on the road flows to the gutters at base of curb face, as does all runoff generated on the sidewalks.

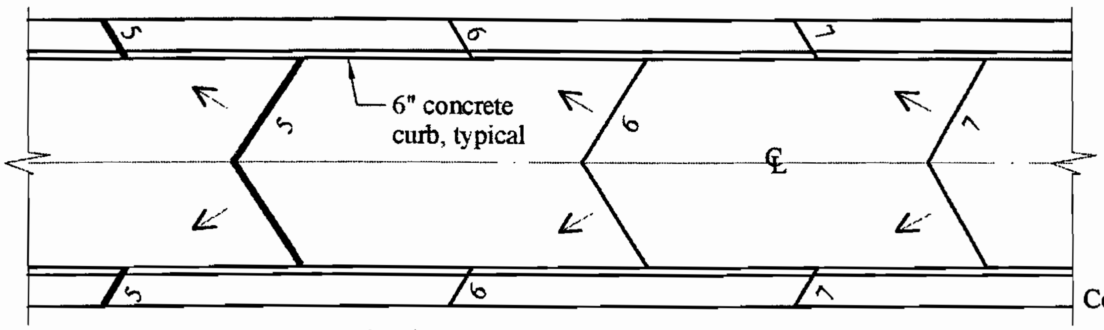


Figure 3-31. Concrete Road With Six-inch Concrete Curbs and Sidwalks Signature

Six-Inch Concrete Curbs — On the LARE curbs have always been standard six-inch concrete curbs (be aware that it is always possible that on a future exam administration a curb height other than six-inches could be required — see Chapter Four for information on how to design for other heights). On the examples below where concrete curbs are shown, a six-inch height is assumed. This makes it very easy to correctly design a road with a curb signature. Follow contour line seven on Figure 3-31. Notice that the point where contour line seven "mounts" the curb is halfway *down* toward the next lower contour line. See "How to Never Again "Invert" a Curb Signature" below. When studying these signatures, keep in mind that the contour line is level; it's the road surface, the curb and sidewalk that are all sloping, and doing so at exactly the same grade as evidenced by the fact that the contour spacing is identical. This concept of the three being *locked together* in terms of grade is important to remember. Understand that if the road and sidewalk had different grades, the two surfaces would diverge in terms of their difference in elevation. The curb would, of necessity, have to be a variable height curb.

Figure 3-32 shows an asphalt concrete (AC) road with crown, but without curbs, sidewalks or any special shoulder treatment. Note the curvilinear shape of contour lines on road. This is a characteristic of asphalt. If AC is called out on the road or in the instructions, the contour lines must be curvilinear. In this example, run-off flows off the road at its edges.

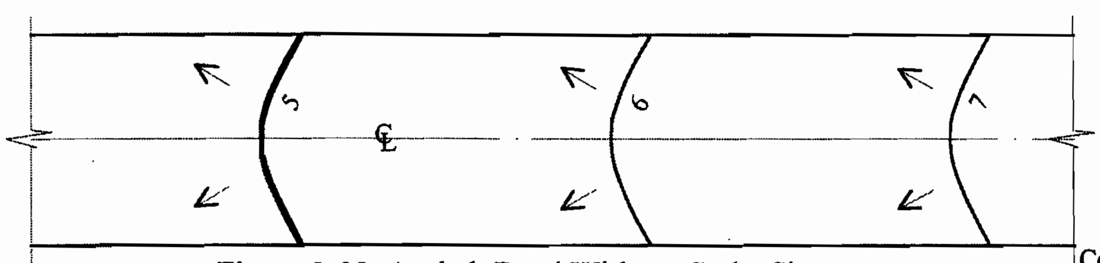


Figure 3-32. Asphalt Road Without Curbs Signature

Figure 3-33 shows an asphalt concrete (AC) road with six-inch concrete curbs and adjacent side-walks. Note again the curvilinear shape of contour lines on road. In this example, all run-off generated on the road flows to the gutters at base of curb face, as does all runoff generated on the sidewalks.

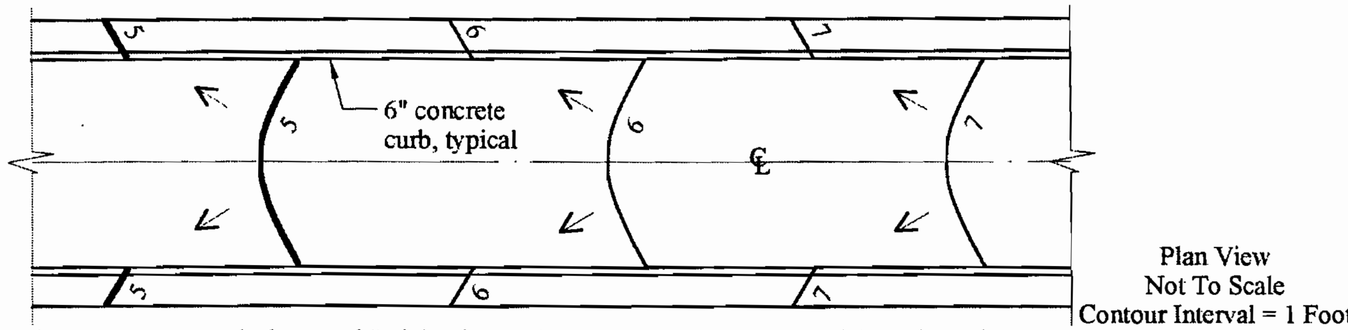


Figure 3-33. Asphalt Road With Six-Inch Concrete Curbs and Sidewalks Signature

Basic Parking Lot Signatures — Conceptually, parking lots are almost identical to roads: The chief difference is that they are much shorter longitudinally. One difference is that many parking lot configurations have depressed centers, while this is fairly rare in road design (alleys and specialized service roads being exceptions). One clear difference between the two is that there are infinitely more possible permutations in shape and drainage patterns. For example, parking lots may be constructed "at grade" meaning that they do not have concrete curbs surrounding them — many real world parking lots are designed in this way, although this is uncommon on the exam. The examples shown below cover only some of the basic possibilities. Figures 3-34 through 3-37 have contour lines that have been extended hypothetically to show the points where they mount the curb.

Figure 3-34 shows a parking lot configuration where all runoff drains to the drop inlet catch basin located in the corner. This is the most common parking lot configuration used on past exams. Although many variations of lot shape and size are possible within the corner catch basin configuration problem type, the contour signature remains conceptually the same. Due to the fact that the paving slopes in one plane toward the catch basin, the contour signatures for portland cement concrete and asphalt concrete appear identical when viewed in plan view.

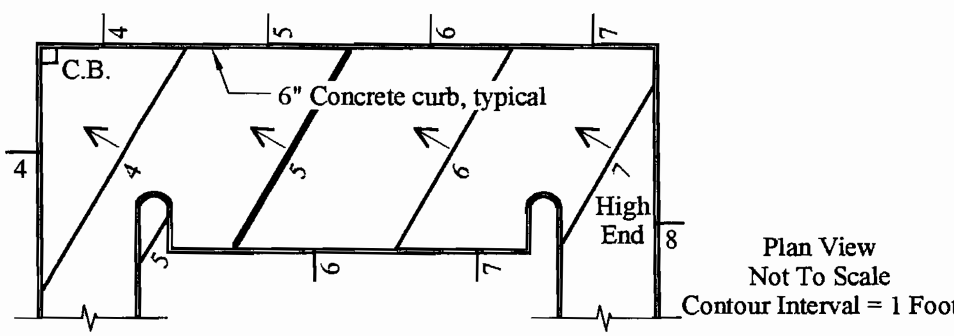


Figure 3-34. Corner Catch Basin Parking Lot

Figure 3-35 shows a parking lot design where runoff drains to the center. The chevron shape of the contour lines indicates that the paving is portland cement concrete in this example. Notice that contour line 5 closes on itself in the center, and contour that line 7 never mounts the curb at the ends. For additional information on how contour lines behave at curbs, see How to Locate Contour Lines at Curbs below.

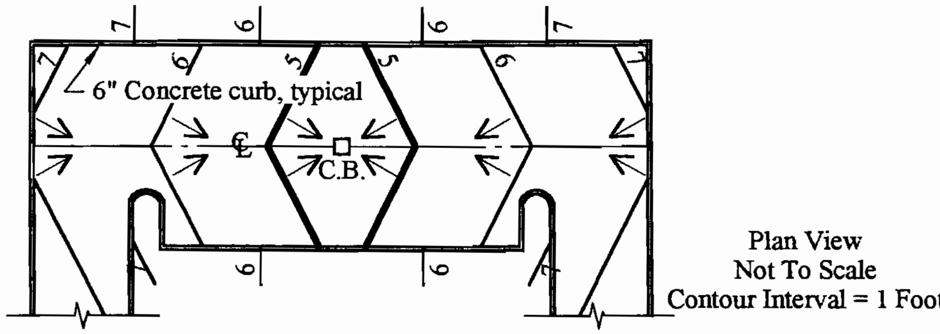


Figure 3-35. Center Catch Basin Parking Lot

Figure 3-36 shows a variation that places the catch basin to one side in the center of the lot. Notice contour line 7 briefly mounts the curb where the curb juts out into the lot at the entrances.

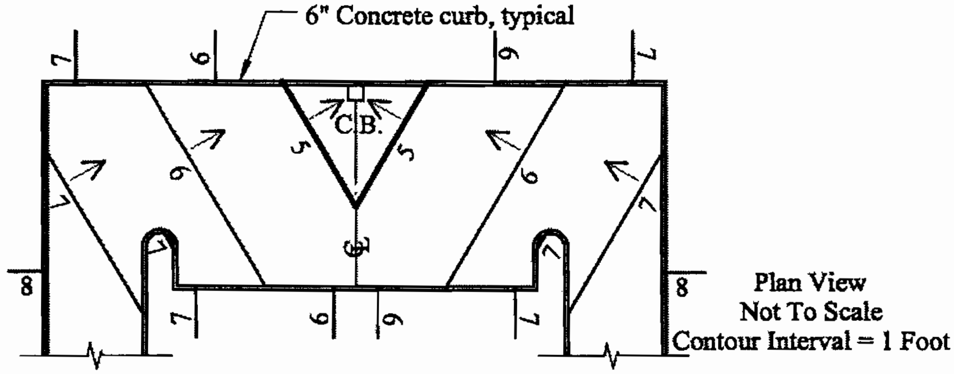


Figure 3-36. Side-Center Catch Basin Parking Lot

Figure 3-37 shows another drainage scheme that has also been popular on past exams. This configuration places the catch basin at the center low end of the parking lot.

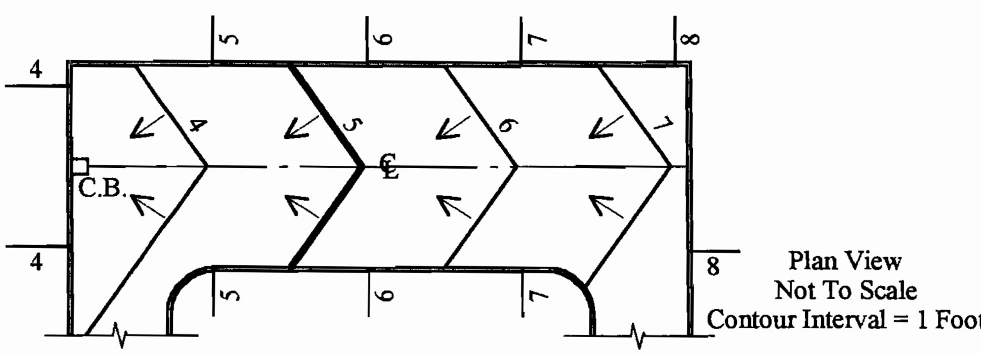


Figure 3-37. End Catch Basin Parking Lot

Figure 3-38 shows the same scheme seen in Figure 3-37, with several differences. First, it has sidewalks on two sides that drain into the parking lot. It also features an island that juts out into the parking lot to provide disabled access. The drainage pattern shown here is ideal for this situation. Due to the fact that all runoff flows to the center, it cannot be trapped behind the island.

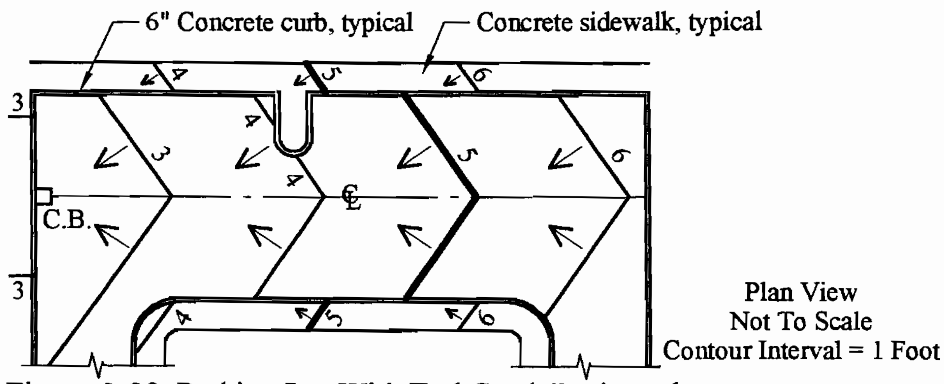


Figure 3-38. Parking Lot With End Catch Basin and Concrete Curbs and Sidewalks

Specialized Signatures

The following three contour signatures are specialized signatures.

15. Contour signature representing a concrete walk with longitudinal slope and cross slope, *and with the finish surface of the walk elevated approximately 1-inch above the adjacent non-paved finish grade.* This is customarily done to keep debris-laden runoff from adjacent non-paved areas off hardscape surfaces. Note that contour line "breaks" at the edge of the walk to denote the 1-inch break in grade, as shown in Figure 3-29. However, at this point in time, CLARB has not required this convention

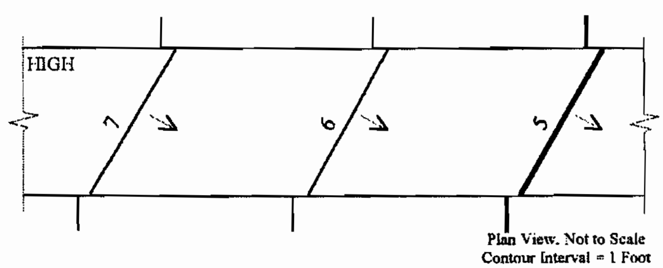


Figure 3-39, Walk 1-Inch Above Adjacent Grade

16. Contour signature representing a dam. Figure 3-30 illustrates a typical dam signature. Note that the basic underlying signature is that of a swale, but with revised contours having been inserted across the swale to block, or dam, runoff flowing into and down the swale. This signature is important in stormwater management problems where a retention or detention basin is required.

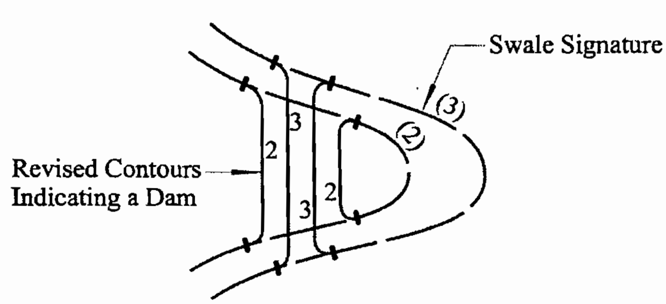


Figure 3-40, Dam Signature

17. Contour signature representing a horseshoe swale around a level slab. The horseshoe swale is used to protect a level slab from downslope runoff. To understand how this protection is accomplished, study Figure 3-41. Note that runoff is intercepted by the swale and taken around and away from the structure. See Chapter 4 for more on horseshoe swale design for both level and sloping surfaces.

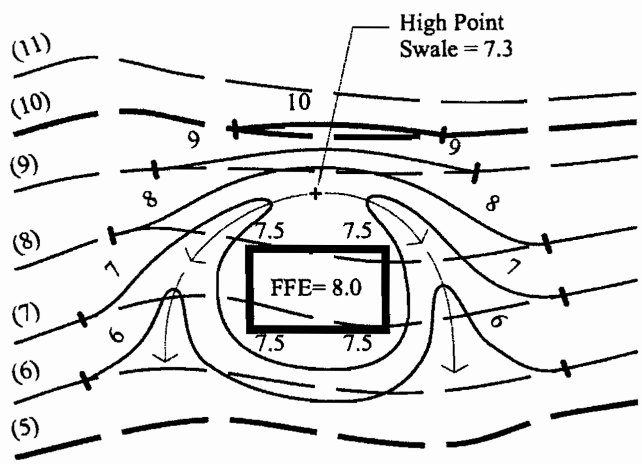


Figure 3-41, Horseshoe Swale to Protect a Level Surface

18. Contour signature representing a horseshoe swale around a sloping plane surface. Like the horseshoe swale designed to protect a level slab from downslope runoff, this grading feature is designed protect a sloping plane surface, such as a terrace or a game court, from downslope runoff. To understand how runoff flows around and away from the sloping plane surface, study Figure 3-42.

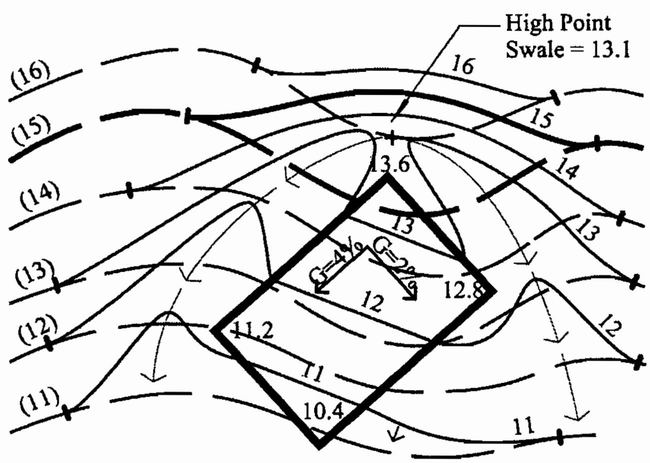


Figure 3-42, Horseshoe Swale to Protect a Sloping Plane Surface

HOW TO NEVER AGAIN "INVERT" A CURB SIGNATURE

Inverting a curb means that the normal relationship of having the top of curb higher than the road or parking lot surface has been reversed; the road or parking lot surface is *above*, or *higher,* than the top of the curb.

Concrete curbs on the exam are a fact of life. Therefore, you must know how to correctly depict them. Rote memorization of road and parking lot signatures is risky because of the variations that are possible. This is particularly true in parking lot design, where the center may be crowned or depressed, and there are an infinite number of options for the placement of drain inlets.

It is important that you understand why the contour signatures for roads and parking lots behave the way they do. These contour signatures are actually combinations of several of the basic signatures that are shown at the beginning of this chapter. For example, the crown of a typical road or parking lot having a raised center is really a flattened ridge signature. Notice in the examples above that the points where the contour lines cross the centerline *point downhill* as they do in a ridge. Further, the gutter at the base of the curb is, in actuality, a *stylized swale* having one vertical side (the curb) and one sloping side (the road or parking lot surface). (In parking lots with depressed centers, the swale concept still applies — the curbs and the depressed center together form the swale signature.) Notice that where the contour lines cross the flowline at the base of the curb, they *point uphill.* Reducing these signatures to their component parts demystifies them. Unfortunately, this knowledge alone cannot guarantee that you won't "invert" a curb signature. The critical task in designing roads and parking lots with curbs is to correctly show the relationship between the surface and the point where the contour lines "mount" or top the curb.

Design Tip — There is a very simple, virtually infallible way, of getting the curb-road surface, or curb-parking lot surface relationship correct, 100% of the time, regardless of whether the surface is crowned or depressed. In the following example, a six-inch concrete curb is assumed; for other curb heights (unlikely on the LARE), the same concept can be applied.

Step 1. Find the mid-point between contour lines 6 and 7 by scaling. Place a tick mark at that point. This should be done with a scale and with care to assure reasonably accuracy. On the plan, write the elevation at the tick mark. In this example, the elevation will be 6.5, which is halfway between 6 and 7 as shown in Figure 3-43.

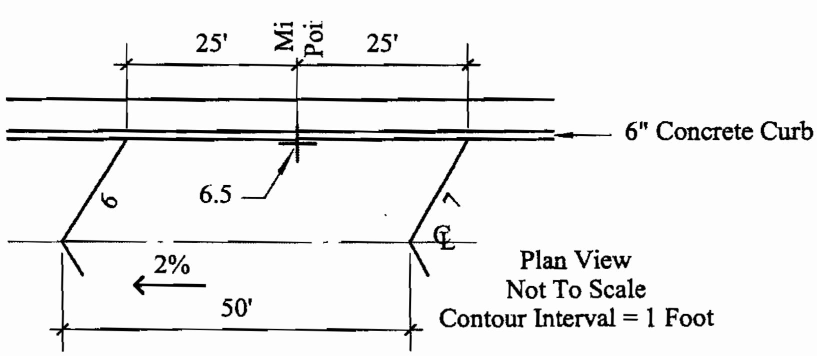


Figure 3-43. Mid-Point With Mid-Point Elevation

Step 2. The curb is six-inches high. Six-inches expressed in tenths of a foot, is point five (.5). Adding .5 to 6.5 equals 7. Therefore, the elevation at the top of the curb immediately above the 6.5 tick mark is 7. **That is the point where contour line 7 mounts the curb as shown in Figure 3-44.**

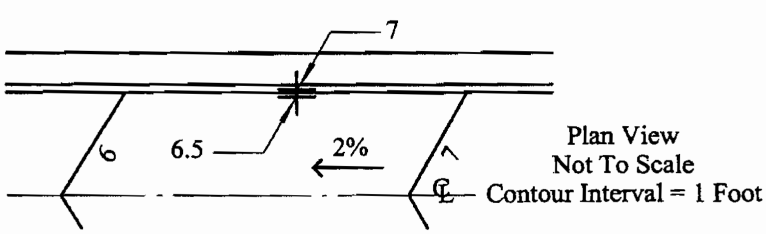


Figure 3-44. Establishing Elevation at Top of Curb

Step 3. Draw the contour line as shown in Figure 3-45. Observe the relationship of the point where contour line 7 on the road surface meets the face of the curb, then runs along the curb face, and finally mounts the curb at a point halfway downslope toward contour 6.

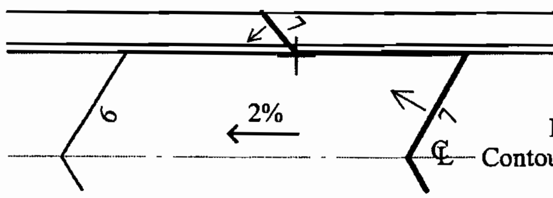


Figure 3-45. Drawing the Contour Line

It can also be helpful to draw flow arrows perpendicular to contour lines, as shown in the figures above. They are an excellent way of quickly double-checking to be sure that runoff is flowing in the intended direction.

Obviously, it is highly desirable to design any curb signatures using the above tip. If the curb is inverted, you'll have to erase and correct your plan. But, what if you find yourself in the situation where you took the chance in plotting contours at a curb, but now you're not sure you're correct. Fortunately, the above method can also be used to verify the signature. Follow the same steps as shown above. If the curb was unintentionally inverted, *the elevation at the top of the curb will be one whole foot off.* Surprisingly, this can sometimes be tricky to spot, so check the numbers carefully — the top of the curb must be *.5 higher* than the number on the road or parking lot surface. If the elevation of the contour line is *one-foot lower* than the mid point elevation plus six-inches, the curb has been inverted.

HOW TO GET CURBS THAT RUN PERPENDICULAR TO THE PARKING LOT RIGHT

Often, at the corner of a parking lot where the curb makes a 90° turn, it is difficult to know exactly where a given contour line mounts the curb. This is also true where an element, such as a handicap ramp island, juts out into a parking lot. Figure 3-46 illustrates these two conditions. The methods shown below are quick, simple and always produce a correct result.

Begin by correctly plotting all whole number contour lines on the parking lot surface. Plotting only the whole number contour lines that cross the north edge of the parking lot (contour lines 4, 5 and 6) would leave contour lines 7 and 8 on the west side of the parking lot still to be plotted, which would require an additional calculation. An easier way to locate these contours is to simply prolongate (extend) the north edge of the parking lot as shown in Figure 3-46, then establish the points where contour lines 7 and 8 would cross on the prolongated line. Knowing when it is necessary to do this is a matter of experience. Use a glide to extend the lines down onto the parking lot surface as shown.

Finally, locate the points where all contour lines mount the six-inch curbs that surround the parking lot. Some of these points are obvious, while others are not so obvious. To find those less obvious points, simply draw light construction lines between, and parallel to, the whole number contour lines already drawn on the lot surface as shown in Figure 3-46. Extend these lines to the bottom of the curb. The point where they meet the curb is the point where the contour lines mount the curb. This technique works regardless of the shape or complexity of the plane surface.

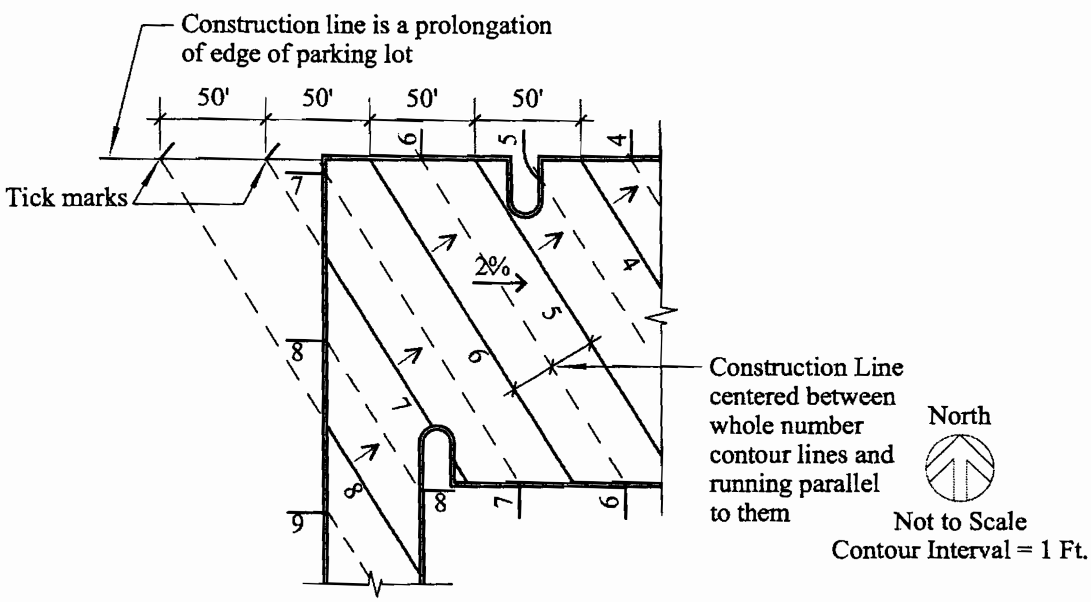


Figure 3-46. Locating Contour Lines at Curbs

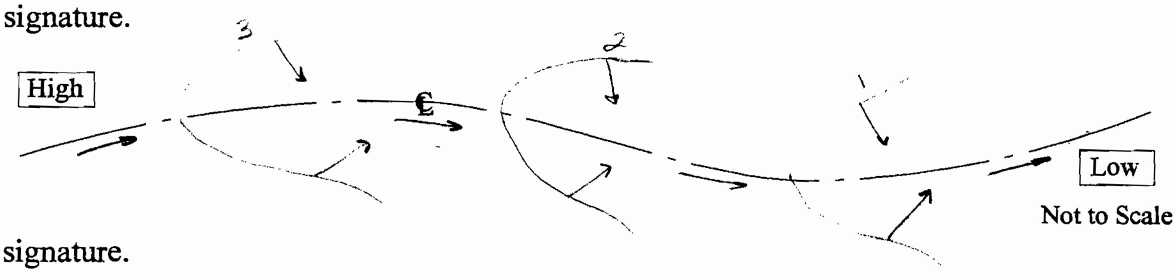
CHAPTER THREE EXERCISES

Instructions: Draw the signature asked for on each of the plan view sketches. Proceed as follows:

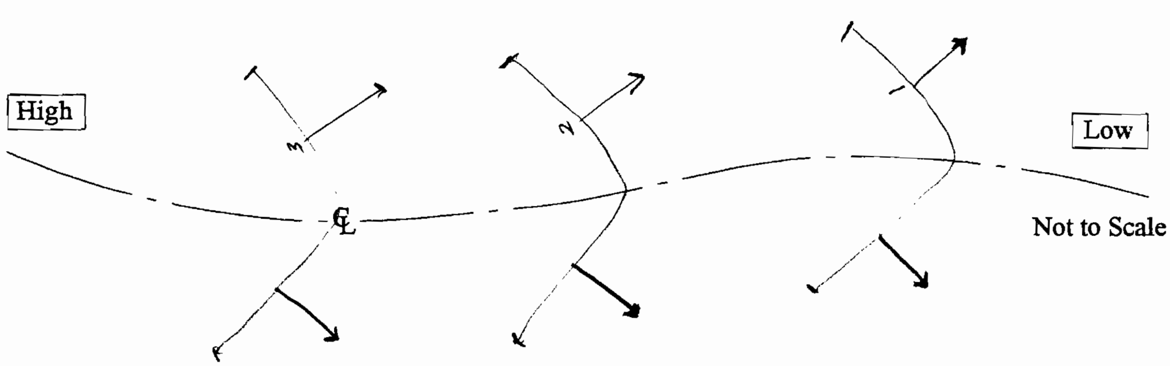
1. Draw three whole number contour lines for each sketch and number them 1, 2, and 3.
2. Note high and low end references, and where cross slope is called for, which side runoff drains to.
3. All grades shall be straight grades (i.e., contour lines evenly spaced).
4. Grade and scale are not relevant, but the orientation of the contour lines is. The intent is to correctly indicate the contour signatures called for.
5. Draw flow arrows sufficient to indicate direction of flow.
6. Concentrate on doing this exercise as quickly as possible. Draw all contours freehand.

Problems:

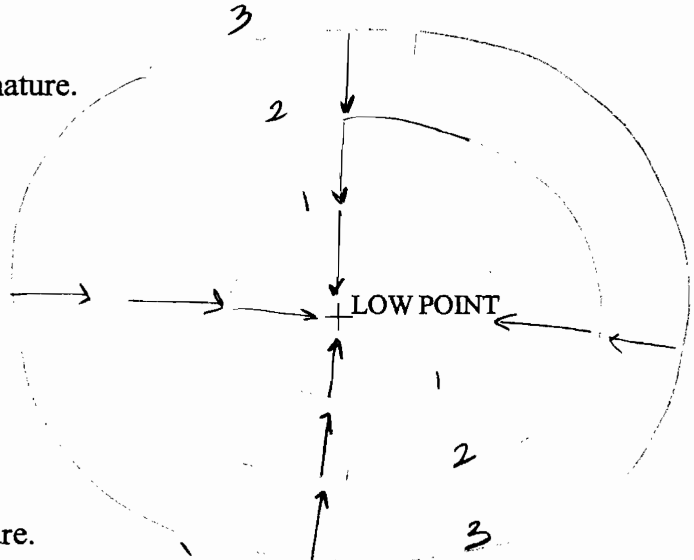
1. Swale signature.



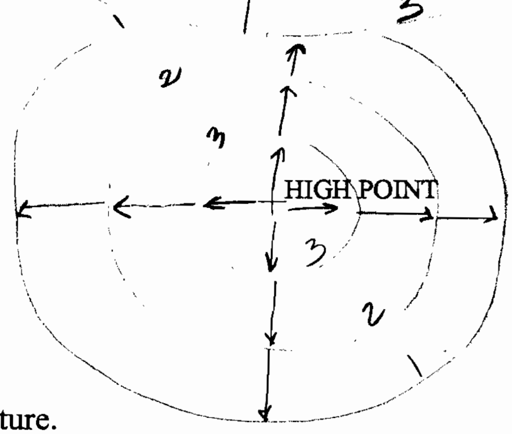
2. Ridge signature.



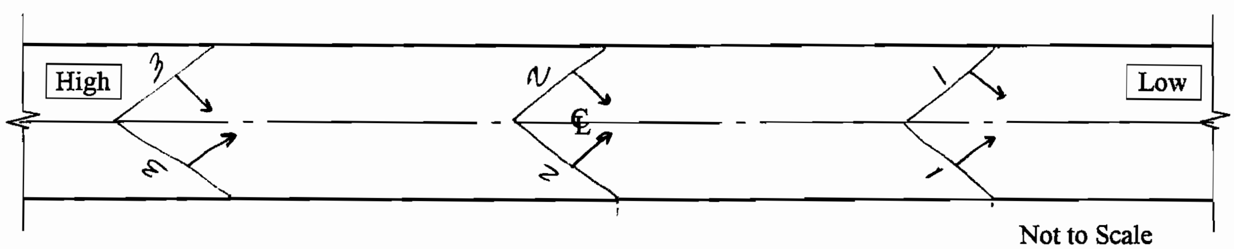
3. Depression signature.



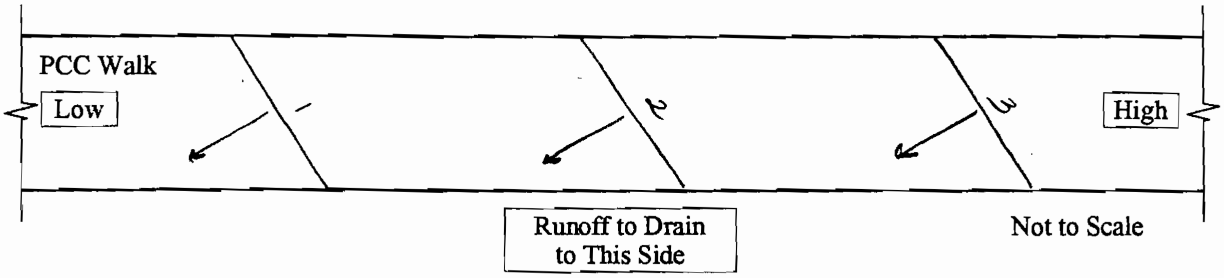
4. Summit signature.



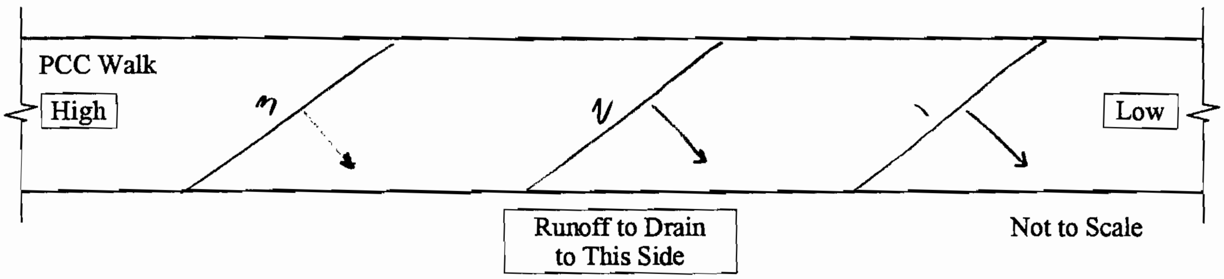
5. Concrete ditch signature.



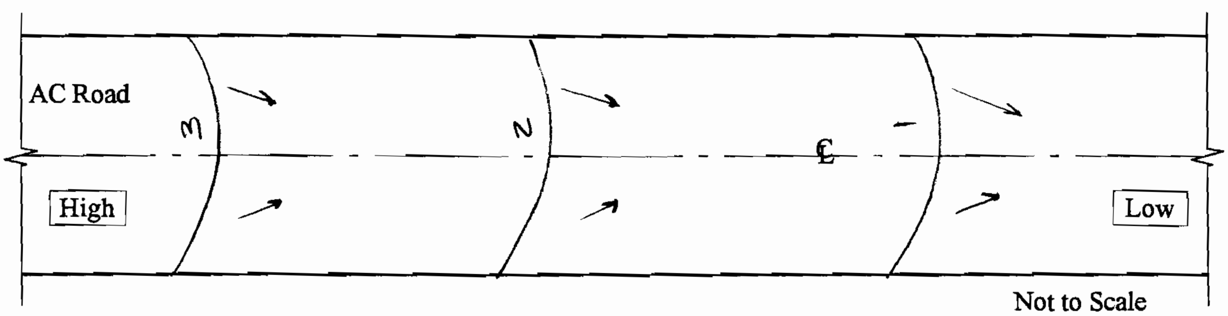
6. Walk with longitudinal slope and cross slope signature. Runoff drains to side indicated.



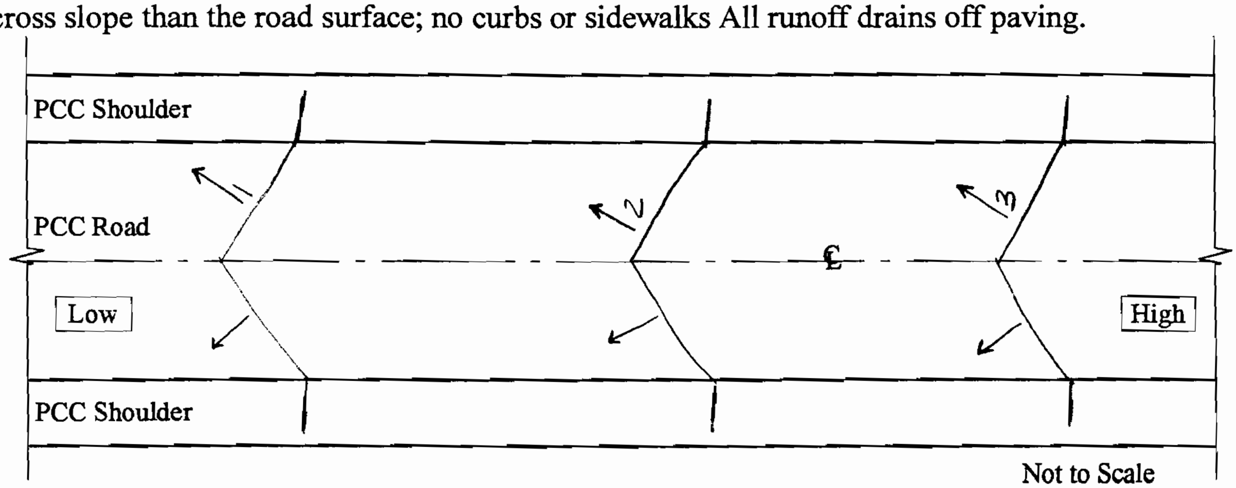
7. Walk with longitudinal slope and cross slope signature. Runoff drains to side indicated.



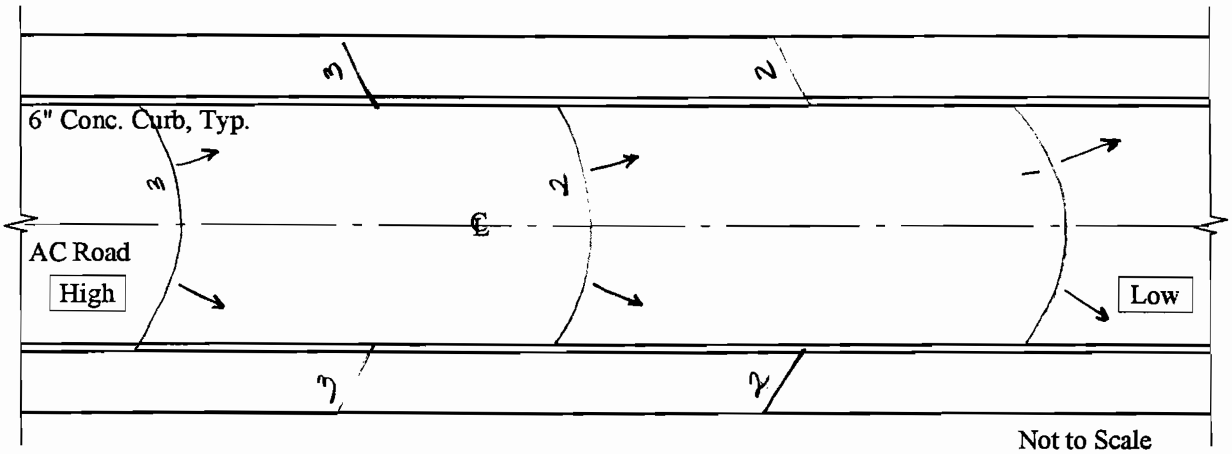
8. Asphalt concrete road with crowned center signature; no curbs, sidewalks, or shoulder treatment. All runoff drains off paving.



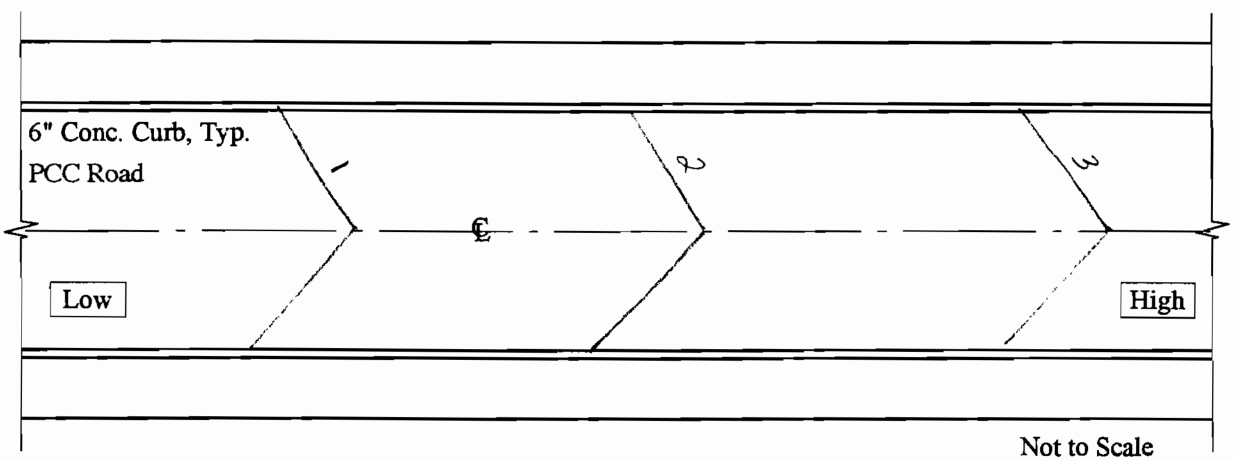
9. Portland cement concrete road with crowned center signature and paved shoulders with a different cross slope than the road surface; no curbs or sidewalks All runoff drains off paving.



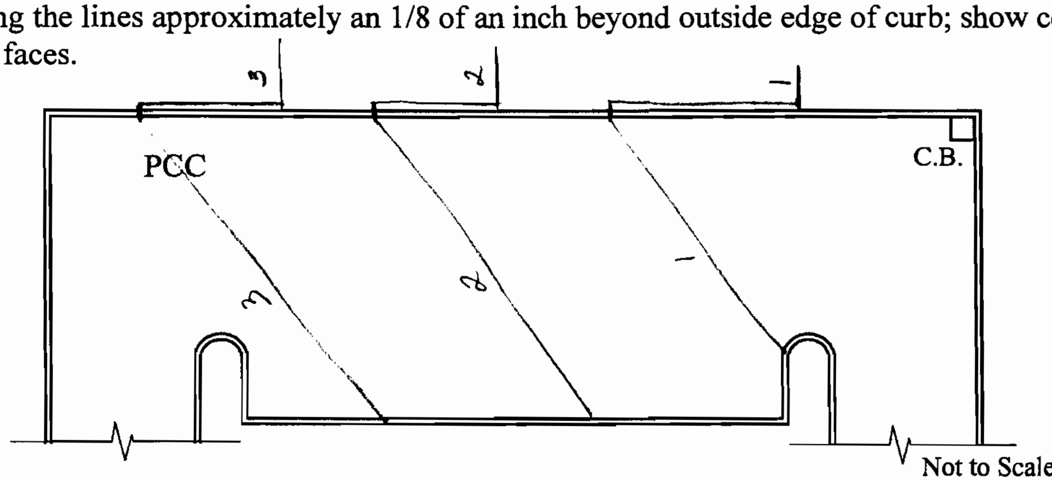
10. Asphalt concrete road with crowned center signature, six-inch concrete curbs and sidewalks. All runoff drains to gutters at base of curbs. Apply the tip given above for not inverting the curb.



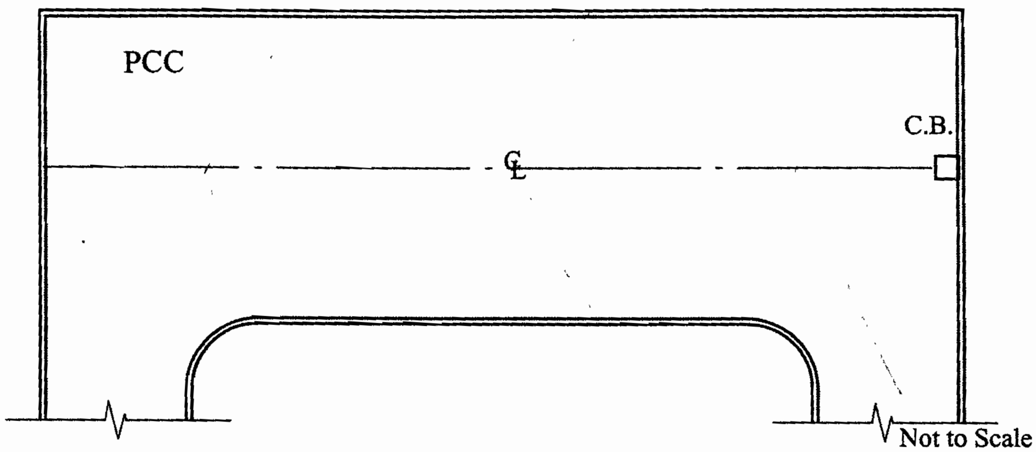
11. Portland cement concrete road with crowned center signature, six-inch concrete curbs and sidewalks. All runoff drains to gutters at base of curbs.



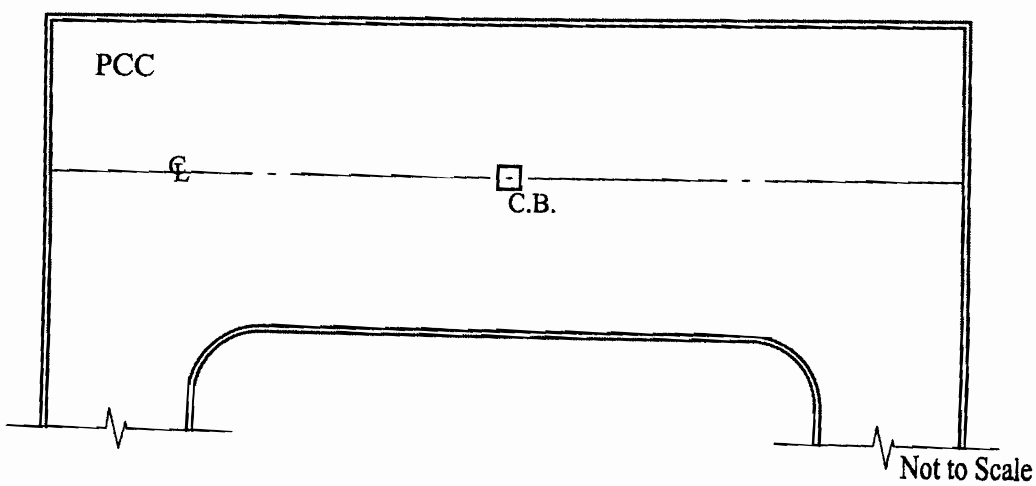
12. Parking lot with catch basin in corner signature. Show points where contour lines mount curbs by extending the lines approximately an 1/8 of an inch beyond outside edge of curb; show contour lines on curb faces.



13. Parking lot with catch basin at centerline at end of parking lot signature. Show points where contour lines mount curbs by extending the lines approximately an 1/8 of an inch beyond outside edge of curb; show contour lines on curb faces.

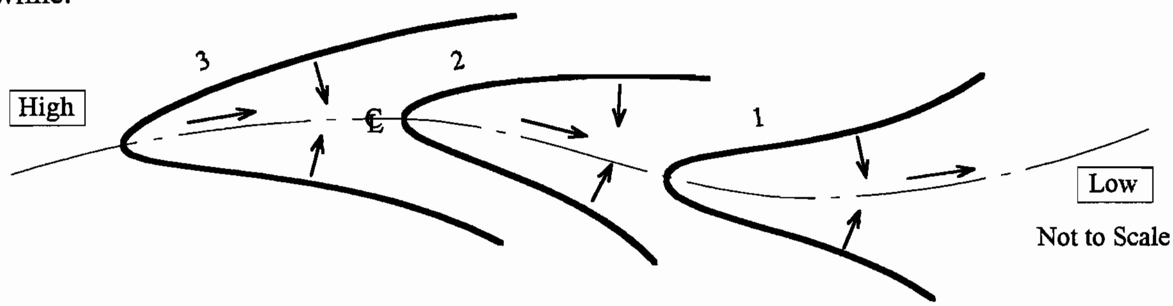


14. Parking lot with catch basin at centerline at center of parking lot signature. On this problem, use six contour lines to create your solution. Show points where contour lines mount curbs by extending the lines approximately an 1/8 of an inch beyond outside edge of curb; show contour lines on curb faces.

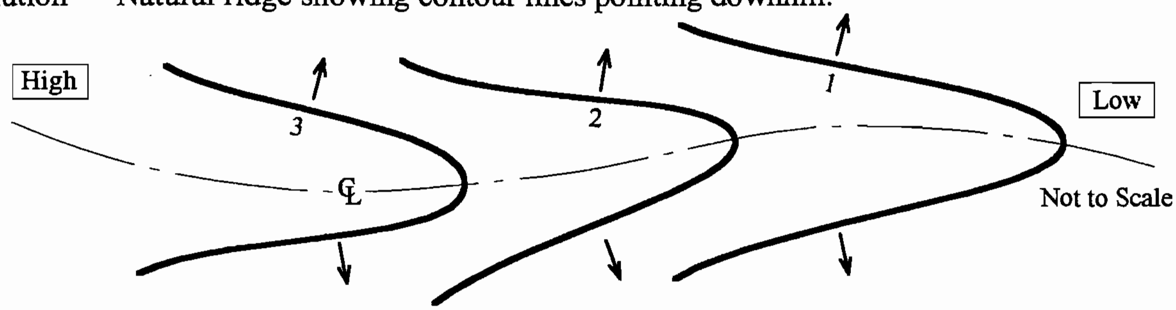


SOLUTIONS

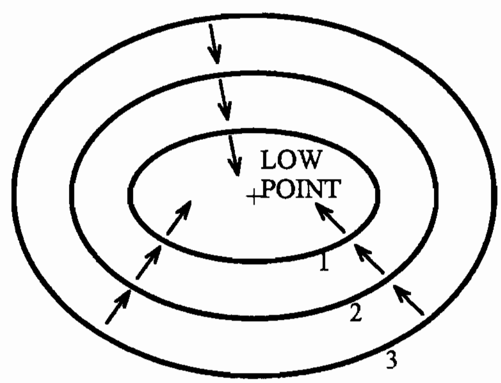
1. Solution — Swale showing contour lines pointing uphill. Notice how contours flare away from the flowline.



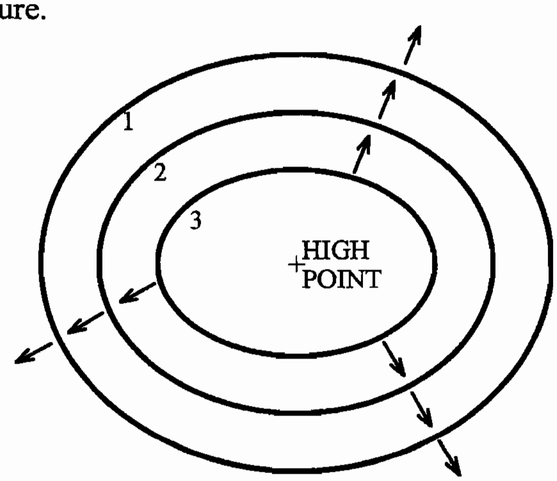
2. Solution — Natural ridge showing contour lines pointing downhill.



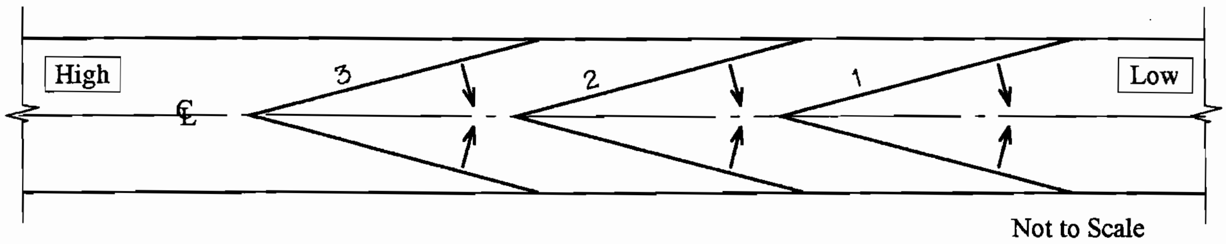
3. Solution — Depression signature.



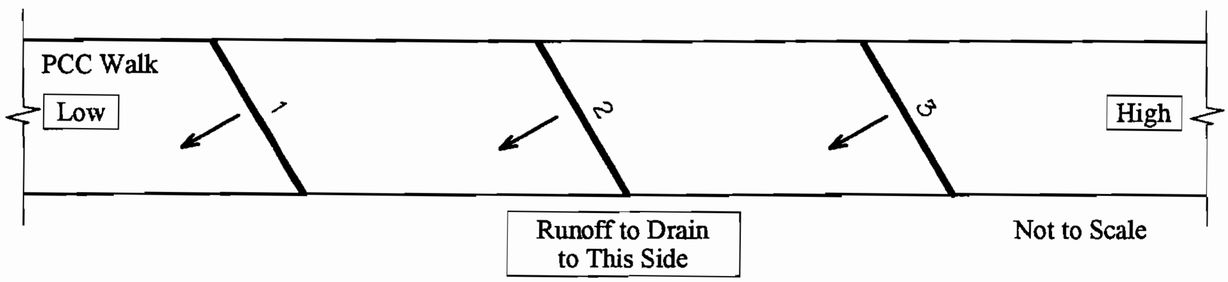
4. Solution — Summit signature.



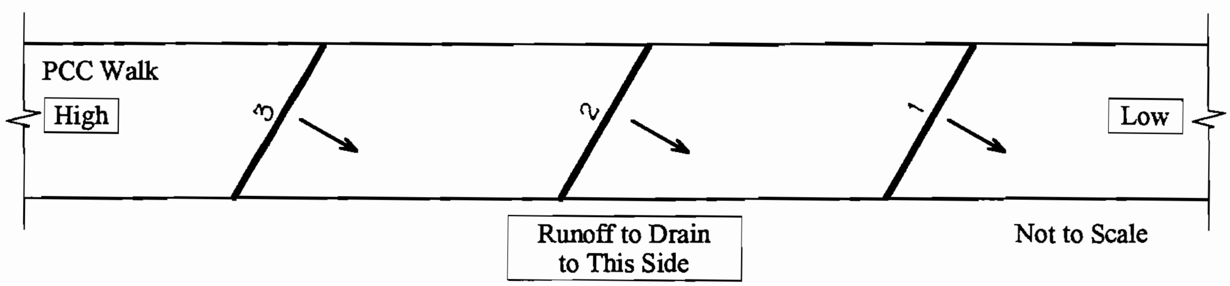
5. Solution — Man-made concrete ditch signature.



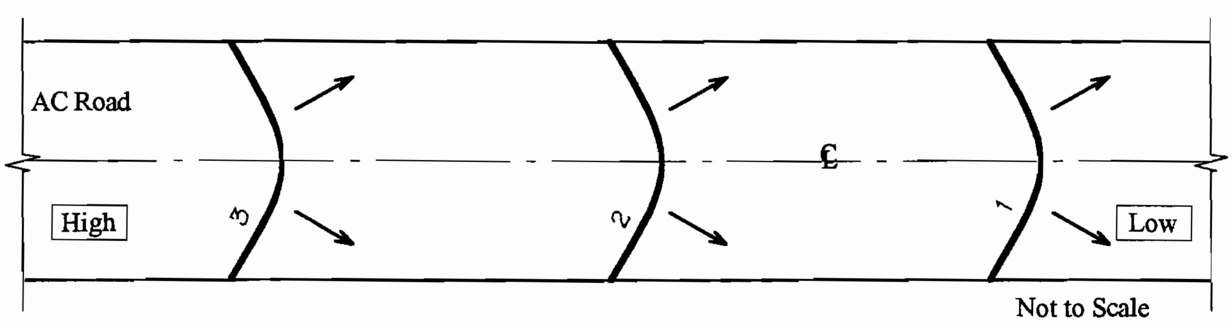
6. Solution — Concrete walk with cross slope signature. If this walk were paved with asphalt rather than concrete, it would appear identical in plan view.



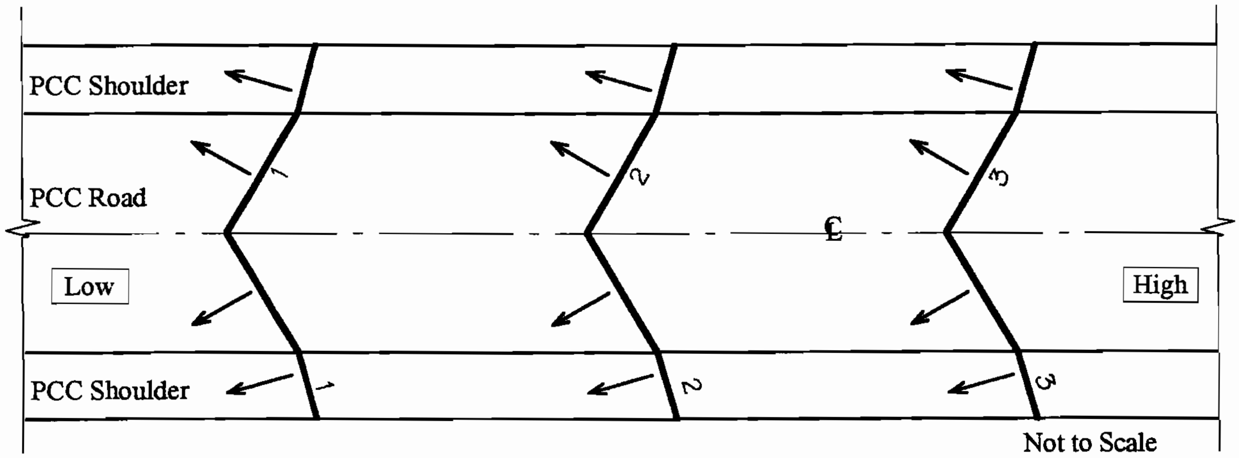
7. Solution — Concrete walk with cross slope signature.



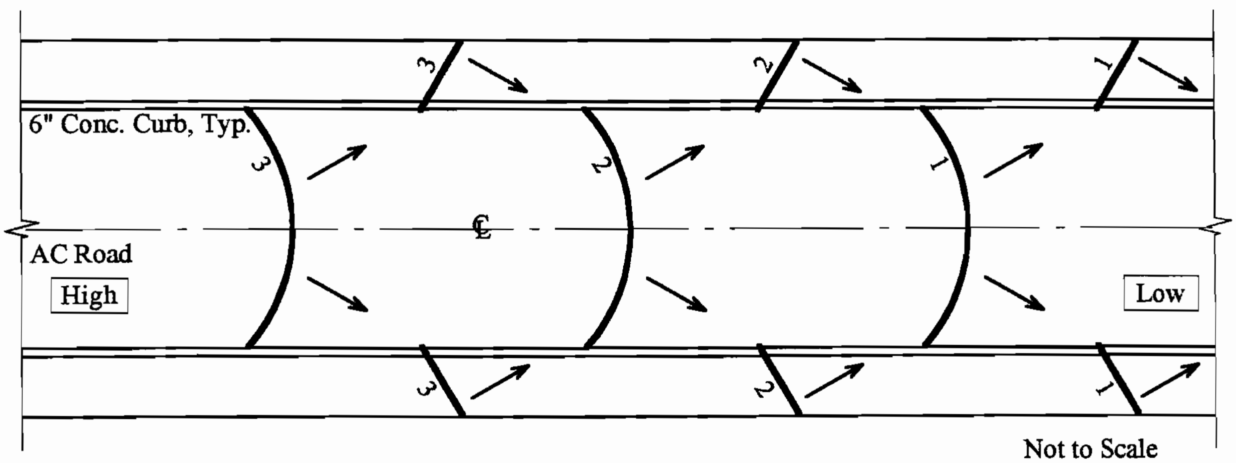
8. Solution — Asphalt concrete road. Note curvilinear contour lines.



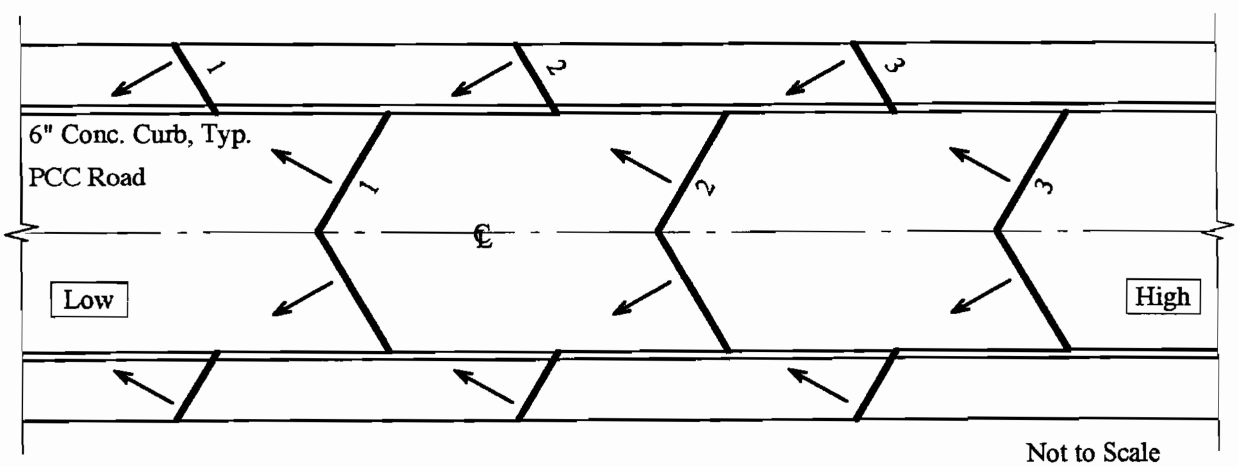
9. Solution — Portland cement concrete road with paved shoulder. Change in angle of contour on shoulder denotes cross slope is different than that of road surface.



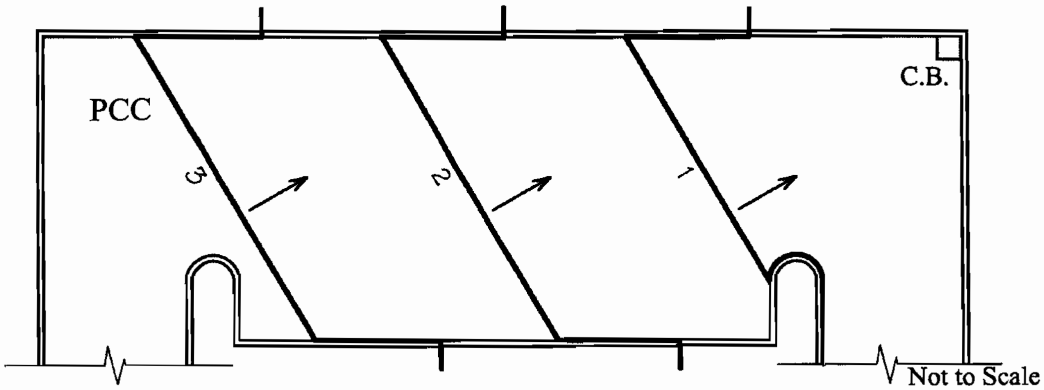
10. Solution — Asphalt concrete road with six-inch concrete curbs and sidewalks signature.



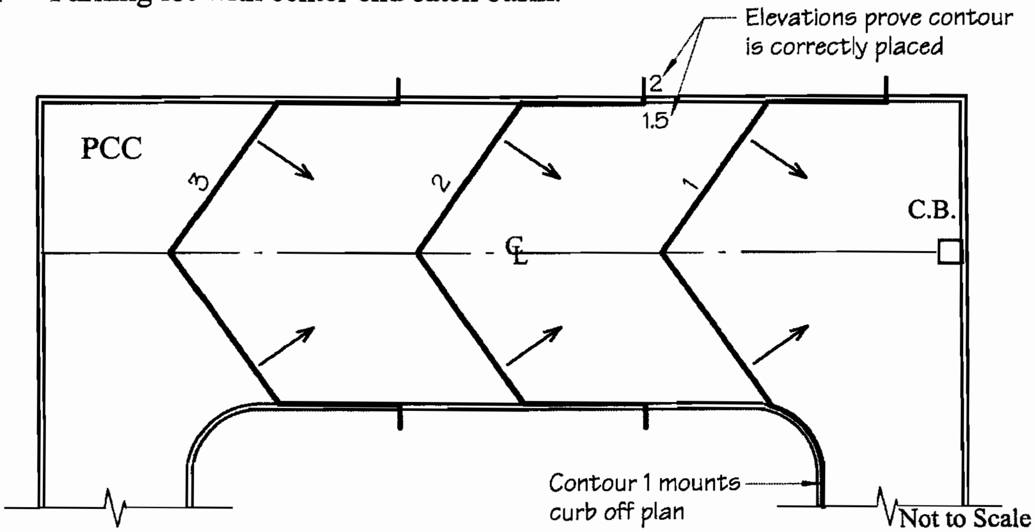
11. Solution — Concrete road with six-inch concrete curbs and sidewalks signature.



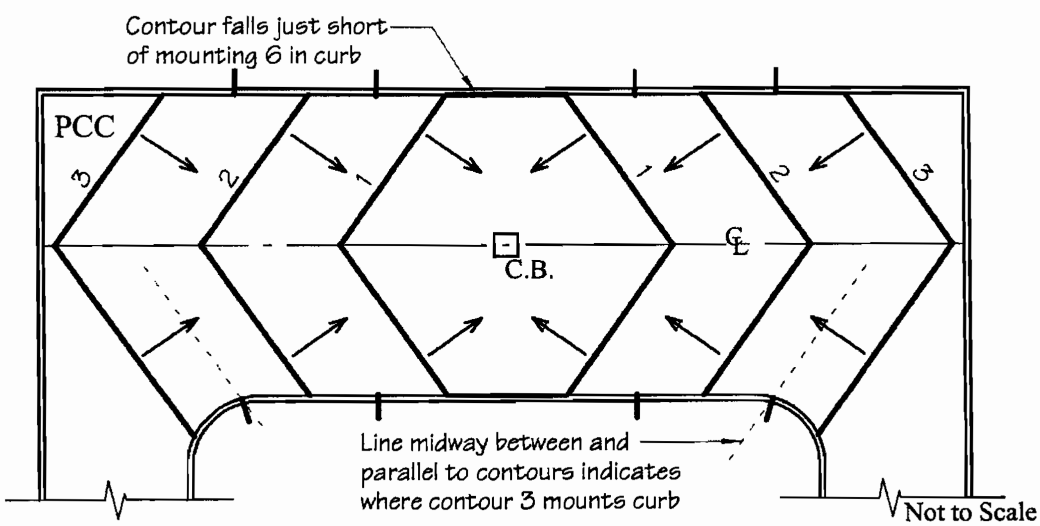
12. Solution — Parking lot with corner catch basin.



13. Solution — Parking lot with center end catch basin.



14. Solution — Parking lot with center catch basin.



Chapter 4
Grading Formulas

REVIEW OF BASICS

The grading formula is comprised of three the terms as shown in Figure 4-1: Grade is expressed as ***G***, Difference in Elevation is expressed as ***D***, and Length is expressed as ***L***. Difference in elevation is also referred to as *Rise*, and Length is also referred to as *run*.

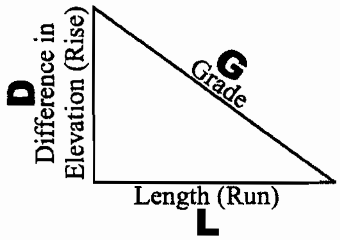


Figure 4-1. Components of the Grading Formula

Grade or ***G***, is the slope or *grade* of a surface expressed as a percentage. When the vertical difference in elevation (*D*) and the length (*L*) are known, or can be determined, the grade may be found by using the formula: $G = \frac{D}{L}$ USE TO FIND **GRADE**

Difference in elevation, or ***D***, is the vertical *difference* in elevation between two points. The elevation of both points must be known to determine the difference. It is found by simple subtraction. The difference in elevation may also be calculated when the horizontal length between two points and the grade are known by using the formula:

$D = G\ L$ USE TO FIND **DIFFERENCE IN ELEVATION**

Length or ***L***, is the horizontal *length* between two points. (Note that term "length" is used, as in "horizontal *length* between two points", rather than "horizontal distance..." *The Term "distance" will be avoided to eliminate confusion with the term "difference."*) If no horizontal dimension is given, it must be scaled by using the appropriate Engineer's or Architect's scale. Length may be calculated when the difference in elevation and the grade are known by using the formula:

$L = \frac{D}{G}$ USE TO FIND **LENGTH**

The three grading formulas must be committed to memory. You may find the memory aids shown in Figure 4-2 helpful:

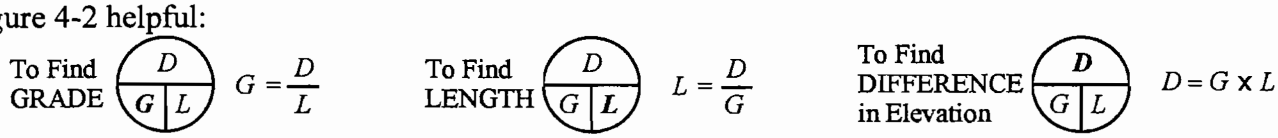


Figure 4-2. Grading Formula Memory Aids

Of the three terms grade, length and difference in elevation, Grade is the most abstract. Figure 4-3 depicts another way to think of grade:

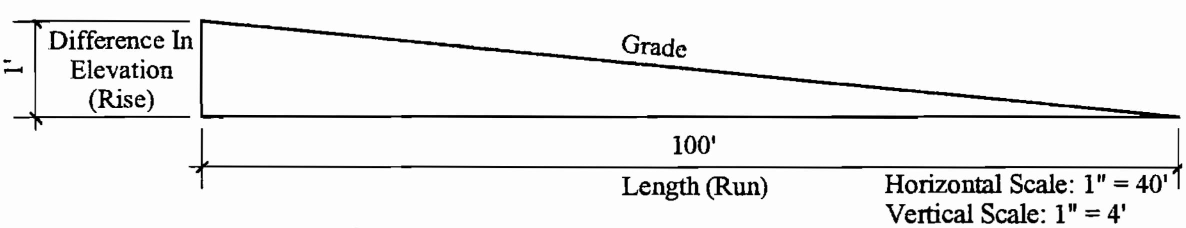


Figure 4-3. Another Way to Think of Grade

- Here's the math: For a 1% grade, the vertical difference in elevation is 1 foot vertically for each 100 feet horizontally.

$$D = G\,L = (.01)\,(100) = 1 \text{ foot}$$

- For a 2% grade, the vertical difference in elevation is 2 feet vertically for each 100 feet horizontally.

$$D = G\,L = (.02)\,(100) = 2 \text{ feet}$$

- For a 3% grade, the vertical difference in elevation is 3 feet vertically for each 100 feet horizontally.

$$D = G\,L = (.03)\,(100) = 3 \text{ feet}$$

- For a 4% grade, the vertical difference in elevation is 4 feet for each 100 feet horizontally.

$$D = G\,L = (.04)\,(100) = 4 \text{ feet}$$

- And so on...

For additional information on basic grading, refer to *Grading Basics — A Grading Primer* that was part of the pre-mailing package you received prior to this review.

At this point, it assumed you know how to apply the three basic grading formulas to solve various grading problems, including finding grade, difference in elevation, length, unknown elevations and how to plot whole number contour lines. Chapter four goes on from this basic starting point and introduces several of the more advanced formulas and processes, such as designing cross slopes and horseshoe swales.

THE CROSS SLOPE FORMULA

Relevancy to the exam: It is a given that your ability to correctly design cross slopes will be tested. Knowing how to do so accurately and very quickly an enormous advantage. The simple *cross slope formula* explained in this section provides exactly that edge. The concept is simple: With a single simple calculation you'll know exactly how far a contour line crossing a plane surface in its short axis must *deflect* from perpendicular to represent the required cross slope. See Figure 4-4.

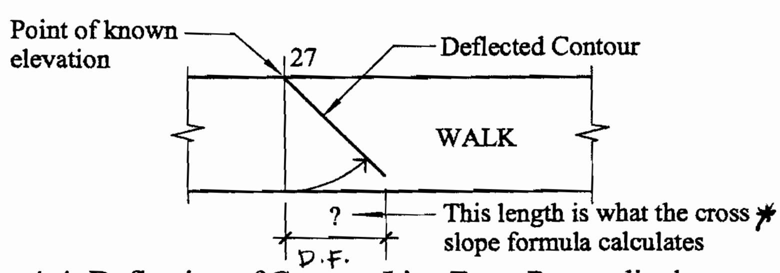


Figure 4-4. Deflection of Contour Line From Perpendicular

The *Cross Slope Formula:*

$$\text{Deflection} = \frac{\text{Cross Slope} \times \text{Width}}{\text{Longitudinal Grade}} \quad \text{or, written in formula form: } Df = \frac{(C\,S)\,(W)}{LG}$$

Where:

Deflection: Represented by "*Df.*" The deflection of the contour from perpendicular (see Figure 36).

Cross Slope: Represented by "*CS.*" The required cross slope expressed in decimal form.

Width: Represented by "*W.*" Width is the short axis dimension of any plane surface, such as a walk, a terrace, or a deck, or the *half-width* of any bilaterally symmetrical plane surface, such as a road.

Longitudinal Grade: Represented by "*LG.*" The long axis grade.

Definition of cross slope: Slope across the short axis of a plane surface, as differentiated from slope along the long axis (longitudinal grade). Most plane surfaces have slope in both the longitudinal and cross slope axis; those that do are said to have cross slope. Examples of some *rectangular plane surfaces* that typically have cross slope are terraces, patios, game courts and sports fields. Examples of *linear plane surfaces* that are likely to have cross slope are walks and roads. The following examples are based on a walk.

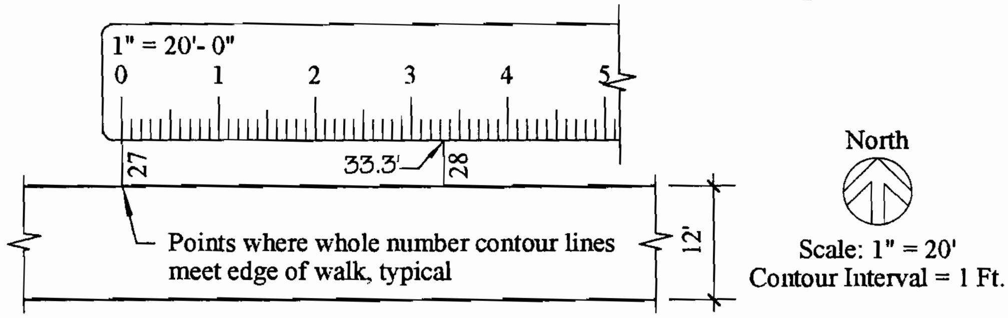
Always read the problem statement carefully for cross slope requirements:

- Is a cross slope required? (It almost always is.)
- If cross slope is required, verify what its grade is to be — it will most frequently be 2%. If it is not given, the default cross slope is 2%.
- In the rare case where cross slope is not specifically required, consider whether providing it is an "implicit" requirement (use 2%).
- If the instructions explicitly say not to provide a cross slope, then obviously, do not do so.

Where cross slope is required, but the problem statement or plan graphic *does not* indicate which side runoff is to be directed to, it is your responsibility to make that determination. A good rule-of-thumb is to match cross slope to the direction the site slopes — if the site slopes east-to-west, the cross slope on the plane surface should slope east-to-west also.

Example: Figure 4-5 shows a walk that is to have a 2% cross slope and runoff directed to its south side. The longitudinal grade is not specified, so it will have to be calculated as a first step.

Step 1. Find longitudinal grade: Scale the length between contour lines *parallel to the edge* of the plane surface as shown in Figure 35. Use the *grade formula* $G = \frac{D}{L}$ to find longitudinal grade.



Requirements: Grade walk with 2% cross slope; runoff to drain to south sied of walk.

Figure 4-5. Determining Grade of Walk

$G = \frac{D}{L} = \frac{1}{33.3} = .03$, or 3%. This is the longitudinal grade of the walk.

Step 2. Determine direction of cross slope (which side of plane surface should runoff drain toward?)

Step 3. Determine the orientation the contour lines will assume on the walk surface. The method shown in Figures 4-6a and 4-6b will insure that the contour is drawn with the correct orientation.

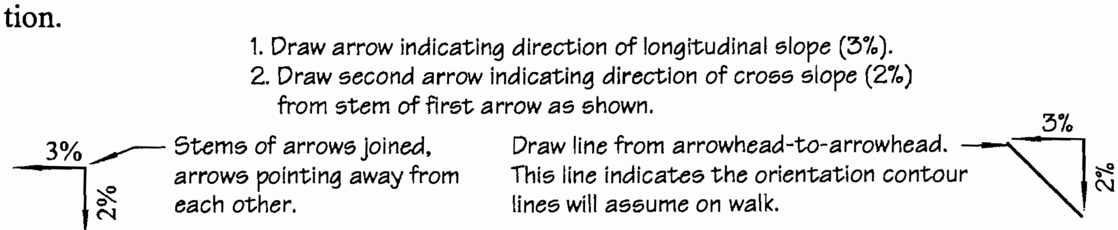


Figure 4-6a. Method for Determining Orientation of Contour Line

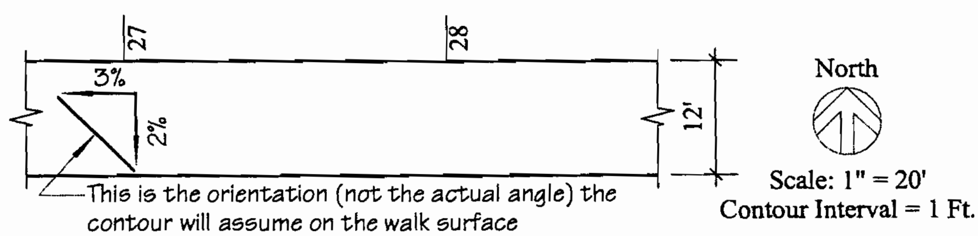


Figure 4-6b. Determining Orientation of Contour Line on Walk

Step 4. Draw a light "construction" line across the short axis of plane surface, perpendicular to the edge at the point *where the known elevation is,* as shown in Figure 4-7. This line will be used to scale the offset:

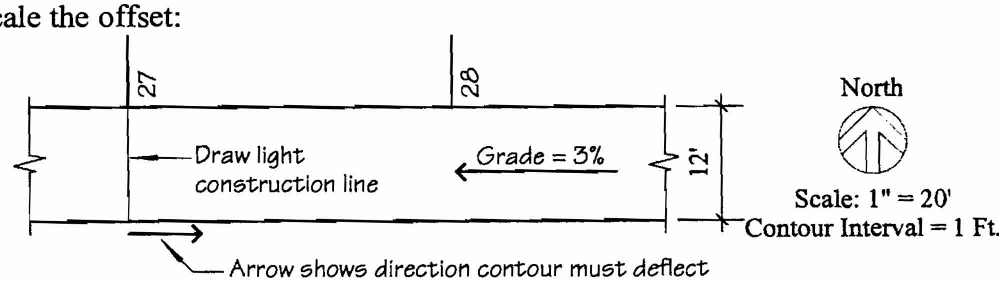


Figure 4-7. Drawing a Construction Line From a Point of Known Elevation

Step 5. Use the *cross slope formula* to find the length of the offset in feet. The calculation is shown here. Substitute in .02 for cross slope grade, 12 feet for width, and .03 for longitudinal grade:

$$Df = \frac{(C\,S)\,(W)}{LG} = \frac{(.02)\,(12)}{.03} = 8 \text{ feet}$$

Step 6. Scale deflection and draw contour lines as shown in Figure 40:

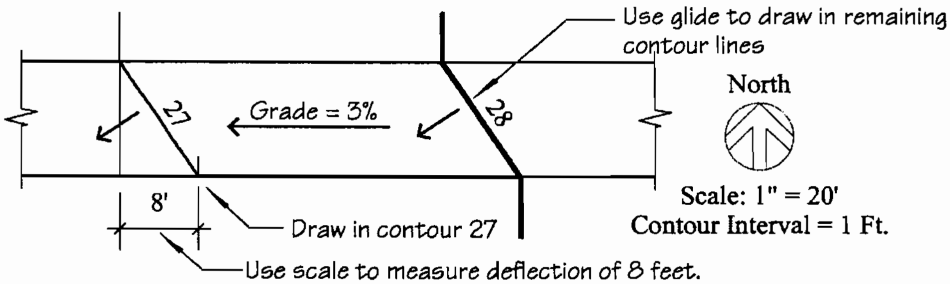


Figure 4-8. Scaling Deflection and Drawing Contour Lines

The Cross Slope Formula works equally well for all types of bilaterally symmetrical site features, including roads and parking lots having either a crowned or depressed center.

IMPORTANT POINT: When designing cross slopes for all bilaterally symmetrical site features, such as a road or parking lot, **use the *half-width* for the calculation** rather than the overall width. A road, for example, could be considered to be two plane surfaces, such as walks, joined along their long-axis edge, that slope in opposite directions. Review Figure 4-9 which shows a road that has a 4% cross slope about its crown. Assume that all runoff drains to gutters.

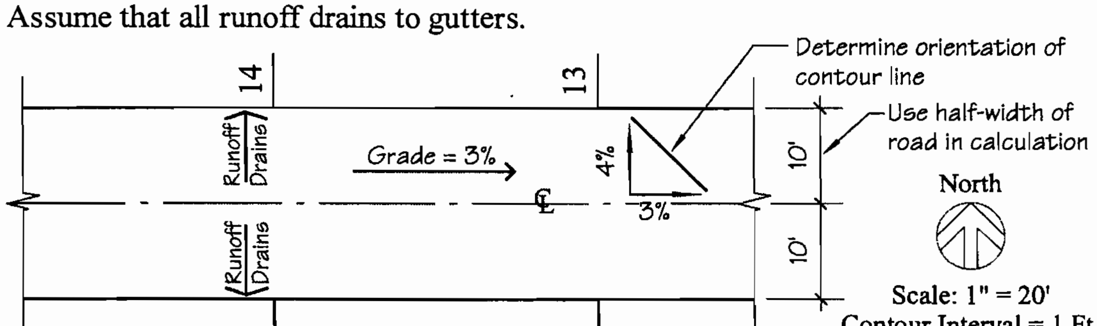


Figure 4-9. Grading Concrete Road with 4% Cross Slope About Its Crown

Note in Figure 4-9 that the longitudinal grade is given, so it need not be calculated.

Step 1. Determine the orientation contours will assume on the road surface as shown in Figure 4-9.

Step 2. Use the *cross slope formula* to find the length of the perpendicular offset in feet. The calculation is shown here. Substitute in .04 for cross slope grade, 10 feet for the *half-width of the road,* and .03 for longitudinal grade:

$$Df = \frac{(C\,S)\,(W)}{LG} = \frac{(.04)\,(10)}{.03} = 13.3 \text{ feet}$$

Step 3. Scale deflection and draw contour lines as shown in Figure 42:

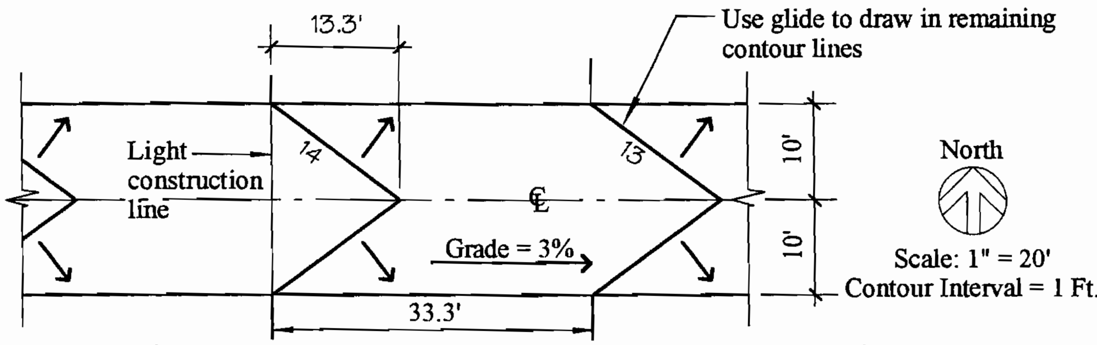


Figure 4-10. Scaling Deflection and Drawing Contour Lines

Tip: Before the exam, think about any formulas you'll need that might be forgotten "in the heat of the exam" (the *cross slope formula*, for instance). Review to rememorize these formulas immediately prior to entering the exam room, then, once the exam has begun, write them down on a trace for later reference.

APPROXIMATING CROSS SLOPES

Relevancy to the exam: Normally, cross slopes should be calculated. However, there are two situations where they might be approximated. 1) On a plan having a scale of 1" = 20', or 1" = 40', the cross slope on incidental walks can be safely approximated. For example, on vignette 33, Townhouses, there are four walks that must be graded. This is an ideal place to approximate cross slope. 2) If you're running short of time, you may not have any choice but to approximate them. Figure 4-11 demonstrates the relationship between longitudinal grade and cross slope grade and how the contours appear as a result.

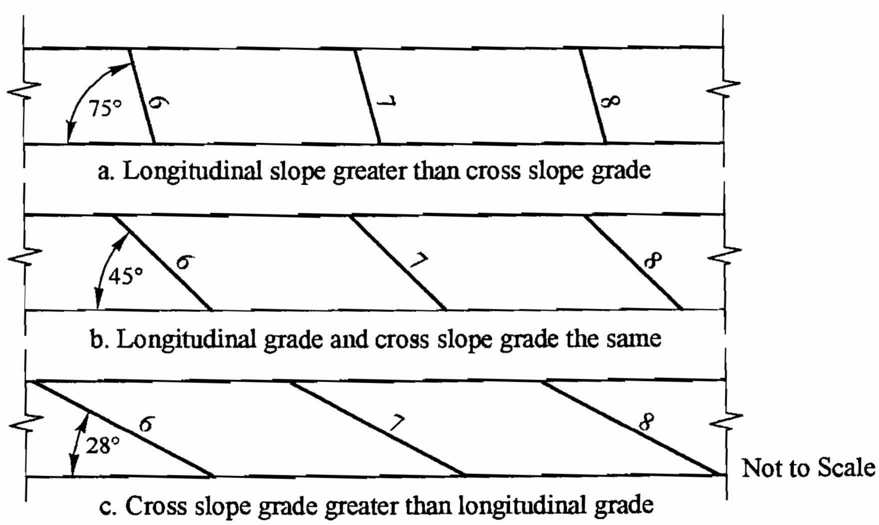


Figure 4-11. Estimating Cross Slopes

Figure 4-11a shows the most common condition: the *longitudinal grade is greater* than the cross slope grade. When this occurs, the deflection angle of the contour, relative to the longitudinal axis of the plane surface, will be *greater* than 45°.

Figure 4-11b shows a condition that occurs surprisingly often on the exam — the longitudinal grade and cross slope grade are identical. Notice here that the angle of the contour, relative to the longitudinal axis of the plane surface, is exactly 45°. When this occurs, you can save the time it takes to calculate the cross slope and simply use a 45° triangle to plot the contours.

Figure 4-11c shows a condition that also sometimes occurs — the *cross slope grade is greater* than the longitudinal grade, so the deflection angle of the contour, relative to the longitudinal axis of the plane surface, will be *less* than 45°.

HOW TO DESIGN A HORSESHOE SWALE

Relevancy to the exam: The horseshoe swale, so-called because of its characteristic horseshoe-like flow-line signature, diverts run-off around and away from site elements that need to be protected from runoff, such as buildings, game courts, parking lots, and so forth. It is virtually certain that the design of at least one horseshoe swale (probably several) will be required on the exam.

There are two types of horseshoe swale conditions. These are shown in the following examples. The first, shown in Figure 4-12, has a *level plane surface.* This would be typical of a slab for a building, a deck, a water feature, a pool, or anything else that must be level.

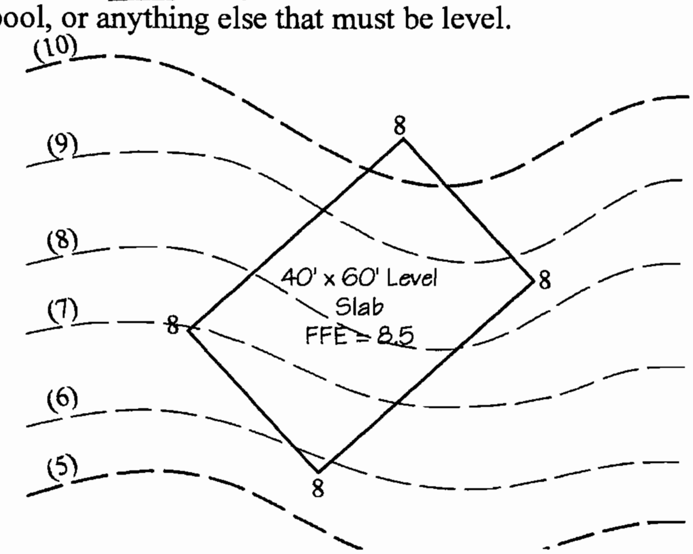


Figure 4-12. Example of Level Plane Surface

Figure 4-13 shows a typical CLARB-style building slab and its relationship to the high point swale elevation. Notice that the adjacent finish grades are set 6 inches below the finish surface elevation, and that the high point swale is set 6 inches below those. The high point swale elevation is set .5 lower than the exterior finish grade elevations to insure that the swale has a minimum depth of 6-inches.

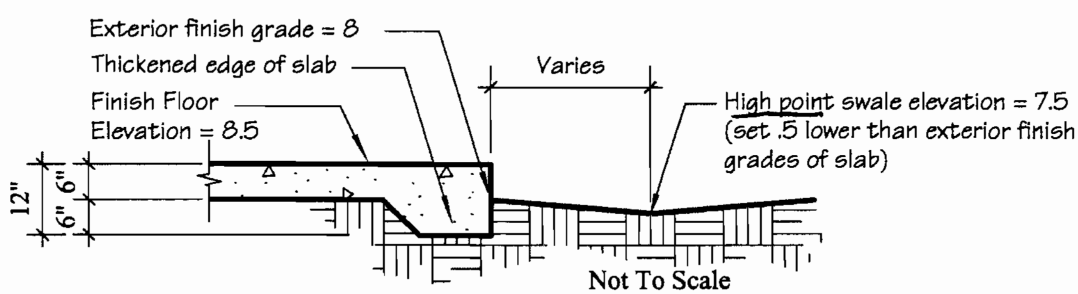


Figure 4-13. Thickened Edge Slab and Relationship to High Point Swale

The second, shown in Figure 4-14, is a *sloping plane surface,* characterized by the contour lines that cross its surface. This would be typical of any plane surface that is sloped to drain, such as a game court, sports field, terrace, or parking lot.

In both cases, the intent of the horseshoe swale is to intercept runoff from the area uphill of the site element *as well as the area immediately adjacent to it.* In other words, even rain falling on the site element itself, and the area surrounding it, is captured by the swale and directed away from the site element. A critical design feature of the horseshoe swale is a high point that should be *set 6 inches lower* than the pad or high point elevation of the plane surface.

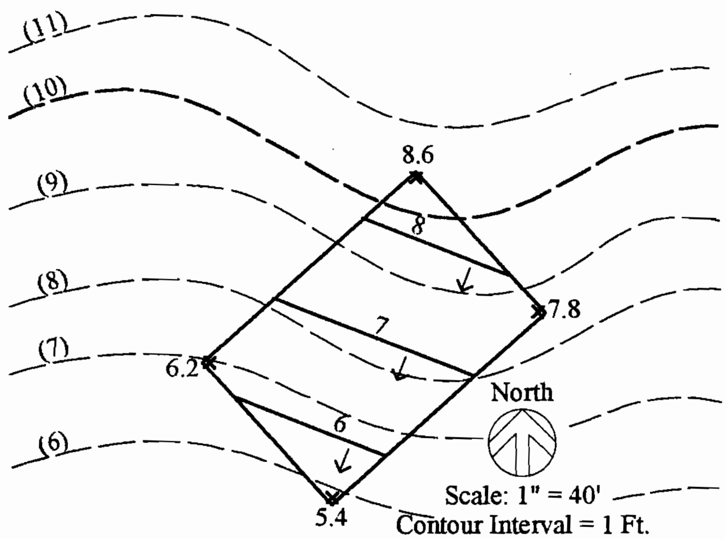


Figure 4-14. Example of Sloping Plane Surface

Horseshoe Swale Terms to Know:

TERM	DEFINITION
Site Element	Site feature that is to be protected from runoff.
Flowline	The line along which runoff flows, defined by the points where the contours cross. Synonymous with centerline.
Slab	Area graded flat to accommodate site element; implies a plane surface that has a site element, such as a building placed on it.
Finish Floor Elevation or FFE	Finish Floor Elevation, abbreviated FFE. This is the surface elevation of the floor of a building. On the LARE, it is always assumed that the entire floor area is the same elevation. This would be provided only on a level pad.

TERM	DEFINITION
Pad	Area graded flat to accommodate site element; implies a plane surface that does not have a concrete slab or other site element placed on it.
Back slope	Slope *uphill* of the site element.
Side slopes	Slopes at the *sides* of the site element, including the slope produced by the contour lines that make up the swale itself.
Front slope	Slope *downhill* of the site element.
Daylighting	Daylighting refers to catching up to the existing contour lines, usually in the backslope area, but it can also apply to the front slope or side slope areas under some circumstances.
Slope ratio	The ratio of horizontal length to vertical rise. 2:1, 3:1, 4:1, and 5:1 are typical slope ratios. A 3:1 slope has contour lines spaced 3 feet apart horizontally, which equals a grade of 33%. Generally, when grades exceed 10% to 15%, they are expressed as a ratio.
Grade (in the context of a swale)	1) Longitudinal grade along flowline as can be determined by the *grade formula* $G = \frac{D}{L}$; it will usually be between 2% and 10%. 2) Back slope, side slope, or front slope grade, per requirements, which will ordinarily be given as a slope ratio.
High Point Swale	The highest point of the swale, but lower than the site element that is to be protected. (May be abbreviated HPS.)
Point of Attack	The point where the existing contour lines that run perpendicular to the site element are in closest proximity to it. See Figure 4-15.

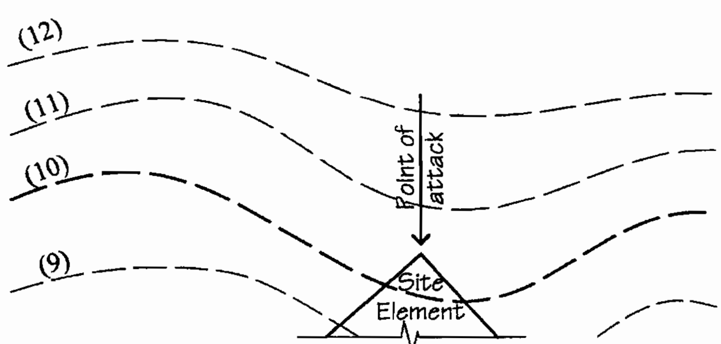


Figure 4-15. Point of Attack

Horseshoe Swale Design Issues

These are the most important design issues that are typically encountered in horseshoe swale design.

1. Horseshoe swale configuration will vary depending on such things as the orientation of the site element and its relationship to the existing contours, existing site conditions including slope steepness, presence of trees or other natural features such as rock outcroppings, riparian areas, or anything on the site that has intrinsic value. Pay particular attention to areas within the driplines of existing trees. Contours must not be revised within the indicated dripline of trees, and the overall elevation around trees must not be raised or lowered under any circumstances; doing so will likely result in a solution being marked Critically Flawed.

2. In designing horseshoe swales, flowline grades are always differentiated from maximum site grades — the flowline grade always being the flatter of the two. Generally, the flowline grade range is a minimum of 2% (contours no more than 50 ft apart), and a maximum of 10% (contours no closer together than 10 ft). If these limits are not specified in the problem statement, assume that they are implicitly required. In contrast to the more restrictive flowline grades, the maximum gradient for all other surfaces is usually between 3:1 and 5:1, depending on the problem. Remember that a slope ratio directly specifies the minimum length permitted between contour lines. For instance, for a slope ratio of 3:1, the contours must be at least three feet apart; they may be further apart, but not closer. For a 5:1 slope, contours must be at least five feet apart, and so forth.

   The reason that flowline grades are kept below roughly 10% is to avoid an erosive gradient. Remember that in a swale, runoff is concentrated in the flowline, and thus, the combination of water quantity and velocity quickly becomes erosive at steeper gradients.

3. Generally, exam designers make an effort to limit swale solutions to a specific area. A variety of plan elements are placed on the plan to accomplish this confinement. Examples of commonly used limiting elements include trees, a contract limit line, or some other plan element that limits the extent of your solution.

4. To elevate the level of rigor of a given vignette, exam designers may challenge you by requiring you to fit a swale into what at first appears to be extremely confined space — for example, an area that is 20 feet wide between a contract limit line and a parking lot. In such cases, a good rule-of-thumb is to center the flow line between the two limits in order to maximize the amount of space available on either side of the flowline for contour line manipulation.

5. Design criteria, such as how much space is needed around the site element, and the impact the configuration has on the surrounding site is usually not a major factor on the exam. Nonetheless, the solution should be as compact as possible to limit disturbance of the site. This will help avoid being penalized for an excessive solution.

6. Another important rule-of-thumb when plotting contour lines for the back-slope or front-slope of a swale is to *space them at the closest permissible spacing,* (e.g., if the required maximum slope is 3:1, space the contours at three feet apart). This will insure that the revised contour lines are able to catch up to the natural contour lines (the term "daylight" is often used to describe this requirement). This is particularly critical in the back slope area, which is where daylighting problems most frequently occur.

7. Be sure contour lines have a correct swale signature. Remember that the contour lines must "flare" away from the flowline and it is now virtually always required that the swale be at least six-inches deep.

8. Placement of high point swale and its relationship to the point of attack: As a rule-of-thumb, start by placing the high point swale at the point where the contours running perpendicular to the site element are in closest proximity to it, as shown in Figure 4-15 above. However, be flexible on this. Sometimes, as is true with all rules-of-thumb, it may not be desirable, or even possible, to do so due to site variables.

9. Obviously, due to constrain of time, all revised contour lines will be drawn freehand. Nonetheless, *use reasonable care* in drawing to keep spacing even and within the prescribed slope ratio.

Using a Tick Sheet

Tip: To aid in drawing revised contour lines when more than a couple of contour lines must be drawn parallel to one another, use a "tick sheet" to facilitate spacing. A tick sheet can be made quickly by placing tick marks *scaled at the interval of the slope ratio* on the edge of on a scrap of paper as shown in Figure 4-16. A 5:1 slope ratio is shown.

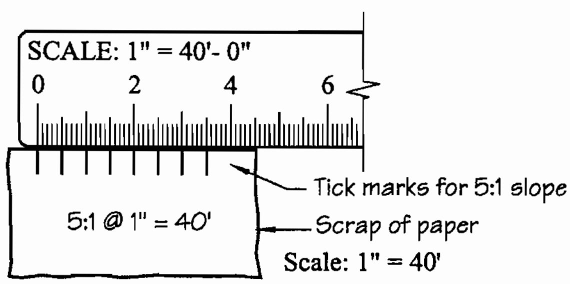


Figure 4-16. Making a Tick Sheet For a 5:1 Slope

On the plan, use the tick sheet to place multiple tick marks *perpendicular* to contour lines. When drawing the revised contour lines, draw the contours "tick-to-tick," using the ticks as a guide as shown in Figure 4-17.

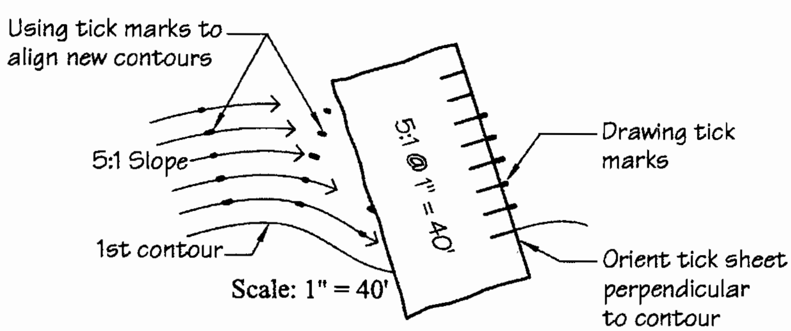


Figure 4-17. Using the Tick Sheet

10. Designing a horseshoe swale is, to some extent, a trial and error process. Practice will improve your chances of getting the horseshoe swale right, or right enough, on the first attempt.

11. Finally, as a counter point, do not become a "swale fanatic." In other words, do not design swales

where they are not needed. Not only does doing so waste time, but also keep in mind that swales concentrate the flow of runoff, which can be highly undesirable, particularly that concentrated runoff is permitted to flow across a property line onto an adjacent property. Evaluate site conditions to see if a swale is legitimately justified. If it is, provided it. If it's not, don't provide it.

DESIGNING A HORSESHOE SWALE FOR A SLOPING PLANE SURFACE

The process for designing a horseshoe swale for a *sloping* plane surface is described in this section. The first example will be based on a sloping plane surface as shown in Figure 4-18. (The second example will explain the design of a horseshoe swale for a *level surface*.)

Design Criteria for the Sloping Plane Surface shown in Figure 4-18:

- Maximum backslope, side slope and front slope grades are 5:1
- Flowline grades are to be 2% minimum, 10% maximum.

Step 1. Study the sloping plane surface shown in Figure 4-18. Points to look for:

- Spot elevation or elevations: What is provided on the plane surface? In this example, spot elevation 8.6 is given. This arrangement is fairly typical of the exam.

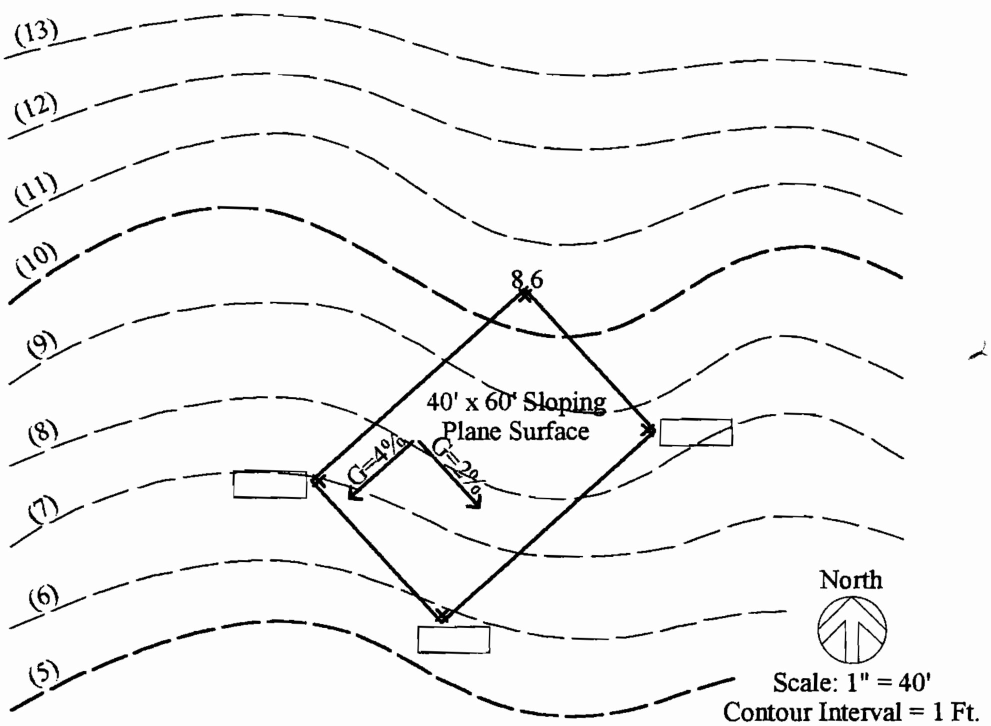


Figure 4-18. Horseshoe Swale for Sloping Plane Surface

- Grade criteria: What is provided on the plane surface or in the problem statement? For this example, a longitudinal grade of 4% and cross slope grade of 2% are given.

- Direction runoff is to flow: In this example, both longitudinal and cross slope runoff directions are shown with flow arrows. If this information is not provided on the plan, it may be found in the problem statement, or, in some cases, it may be up to you to determine direction.

- Does the problem require that corner point elevations be calculated? In this example, corner elevations are required, as evidenced by the boxes. This is typical of the exam.
- One important issue in designing a horseshoe swale is where flow is to be directed. Often, drain inlets or an existing natural watercourse, or some other appropriate drainage target will be provided. If this is the case, that is where the flowline must direct runoff. If none of these exists, terminate the flowline and the swale signature in the vicinity *of the lower end* of the site element. This will allow runoff that has been concentrated by the swale to simply dissipate and spread.

Step 2. Calculate the corner point elevations. Refer to Figure 4-19.

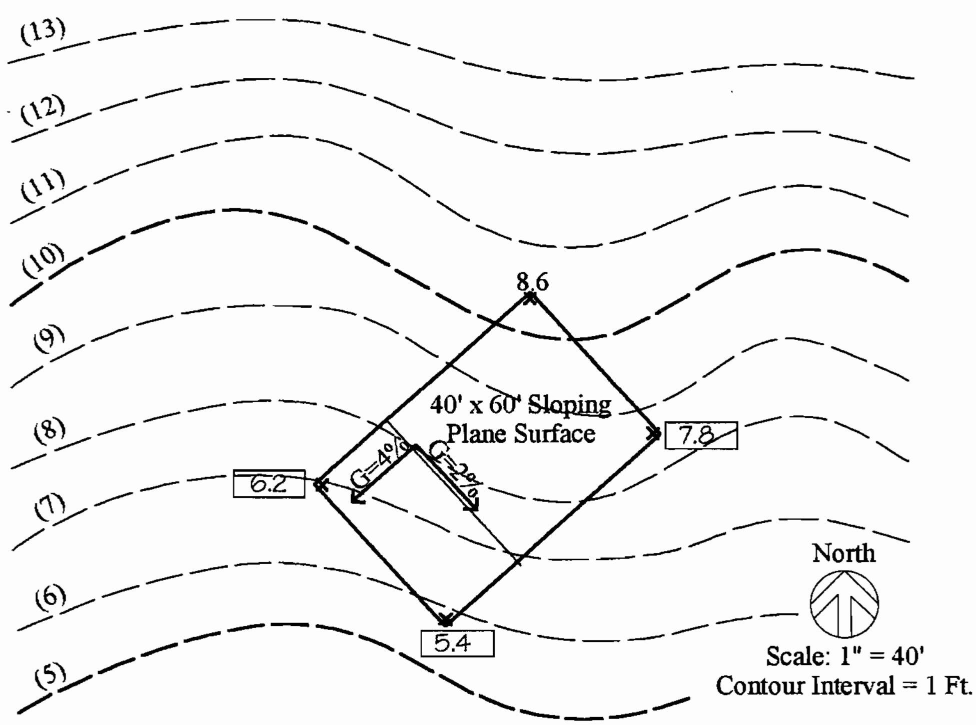


Figure 4-19. Calculating Corner Point Elevations

Starting with the high point elevation of 8.6, calculate the unknown corner point elevations. West corner: Find the difference in elevation between elevation 8.6 and the west corner:

$$G = .04 \quad L = 60 \text{ feet}$$

$$D = G\,L = (.04)(60) = 2.4$$

Since the west corner is *lower* than the north corner, subtract to find the difference in elevation:

$$8.6 - 2.4 = 6.2$$

East corner: Find the difference in elevation between elevation 8.6 and the east corner:

$$G = .02 \quad L = 40 \text{ feet}$$

$$D = G\,L = (.02)(40) = .8$$

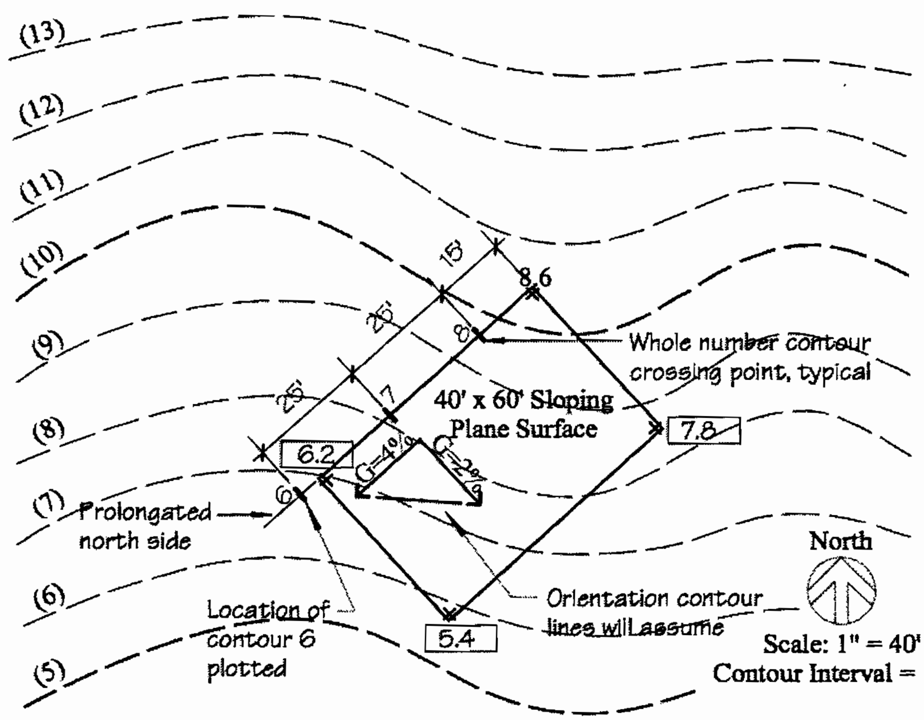
Since the east corner is *lower* than the north corner, subtract to find the difference in elevation:

$8.6 - .8 = 7.8$

South corner: The south corner spot elevation must be based on the previously found elevation of either the west or the east corner. In this example, the east corner will be used as the basis for the south corner. Because the south side of the plane surface is the same length and has the same grade as the north side, the difference in elevation of 2.4 as found above will be used.

$7.8 - 2.4 = 5.4$ Figure 4-19 shows the plane surface with the three corner elevations.

Step 3. Plot points where whole number contour lines cross north side of plane surface as shown in Figure 4-20.



TOP
WORK
DOWN

H.P 8.6
8.6 - 8.=
.6

Figure 4-20. Calculating Whole Number Contour Line Crossing Points

Find the length to the point where first whole number contour line (8) crosses north side:

$D = .6 \quad G = .04$

$$L = \frac{D}{G} = \frac{.6}{.04} = 15 \text{ feet.}$$

Scale 15 feet along north side from elevation 8.6 to set point where contour 8 crosses the plane surface.

Find the length to the points where the remaining contour lines (7 and 6) cross north side.

$D = 1 \quad G = .04$

$$L = \frac{D}{G} = \frac{1}{.04} = 25 \text{ feet}.$$

Scale 25 feet along north side from elevation 8 to set the point where contour 7 crosses.

Now, look at the plane surface. Ask yourself if any other contours, in addition to contours 7 and 8, will need to be plotted on the plane surface? The answer is "yes," contour 6 will have to cross the plane surface. To anticipate the placement of contour 6, you'll need to visualize the plane surface *with all its contour lines* correctly plotted. Begin by noting the locations of contours 7 and 8. Look at the grade arrows to determine the orientation the plotted contours will assume. It will be apparent, by extrapolating from the positions of contours 7 and 8, that contour 6 will also cross the plane surface, although it will not cross its north edge. To plot the crossing point for contour 6, prolongate the north edge of the plane surface as shown in Figure 4-20. Doing so at this stage will save time later. Scale an additional 25 feet from contour 7 and place a tick mark on the prolongated line for contour 6.

Step 4. Calculate the cross slope using the *cross slope formula* and plot contour lines 6, 7 and 8 as shown in Figure 4-21.

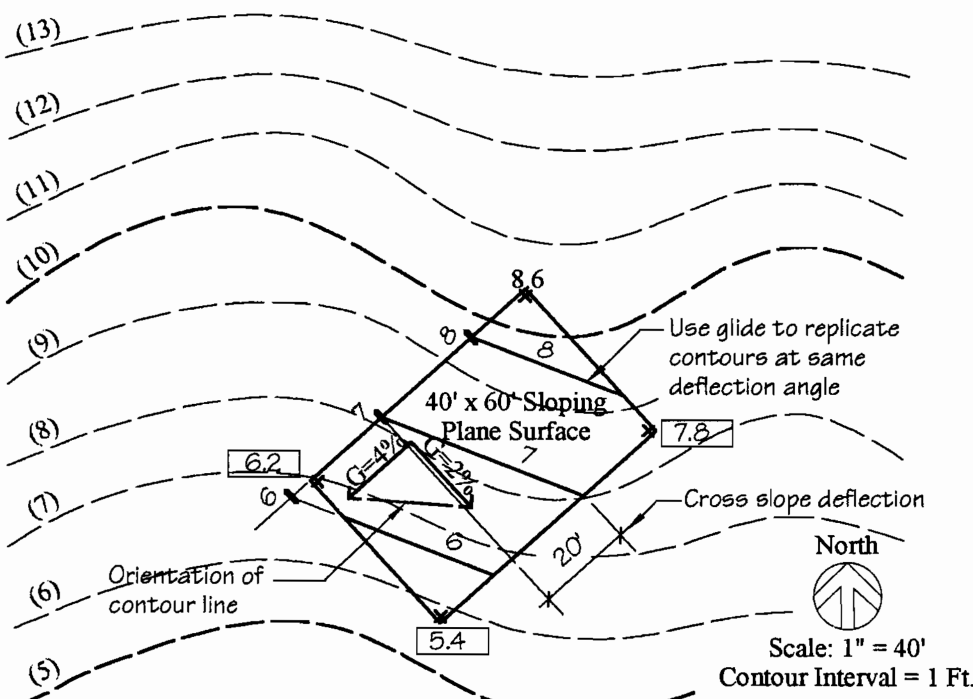


Figure 4-21. Calculating Cross Slope and Plotting Contours

$$CS = .02 \quad W = 40 \text{ feet} \quad LG = .04$$

$$Df = \frac{(CS)(W)}{LG} = \frac{(.02)(40)}{.04} = 20 \text{ feet}$$

Step 5. Establish the "Point of attack," high point swale elevation, and flowline as shown in Figure 4-22.

- Determine the point of attack as explained above (refer to Figure 4-15).

- Draw the flowline. For a variety of reasons, examinees occasionally have difficulty deciding where to draw the flowline. It's actually very easy to do. First of all, recognize that there is no single "right way" to draw a flowline. Rather, there are an infinite number of possible right ways. As a rule of thumb, keep the flowline close to the site element to be protected from runoff while allowing enough room between the site element and the flowline to comfortably manipulate contour lines. In all cases, the swale must completely protect the site element. Therefore, the flowline should generally extend to a point roughly in line with the down-slope end of the site element. Doing the practice exercises at the end of the chapter will give you a feel for how to develop an appropriate flowline, and will help build your confidence in swale design while reducing the potential for time consuming trial and error experimentation.

- Establish the high point swale. On the exam, it is suggested that the high point swale simply be set 6 inches lower than the corner elevation of the site element to be protected. This will ensure from the outset that the swale maintains a minimum depth of at least 6 inches.

$$8.6 - .5 = 8.1$$

Figure 4-22 shows the point of attack, a workable flowline, and a high point swale elevation of 8.1.

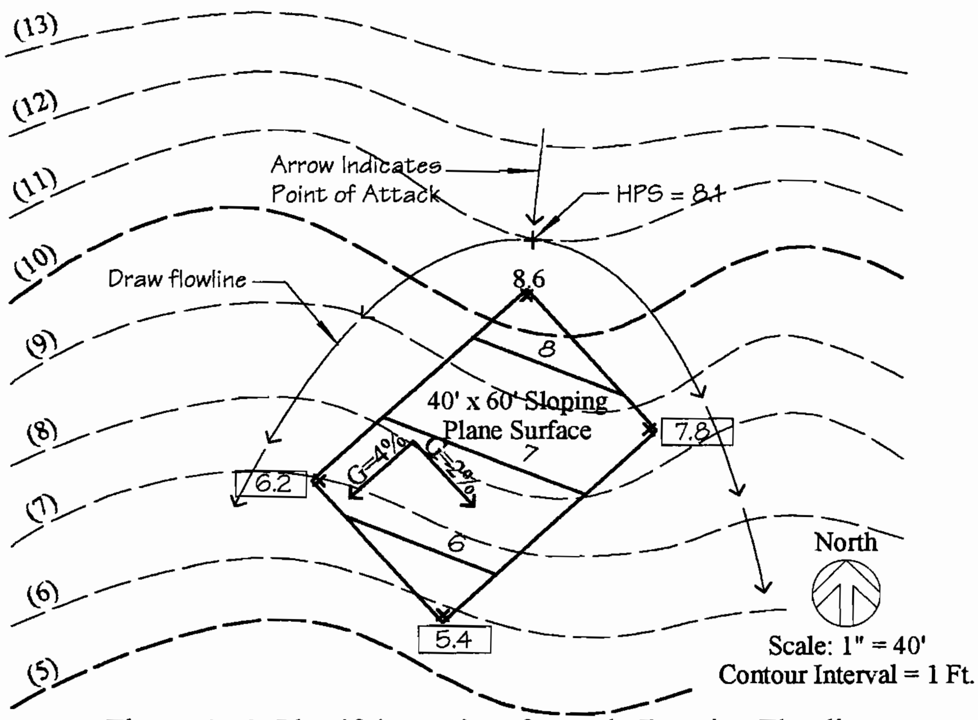


Figure 4-22. Identifying Point of Attack, Drawing Flowline, and Setting High Point Swale

Step 6. Identify the whole number contour line crossing points for the first contour below the high point swale as shown in Figure 4-23. Since the high point swale elevation is 8.1, contour 8 will be the first whole number contour below it. Note that contour 8 crosses the flowline at two points — one on each side of high point swale. Calculate the grade between the high point swale and the first contour below it to be certain that the grade is at least 2%. This should be calculated because unless the high point swale happens to be a whole number, which is not likely, the length to the first whole number contour line cannot simply be scaled 50 feet from the high point swale. To determine how far along the flowline contour 8 needs to be positioned from the high point swale, the *length formula* will be used. Substitute in the grade (2%) and the difference in elevation (.4).

$$D = .1 \quad G = .02$$

$$L = \frac{D}{G} = \frac{.1}{.02} = 5 \text{ feet}$$

Therefore, the crossing points for contour 8 will be located 5 feet from the high point swale.

Although the swale "starters" shown on Figures 4-23 are optional, they can help you correctly orient the contour lines to create a swale signature in the next step.

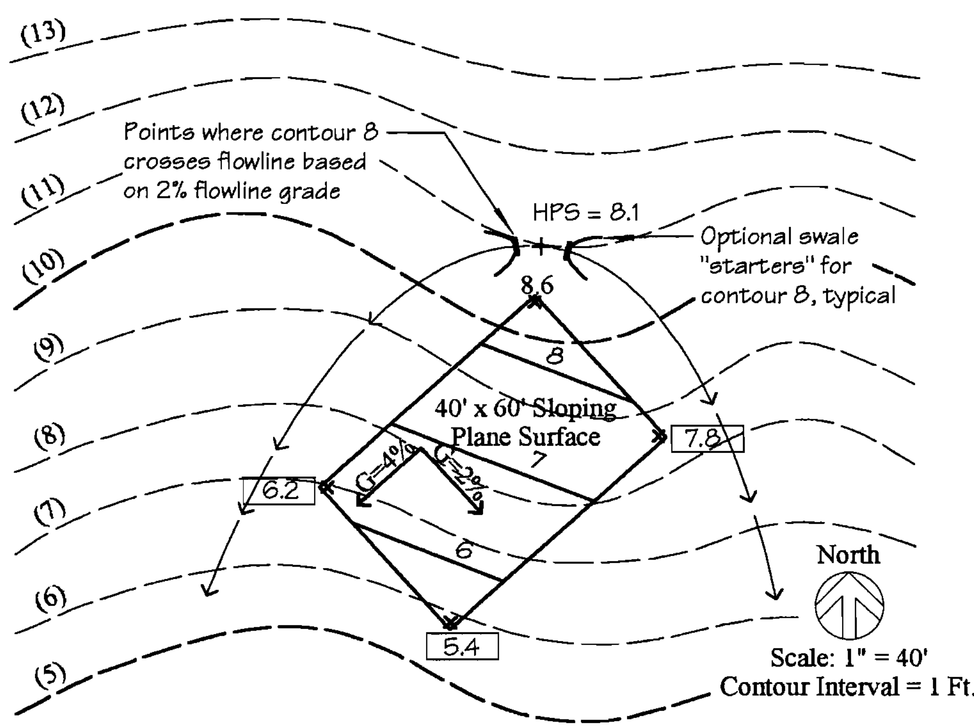


Figure 4-23. Finding Length to Points Where Contour 8 Crosses Flow Line

Next, draw contour 8 as shown in Figure 4-24. To better understand the concept behind the horseshoe swale for a sloping plane surface, trace the path of the contour, then consider the runoff patterns that the contour creates.

Because the plane surface is sloping (contours 6, 7 and 8 cross it), each of the contours comprising the swale must connect to them as shown in Figure 4-25. Bear in mind that just as in drawing the flowline, there is no one right way to draw the swale contours. As long the as maximum and minimum grade requirements are adhered to, there are an infinite number of correct solutions possible. The overall goal should be to minimize the amount of grading required, which will minimize disturbance of the site. Within reason, keep all contour revisions as compact as possible while still fulfilling the intent of the problem.

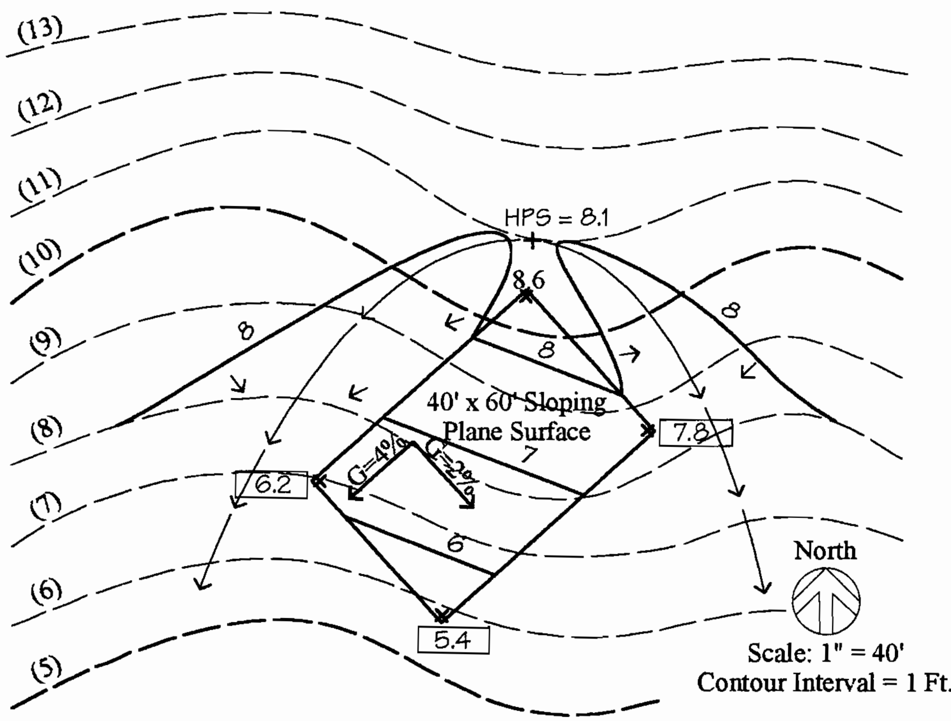


Figure 4-24. Drawing Contour 8

Step 7. In this step, remaining whole number contours (6 and 7) are drawn as shown in Figure 4-25. The first task in this step is to locate the points along the flowline below contour 8 where the next lower contours are to cross. To save time and simplify the design process, "eye-ball" these contour crossing points. This is perfectly acceptable unless the problem statement explicitly requires a specified grade and/or a straight grade. Nevertheless, there are two points to keep in mind: First, the flow line grade must fall within the prescribed slope range, which is typically a minimum slope of 2% and a maximum slope of 10% (verify this with the problem statement), which translates to a spacing range of not greater than 50-feet (2%), to not less than 10-feet (10%). Positioning the points along the flowline where the contours cross is a matter of experience that, with practice, will become second nature. Although in the example the grades between the crossing points were eyeballed as explained above, the actual grades were calculated for informational purposes. As pointed out previously, there is no one correct solution. In this example, the contour crossing points could have been placed closer together, or further apart, without materially changing their effectiveness — or the correctness of the solution. The main requirement is to make sure they fall within the stipulated grade range, and that runoff is carried away from the plane surface. This completes the swale itself. The next step will be to complete the grading at the front and back slope areas, and to number the contour lines.

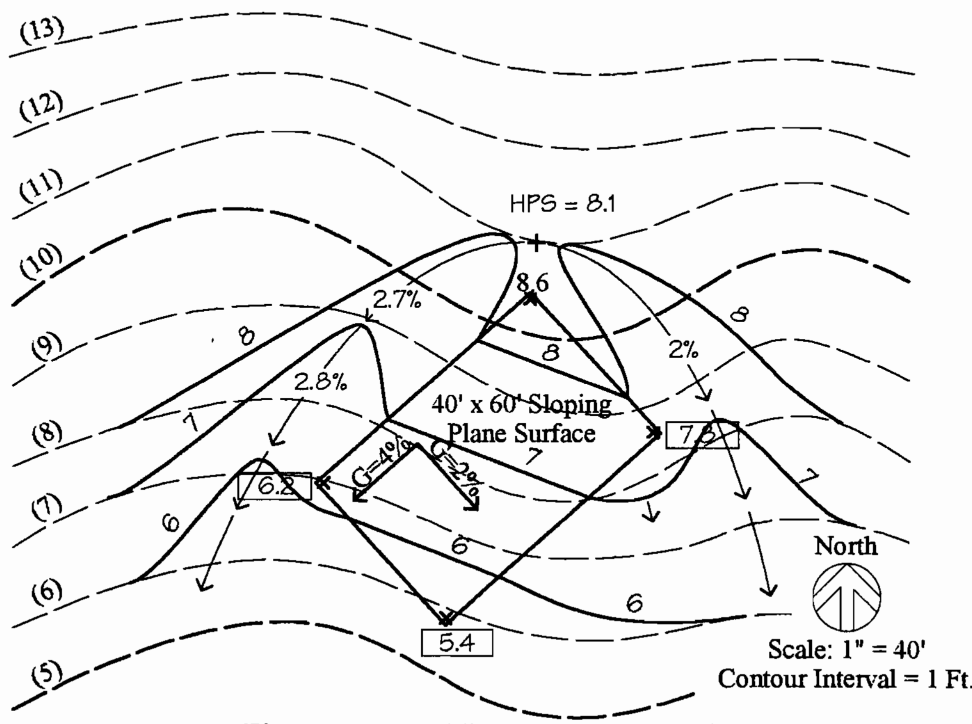


Figure 4-25. Adding Contours 7 and 6

Step 8. Grade the back slope and front slope areas to "catch up" to the existing grades as shown in Figure 4-26.

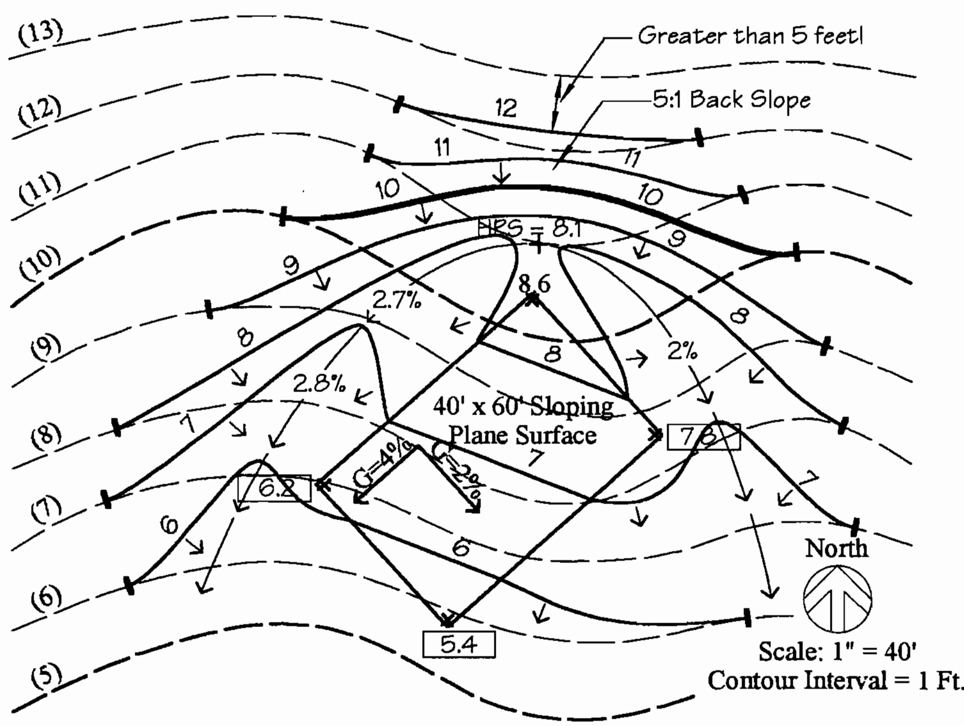


Figure 4-26. Completed Horseshoe Swale

Remember that the back slope and front slope contour revisions are as much a part of the solution as the contours that make up the swale itself. Be aware that this is one of the most frequent omissions in swale design. Also, as you work on the revised contours, stay focused on the specified slope ratio. If it is 5:1, contour lines must not be spaced closer than 5 feet, but they can be spaced further apart. Of course, remember that revised contours must "catch up" to the existing slope. Therefore, it is strongly suggested that you stay at, or close to, the prescribed slope ratio. *

Begin with the back slope area. Note that contour 8 is the highest contour that crosses the flow-line, and that it passes over existing contours 9 and 10. It will therefore be necessary to revise these contours, keeping them at least 5 feet apart. Keep revising contours in this manner until the length between the last contour revised (contour 12 in this example) and the *next higher existing contour* is five feet or greater.

Next, look at the front slope area. In this example, contour revisions will not be required because the elevation of 5.4 at the southwest corner of the plane surface and existing contour 5 produces a grade of only about 4%, which is well within the maximum and minimum slope requirements.

Step 9. Lastly, compete the horseshoe swale by numbering all revised contours, adding tick marks at the points where they rejoin existing contours, drawing every 5th contour heavier, and add any other information, such as flow arrows and grades along the flow line. The completed solution of the horseshoe swale for a sloping plane surface is shown in Figure 4-26.

DESIGNING A HORSESHOE SWALE FOR A LEVEL PLANE SURFACE

The process for designing a horseshoe swale for a *level* plane surface is described in this section. The example shown in Figure 4-27 will be used to demonstrate the process of designing a horseshoe swale to protect a level plane surface.

The process of designing a horseshoe swale for a level surface is very similar to that of designing one for a sloping plain surface, particularly in its final stages. The chief difference occurs at the beginning when, rather than calculating corner elevations and plotting contours, the finish floor elevation (FFE) of the plane surface must be chosen and set.

Design Criteria for the Level Plane Surface shown in Figure 4-27:

- Maximum backslope, side slope and front slope grades are 5:1
- Flowline grades are to be 2% minimum, 10% maximum.

Step 1. Set the finish floor elevation and exterior corner point elevations. A rule-of-thumb technique for setting the finish floor elevation that works in the majority of cases is to simply add 6 inches to the existing whole number contour line that *comes closest to passing through the mid-point of the plane surface.* In this example, that is contour 8 as shown in Figure 4-27.

Adding 6-inches (.5) to 8 equals an elevation of 8.5.

$$8 + .5 = 8.5$$

Therefore, the finish floor elevation will be set at 8.5.

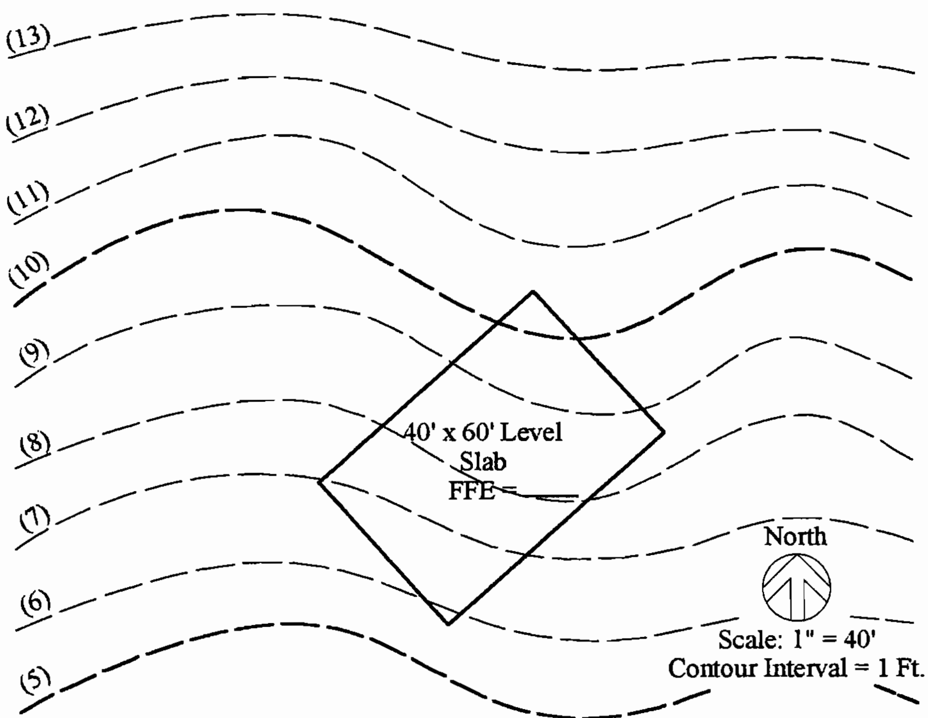


Figure 4-27. Horseshoe Swale for Level Plane Surface

Next, set the exterior finish grade elevations at the corners of the slab. Based on the typical CLARB slab detail shown earlier in Figure 4-13, the elevations of these four points will be set 6-inches (.5) lower than the finish floor elevation of 8.5.

$$8.5 - .5 = 8.0$$

Therefore, the exterior finish grades at the corners of the level slab will be 8.0 as shown in Figure 4-28.

Step 2. Establish the "point of attack," the high point swale elevation, and design the flowline.

- Establish the high point swale. Similarly to the sloping plane surface, it is suggested that the high point swale be set 6 inches lower than the exterior corner elevations of the slab. This will ensure from the outset that the swale has a minimum depth of at least 6 inches.

$$8.0 - .5 = 7.5$$

Figure 4-29 shows the point of attack, a workable flowline, and a high point swale elevation of 7.5.

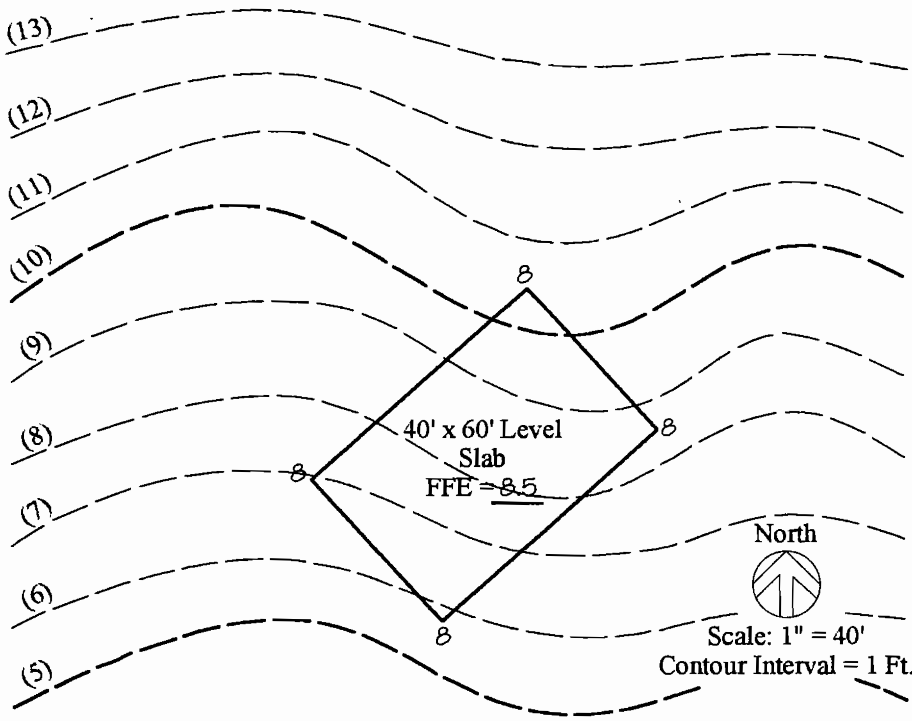


Figure 4-28. Setting The Finish Floor Elevation and Exterior Corner Points

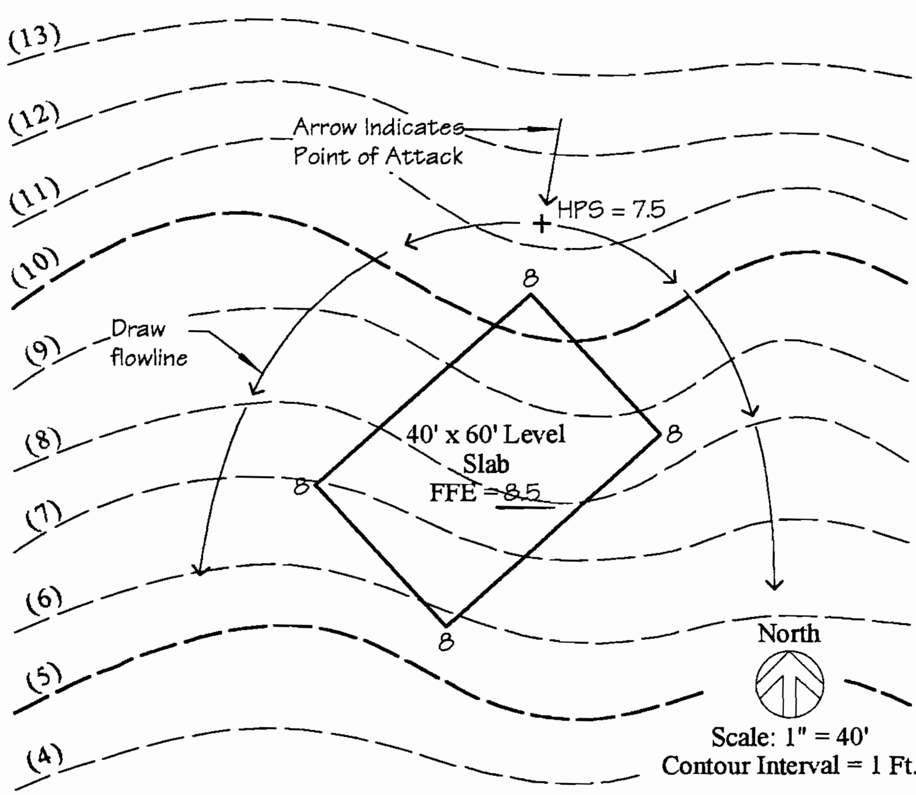


Figure 4-29. Identifying Point of Attack, Drawing Flowline, and Setting High Point Swale

Step 3. Find the whole number contour line crossing points for the first contour below the high point swale. Since the high point swale elevation is 7.5, contour 7 will be the first whole number contour below that point. Note that it will cross the flowline two times — once on either side of high point swale as shown in Figure 4-30. Calculate the grade between the high point swale and the first contour to be certain that the grade is at least 2%. To determine how far contour 7 needs to be located from the high point swale, the *length formula* will be used.

$$D = .5 \quad G = .02$$

$$L = \frac{D}{G} = \frac{.5}{.02} = 25 \text{ feet}$$

Therefore, to ensure a minimum flowline grade of 2%, the crossing points for contour 7 will be located 25 feet from the high point swale.

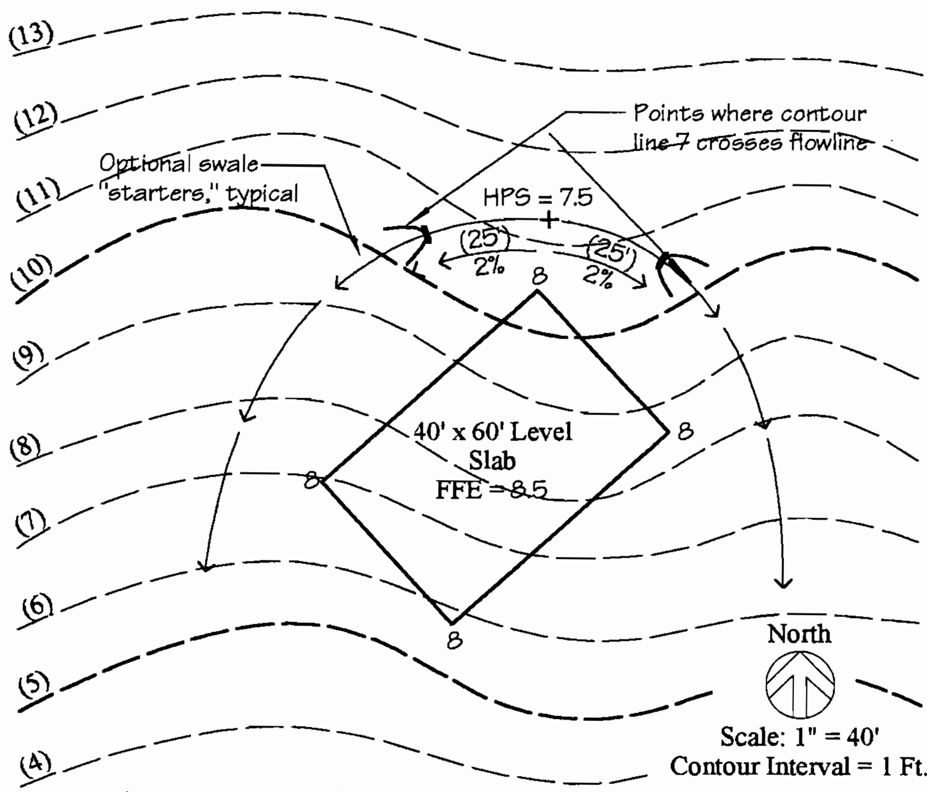


Figure 4-30. Finding Length to Points Where Contour 7 Crosses Flow Line

Step 4. Draw contour 7 as shown in Figure 4-31. This is a good point at which to review the concept behind the horseshoe swale for a level slab. Trace the path that the contour follows. Notice that it deflects down and around the *downhill end* of the plane surface. Now, study the flow arrows and consider the runoff patterns that are created by contour 7. One important characteristic of the horseshoe swale for a level slab is that the swale not only intercepts runoff coming down the slope toward the site element, but also runoff generated by the site element itself and the area immediately surrounding it. One additional point to be aware of is that, as shown in this example, the exterior elevations at the corner points of the plane surface are exactly at elevation 8, meaning that contour 8, although not graphically shown, goes around the slab, closing on itself. Because of this unseen contour, contour 7 must be kept at least 5 feet away from the slab corners to fulfill the required 5:1 slope ratio requirement. Of course, depending on the finish floor elevation of the slab, this may be, or may not be, the case in any given solution. Nonetheless, in a level plane surface solution, the next contour lower in elevation than the exterior finish grades of the slab or pad will always trace the pattern shown in Figure 4-31.

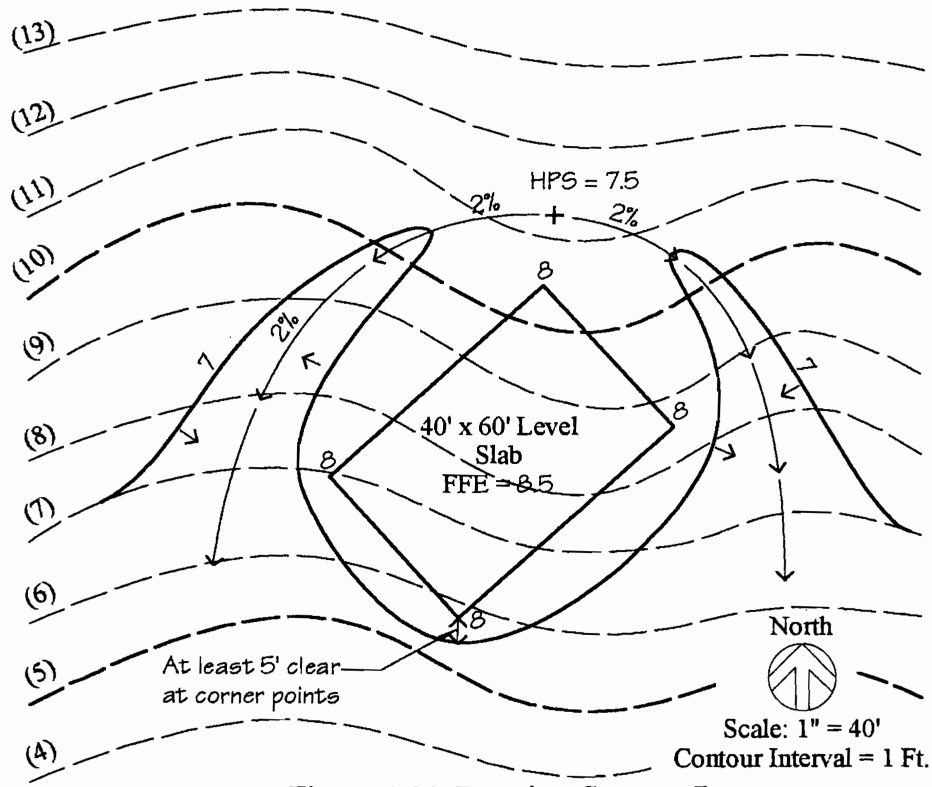


Figure 4-31. Drawing Contour 7

Step 5. Add the next lower contour, which in this example will be contour 6. Begin by determining the points where it is to cross the flow line. As noted in explanation for designing a horseshoe swale for a sloping plane surface, to save time, it is suggested that these contour crossing points be "eye-balled". The result of doing this is illustrated in Figure 4-32, where the flowline grade on the east side is not a straight grade — it begins at the highpoint swale at 2%, then increases to 2.5%. As mentioned earlier, this is perfectly acceptable unless the problem statement specifically requires a straight grade. Again, the flow line grade must fall within the prescribed slope range, which is typically a minimum slope of 2% and a maximum slope of 10% (as always, verify all criteria with the problem statement). Once the crossing points have been established, draw contour 6, keeping it at least 5 feet away from contour 7. Review Figure 4-32. Again, remember that there is no one correct solution; moving the contour crossing points in either direction would alter the overall appearance of the solution, but not its functionality — or correctness. This completes the swale itself, which leaves the front and back slope areas to grade.

Step 6. Grade the back slope and front slope areas to daylight or "catch up" to the existing grades as shown in Figure 4-33. As in the first example, remember that the slope ratio, 5:1, must be strictly adhered to, meaning that the contours cannot be placed closer than 5 feet together.* However, they may be spaced further apart, but again, keep in mind that the revised contours must daylight.

This is the phase in the process of designing a horseshoe swale for a flat slab where more than one FFE may have to be tried (the trial-and-error aspect of designing a horseshoe swale). If it is not possible to catch up to the existing contours in either the front or back slope areas, the FFE will need to be adjusted up or down. Apply the following guidelines:

- To *reduce* the back slope and increase the front slope, raise the FFE;
- To *increase* the back slope and reduce the front slope, lower the FFE.

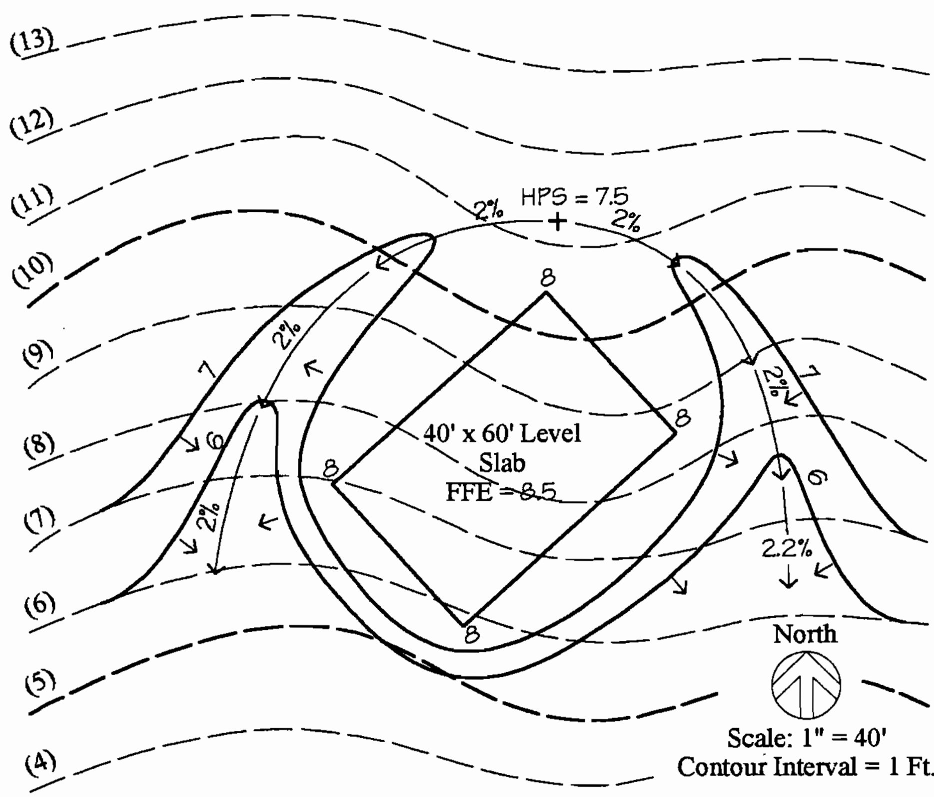


Figure 4-32. Adding Contour 6

Step 7. Lastly, as always, number all revised contours, add tick marks at the points where they rejoin existing contours, and be sure to draw every 5th contour heavier. Add any other important information, such as grades along the flow line that should be shown. It can also be helpful to add flow arrows. The completed solution for the horseshoe swale around a level plane surface is shown in Figure 4-33.

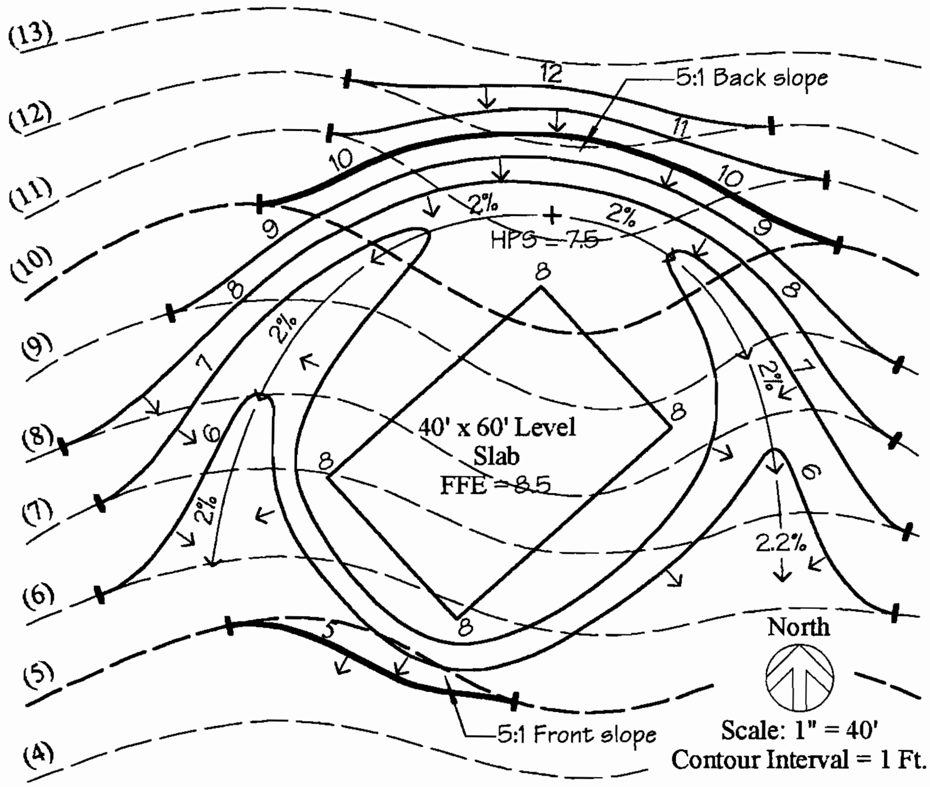


Figure 4-33. Completed Horseshoe Swale

One final note about swales: The two examples shown above are "traditional" horseshoe swales. Be mindful of the fact that there are an infinite number of possible site conditions that might be encountered on the exam. Some swales will not even be "horseshoes" in the sense that they have two legs emanating from a single high point. On the contrary, some swales will have a single leg, while others will be grossly asymmetrical. Nonetheless, the basic horseshoe swale concept remains the same, regardless of site conditions or the configuration or placement of the site element that is to be protected — there will be a highpoint swale, a flowline with contours crossing it. Stay focused on one underlying goal: that is, to intercept all runoff from upslope as well as from the site element and its immediate surrounding area. As pointed out previously, drawing flow arrows perpendicular to the contours provides a convenient and effective means for validating the effectiveness of the your solution in fulfilling the requirements of the problem.

CHAPTER FOUR EXERCISES

The following exercise problems are specifically designed to reinforce the material presented in Chapter 4. They begin simply and somewhat hypothetically, but build in rigor and complexity to a level similar to what you can expect on the exam. The only element lacking is the 11" x 17" format size of LARE vignettes; that will come later.

A word about the solutions to the exercises: In performing calculations, how you round off makes a difference in the final answer. Does this matter? Yes, and no. When it comes to plotting whole number contour lines, the answer is an emphatic "yes." Rounding off can make enough of a difference to fail the solution. On the other hand, for most other calculations, although the answers arrived at will differ slightly, the magnitude of difference is within the tolerances permitted in scoring the exam.

This same round-off issue impacts the answers for the solutions shown for the exercises. Most solution calculations were performed *without removing any digits from the calculator's display* — that is the numbers have not been rounded off. Depending on whether or not you round off, or where you round off, your calculations may differ slightly from those shown in the solutions. Note that in the case of whole number contour plotting problems, non-rounded off answers are given in parentheses. Review the following to get a sense of how rounding off impacts the results of calculations:

Express five-inches in decimal feet:

$\frac{5}{12} = .416666666$ This is the number expressing five-inches as decimal feet that will appear on the display of the calculator.

Assume a length between contours of 44 feet. Find the grade based on 44-feet:

$G = \frac{1}{44} = .022727272$. This is the number representing Grade that will appear on the display of the calculator.

Now, experiment with dividing .416666666 by .022727272. The following examples show the four possible iterations of how this particular division can be done: the first shows no round off, then rounding off the dividend, then rounding off the divisor, then both the divisor and the dividend.

$$L = \frac{.416666666}{.022727272} = 18.33333392 \text{ feet, which rounds off to } 18.3 \text{ feet}$$

$$L = \frac{.42}{.022727272} = 18.48 \text{ feet, which rounds off to } 18.5 \text{ feet}$$

$$L = \frac{.416666666}{.02} = 20.83333333 \text{ feet, which rounds off to } 20.8 \text{ feet}$$

$$L = \frac{.42}{.02} = 21 \text{ feet}$$

Notice that rounding the grade off (the divisor) has the largest effect on accuracy. The most conservative solution is not to round off anything that is calculated. It is also the easiest and safest solution because the number is left on the display, or stored in its entirety in memory, eliminating the chance for an error when re-entering the number.

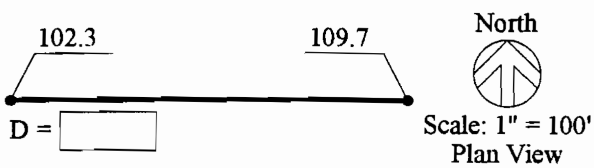
Exercise instructions are given for each group of problems; solutions appear at the end of each group.

Chapter Four, Group 1 Exercises — Difference in Elevation, Grade, and Finding an Unknown Elevation (Problems 1 through 19)

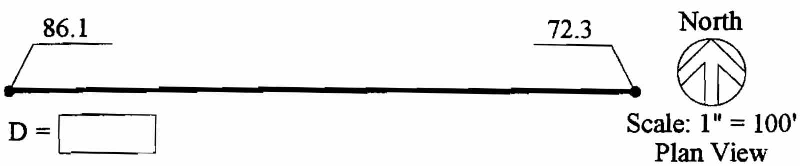
The following set of problems focuses on finding difference in elevation, grade, and finding an unknown elevation based on grade and length. Instructions: Provide the information asked for on each problem.

These problems are similar to those given on the optional Warm Up Homework Assignment. (Although similar, these problems are unique.) They're offered here for those who believe they would benefit from additional drill. Do those you're not as comfortable with.

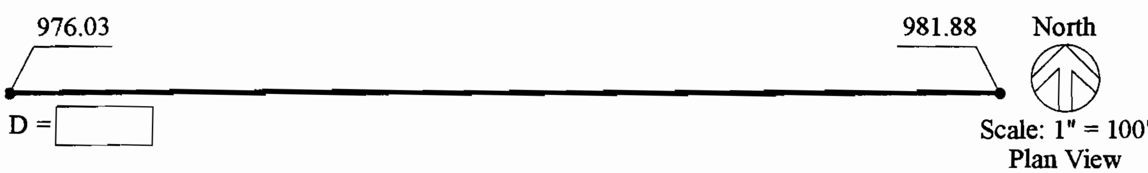
1. Find the difference in elevation between the two ends.



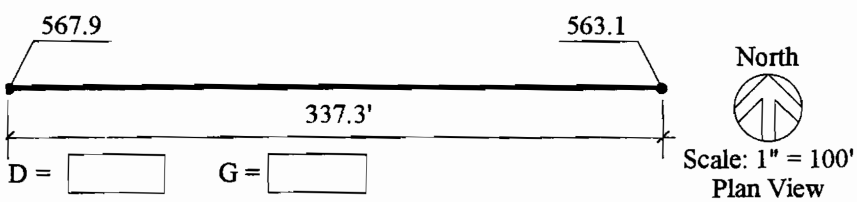
2. Find the difference in elevation between the two ends.



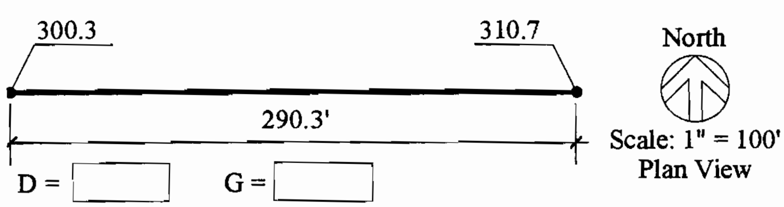
3. Find the difference in elevation between the two ends.



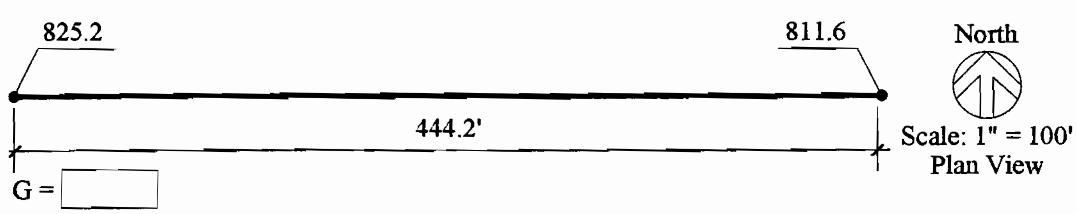
4. Find the difference in elevation and grade between the two ends.



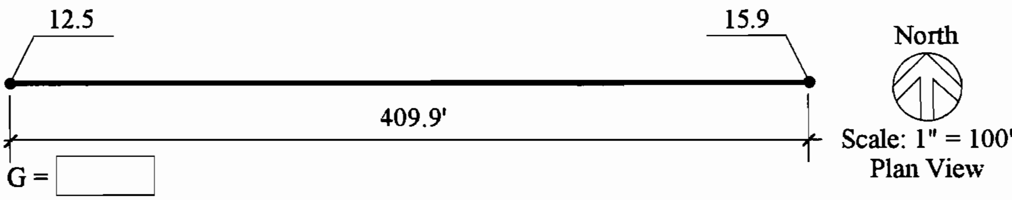
5. Find the difference in elevation and grade between the two ends.



6. Find the grade between the two ends.

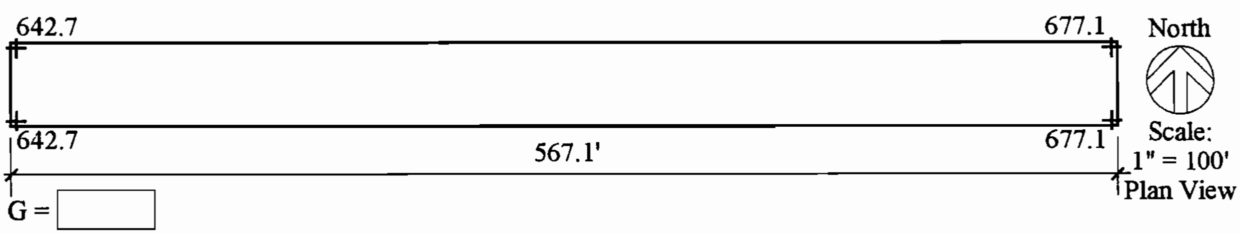


7. Find the grade between the two ends.

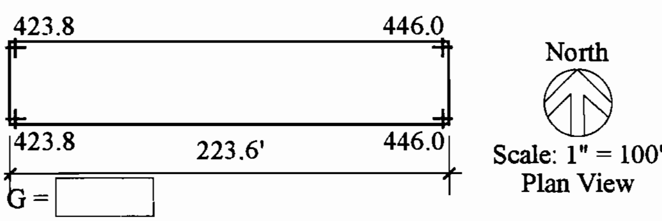


8. Find the grade between the two ends.

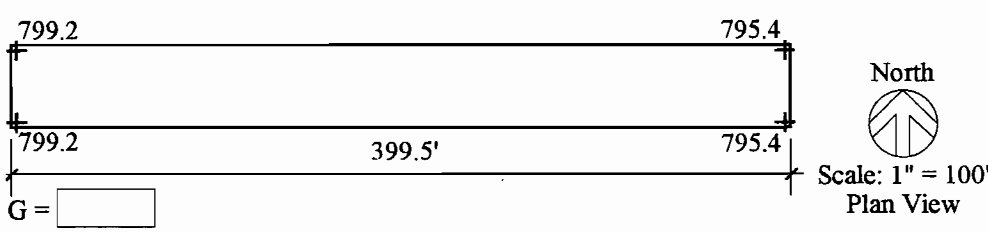
9. Find the grade between the two ends of the plane surface.



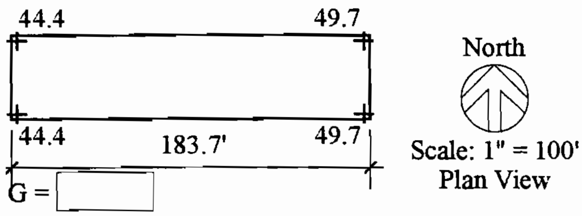
10. Find the grade between the two ends of the plane surface.



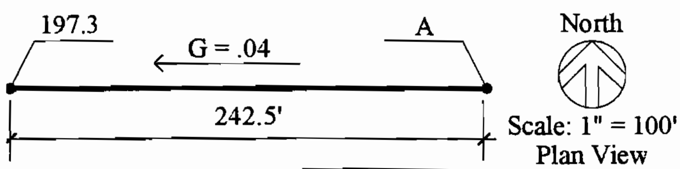
11. Find the grade between the two ends of the plane surface.



12. Find the grade between the two ends of the plane surface.

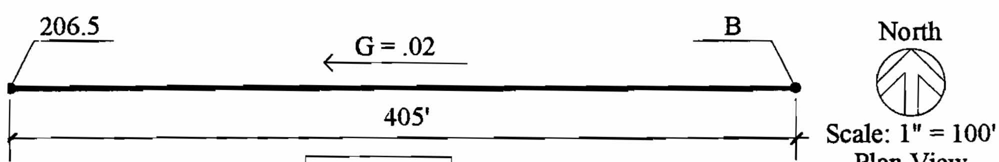


13. Find the elevation at end A.



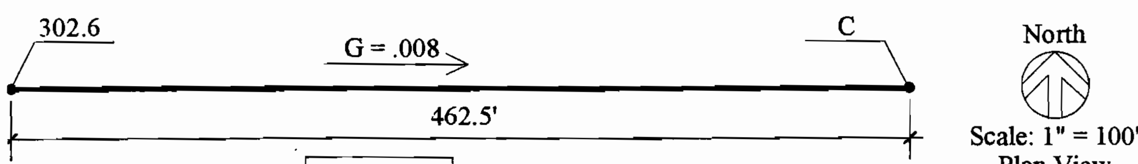
The Elevation at End A =

14. Find the elevation at end B.



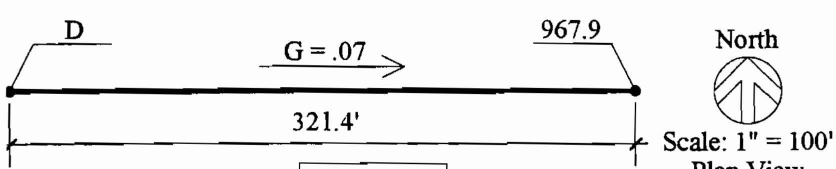
The Elevation at End B =

15. Find the elevation at end C.



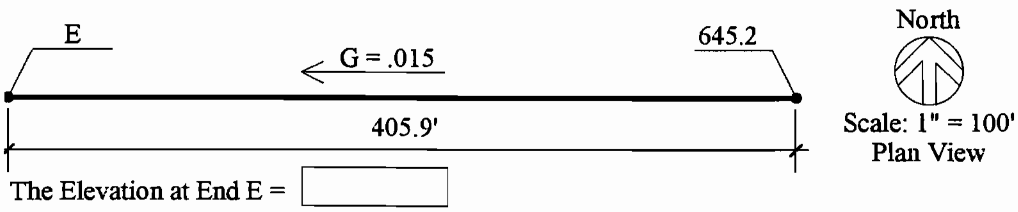
The Elevation at End C =

16. Find the elevation at end D.

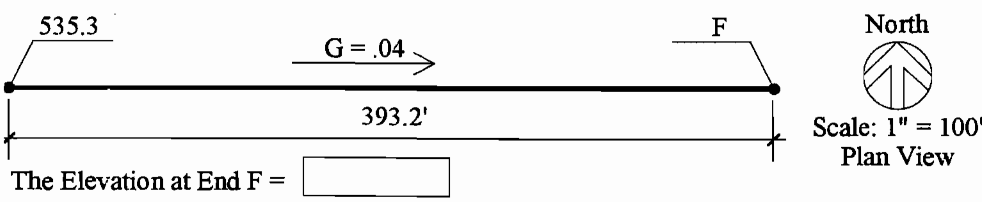


The Elevation at End D =

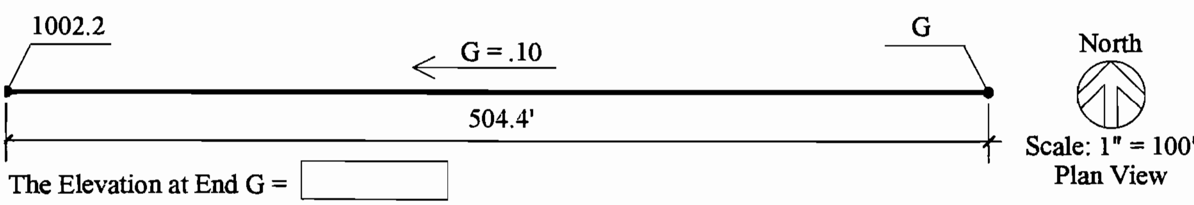
17. Find the elevation at end E.



18. Find the elevation at end F.

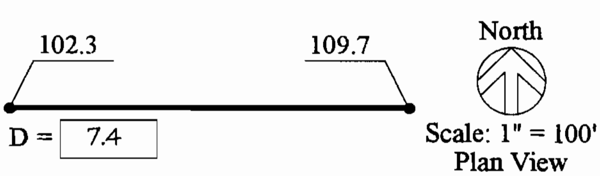


19. Find the elevation at end G.



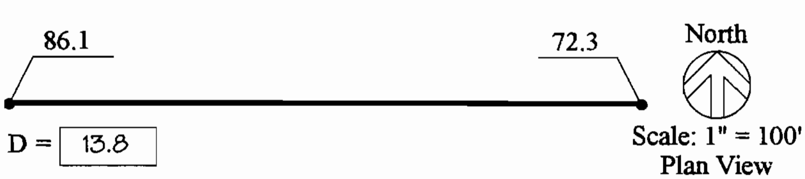
Chapter 4, Group 1 Solutions — Difference in Elevation, Grade, and Finding an Unknown Elevation (Problems 1 through 19)

1. Solution — Find difference in elevation.



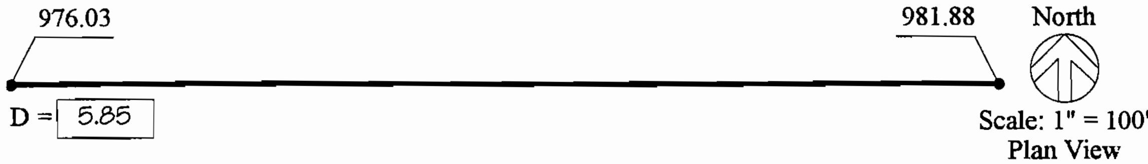
$$109.7 - 102.3 = 7.4 \text{ difference in elevation}$$

2. Solution — Find difference in elevation.



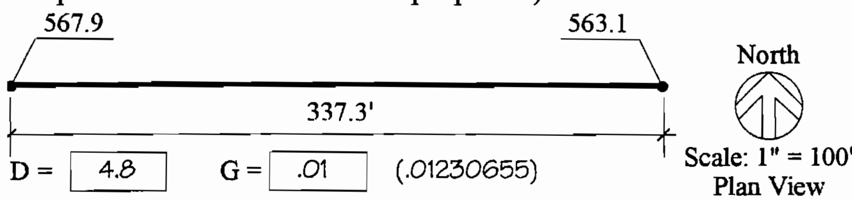
$$86.1 - 72.3 = 13.8 \text{ difference in elevation}$$

3. Solution — Find difference in elevation.



$$981.88 - 976.03 = 5.85 \text{ difference in elevation}$$

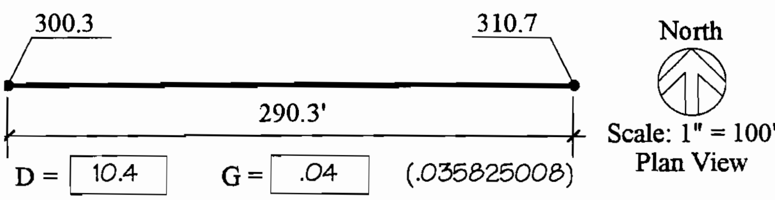
4. Solution — Find difference in elevation and grade. (Note that the correct answer has been rounded off to the nearest 1/100, or as appropriate. The answers in parentheses are in non-rounded form and are provided for informational purposes.)



$$567.9 - 563.1 = 4.8 \text{ difference in elevation} \quad L = 337.3 \text{ feet}$$

$$G = \frac{D}{L} = \frac{4.8}{337.3} = .01230655\text{, rounds off to .01}$$

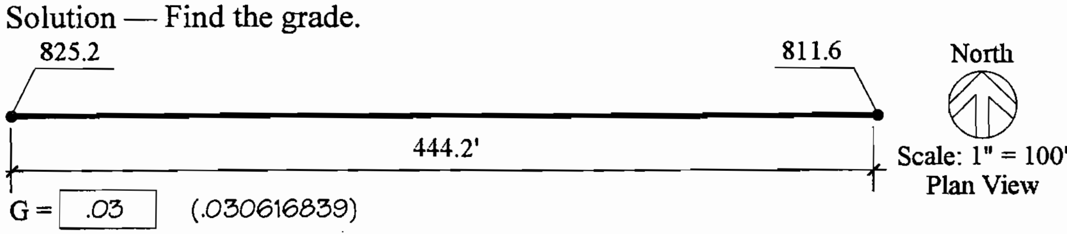
5. Solution — Find difference in elevation and grade.



$$310.7 - 300.3 = 10.4 \text{ difference in elevation} \quad L = 290.3 \text{ feet}$$

$$G = \frac{D}{L} = \frac{10.4}{290.3} = .035825008\text{, rounds off to .04}$$

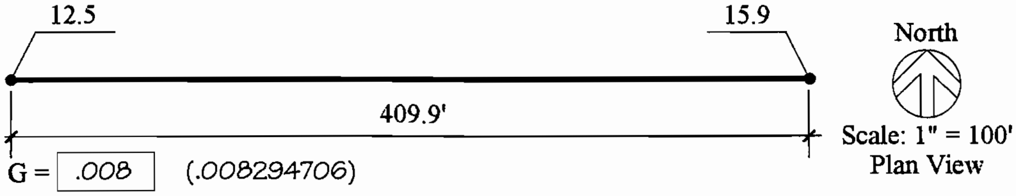
6. Solution — Find the grade.



$$825.2 - 811.6 = 13.6 \text{ difference in elevation} \quad L = 444.2 \text{ feet}$$

$$G = \frac{D}{L} = \frac{13.6}{444.2} = .030616839\text{, rounds off to .03}$$

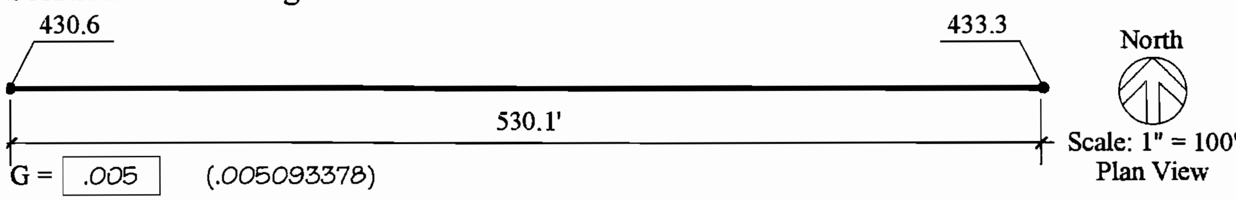
7. Solution — Find the grade.



$15.9 - 12.5 = 3.4$ difference in elevation $\quad L = 409.9$ feet

$$G = \frac{D}{L} = \frac{3.4}{409.9} = .008294706, \text{ rounds off to } .008$$

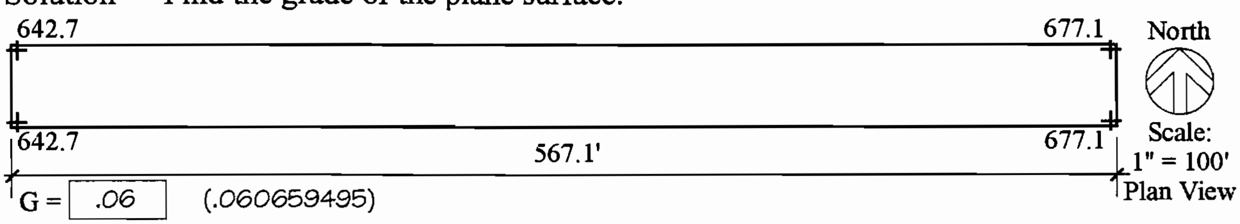
8. Solution — Find the grade.



$433.3 - 430.6 = 2.7$ difference in elevation $\quad L = 530.1$ feet

$$G = \frac{D}{L} = \frac{2.7}{530.1} = .005093378, \text{ rounds off to } .005$$

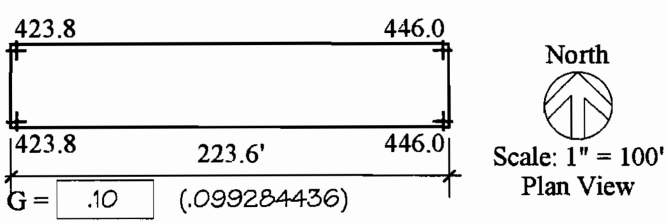
9. Solution — Find the grade of the plane surface.



$677.1 - 642.7 = 34.3$ difference in elevation $\quad L = 567.1$ feet

$$G = \frac{D}{L} = \frac{34.4}{567.1} = .060659495, \text{ rounds off to } .06$$

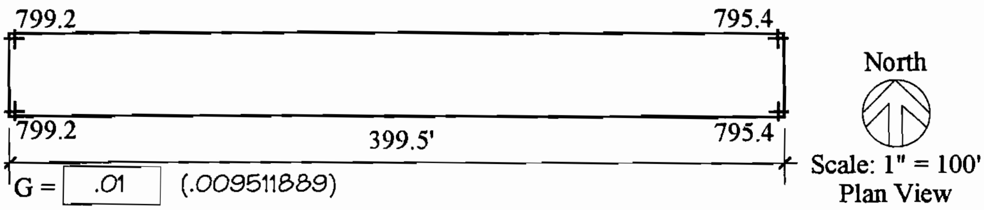
10. Solution — Find the grade of the plane surface.



$446.0 - 423.8 = 22.2$ difference in elevation $\quad L = 223.6$ feet

$$G=\frac{D}{L}=\frac{22.2}{223.6}=.099284436\text{, rounds off to .10}$$

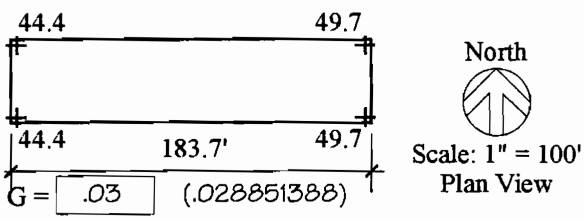
11. Solution — Find the grade of the plane surface.



$799.2 - 795.4 = 3.8$ difference in elevation $L = 399.5$ feet

$$G=\frac{D}{L}=\frac{3.8}{399.5}=.009511889\text{, rounds off to .01}$$

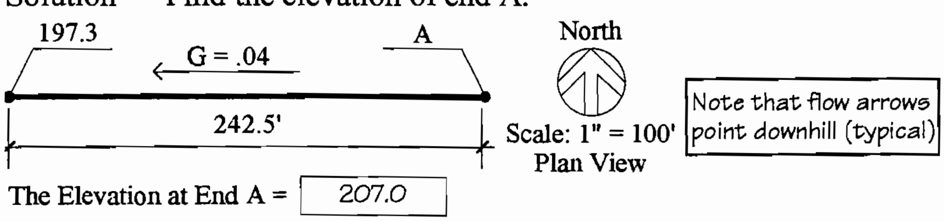
12. Solution — Find the grade of the plane surface.



$49.7 - 44.4 = 5.3$ difference in elevation $L = 183.7$ feet

$$G=\frac{D}{L}=\frac{5.3}{183.7}=.0028851388\text{, rounds off to .03}$$

13. Solution — Find the elevation of end A.



Find difference in elevation between known elevation 197.3 and unknown elevation at end A:

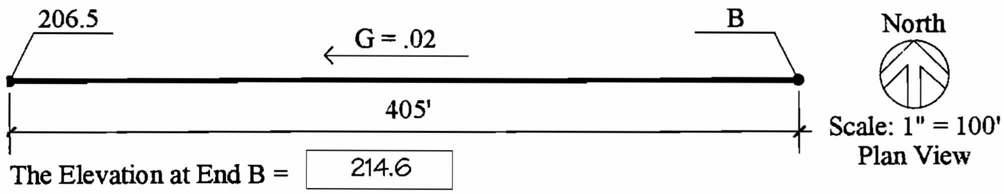
$G = .04 \quad L = 242.5$ feet

$D = G\,L = (.04)\,(242.5) = 9.7$

As noted, flow arrows points downhill. Therefore, end A is *higher* than known elevation 197.3, so the difference in elevation of 9.7 must be *added* to 197.3 to determine the elevation at end A:

$197.3 + 9.7 = 207.0$

14. Solution — Find the elevation of end B.



Find difference in elevation between known elevation 206.5 and unknown elevation at end B:

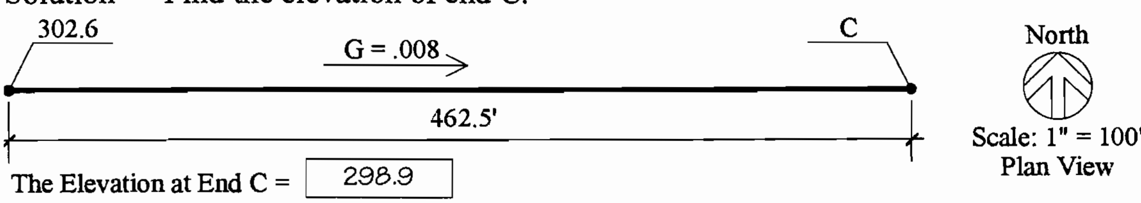
$G = .02 \quad L = 405$ feet

$D = G\,L = (.02)\,(405) = 8.1$

Because end B is *higher* than known elevation 206.5, the difference in elevation of 8.1 must be *added* to 206.5 to determine the elevation at end B:

$206.5 + 8.1 = 214.6$

15. Solution — Find the elevation of end C.



Find difference in elevation between known elevation 302.6 and unknown elevation at end C:

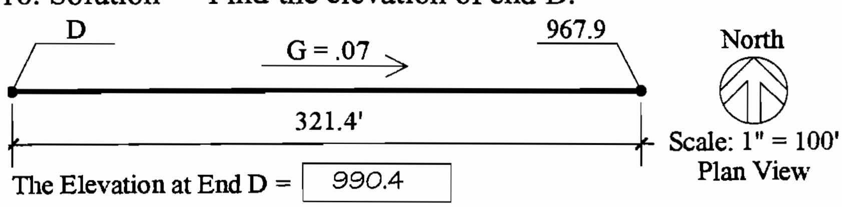
$G = .008 \quad L = 462.5$ feet

$D = G\,L = (.008)\,(462.5) = 3.7$

Because end C is *lower* than known elevation 302.6, the difference in elevation of 3.7 must be *subtracted* from 302.6 to determine the elevation at end C:

$302.6 - 3.7 = 298.9$

16. Solution — Find the elevation of end D.



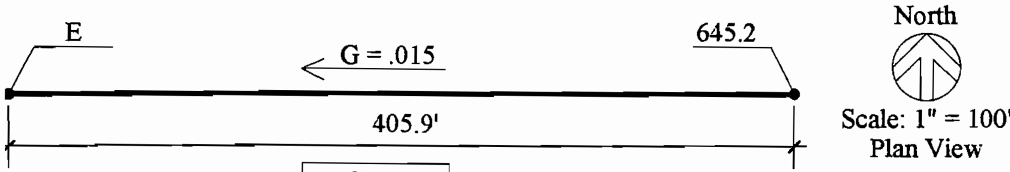
$G = .07 \quad L = 321.4$ feet

$D = G\,L = (.07)\,(321.4) = 22.498$, rounds off to 22.5

Because end D is *higher* than known elevation 967.9 the difference in elevation of 22.5 must be *added* to 967.9 to determine the elevation at end D:

$967.9 + 22.5 = 990.4$

17. Solution — Find the elevation of end E.



The Elevation at End E = 639.1

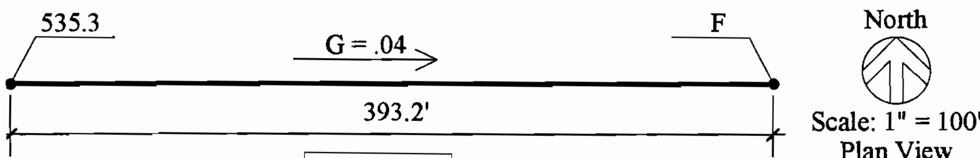
$G = .015 \quad L = 405.9$ feet

$D = G\,L = (.015)\,(405.9) = 6.0885$, rounds off to 6.1

Because end E is *lower* than known elevation 645.2, the difference in elevation of 6.1 must be *subtracted* from 645.2 to determine the elevation at end E:

$645.2 - 6.1 = 639.1$

18. Solution — Find the elevation of end F.



The Elevation at End F = 519.6

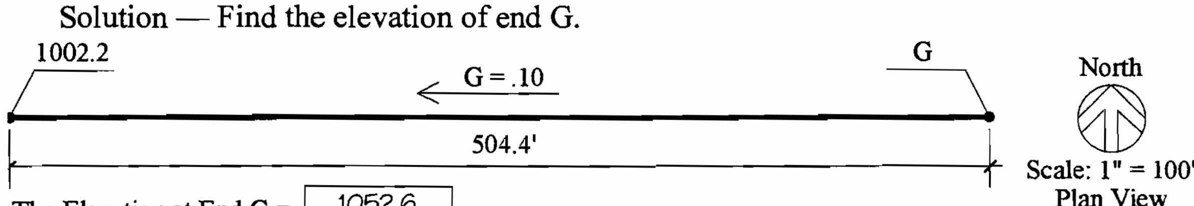
$G = .04 \quad L = 393.2$ feet

$D = G\,L = (.04)\,(393.2) = 15.728$, rounds off to 15.7

Because end F is *lower* than known elevation 535.3, the difference in elevation of 15.7 must be *subtracted* from 535.3 to determine the elevation at end F:

$535.3 - 15.7 = 519.6$

19. Solution — Find the elevation of end G.



The Elevation at End G = 1052.6

$G = .02 \quad L = 405$ feet

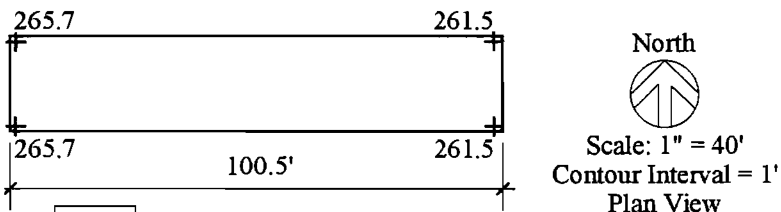
$D = G\,L = (.02)\,(405) = 8.1$

Chapter Four, Group 2 Exercises — Plotting Whole Number Contour Lines (Problems 20 through 34) This set of problems focuses on plotting whole number contour lines.

Instructions: Calculate the grade and write answer in rounded form in the box provided. Calculate the length to the first whole number contour from the *high end,* and the remaining whole number contour lines. Write answers in boxes provided. Draw and number contours on plane surfaces. **As explained in**

***Grading Basics — A Grading Primer,* the grade used to perform the *length calculations* must not be rounded off.** The numbers in parentheses are shown in non-rounded form for informational purposes. The calculations for all solutions are based the numbers shown in parentheses. Lengths should be shown to the nearest 1/10 of a foot.

20. Plot whole number contour lines on plane surface.

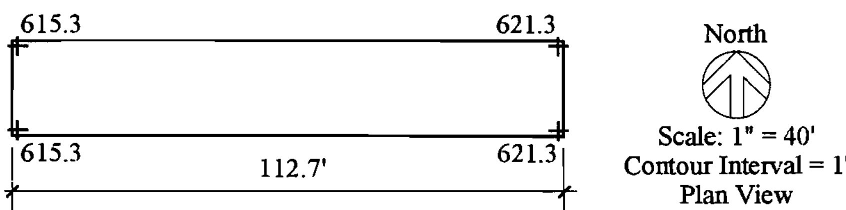


G = ☐ Non-rounded grade: ____________

Length from high end to first whole number contour line = ☐

Length between remaining whole number contour lines = ☐

21. Plot whole number contour lines on plane surface.

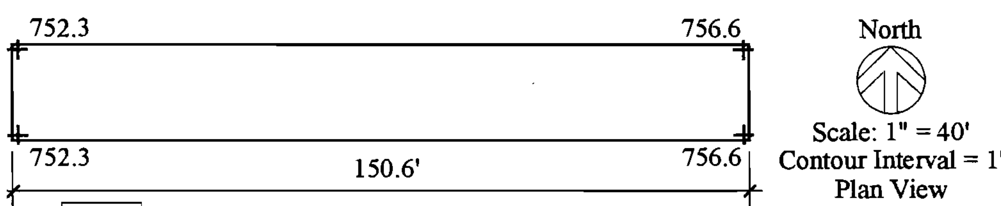


G = ☐ Non-rounded grade: ____________

Length from high end to first whole number contour line = ☐

Length between remaining whole number contour lines = ☐

22. Plot whole number contour lines on plane surface.

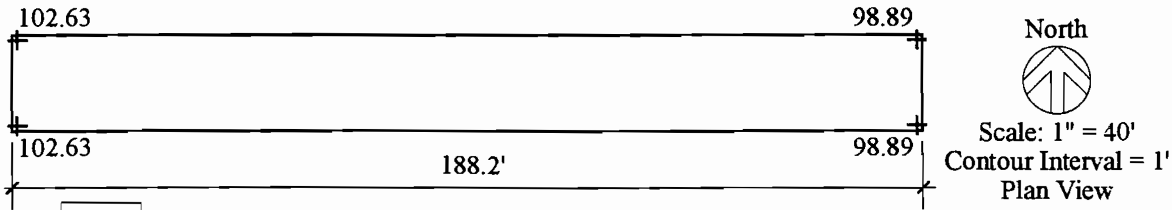


G = ☐ Non-rounded grade: ____________

Length from high end to first whole number contour line = ☐

Length between remaining whole number contour lines = ☐

23. Plot whole number contour lines on plane surface.

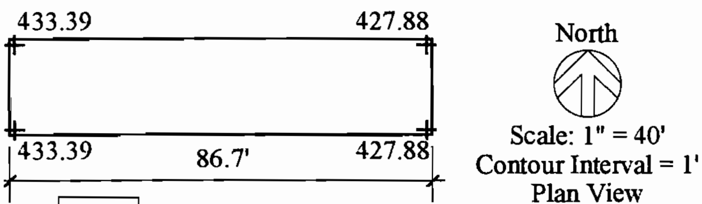


G = ☐ Non-rounded grade: ___________

Length from high end to first whole number contour line = ☐

Length between remaining whole number contour lines = ☐

24. Plot whole number contour lines on plane surface.

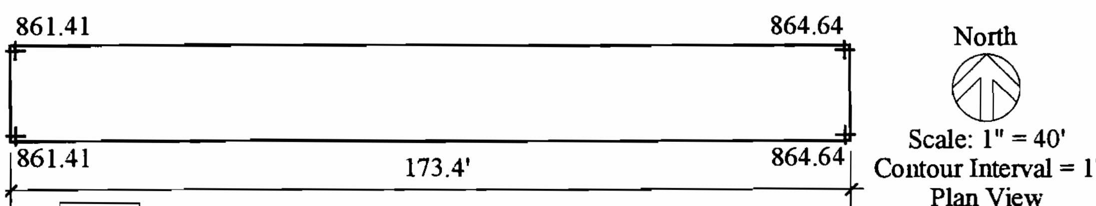


G = ☐ Non-rounded grade: ___________

Length from high end to first whole number contour line = ☐

Length between remaining whole number contour lines = ☐

25. Plot whole number contour lines on plane surface.

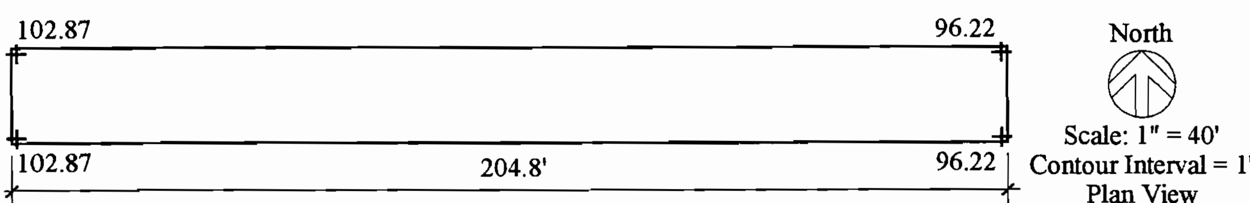


G = ☐ Non-rounded grade: ___________

Length from high end to first whole number contour line = ☐

Length between remaining whole number contour lines = ☐

26. Plot whole number contour lines on plane surface.

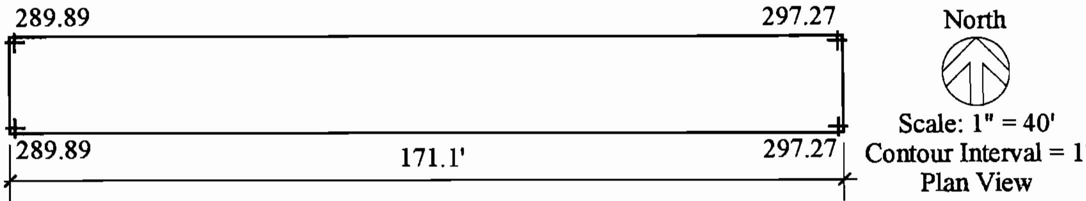


G = ☐ Non-rounded grade: ___________

Length from high end to first whole number contour line = ☐

Length between remaining whole number contour lines = ☐

27. Plot whole number contour lines on plane surface.

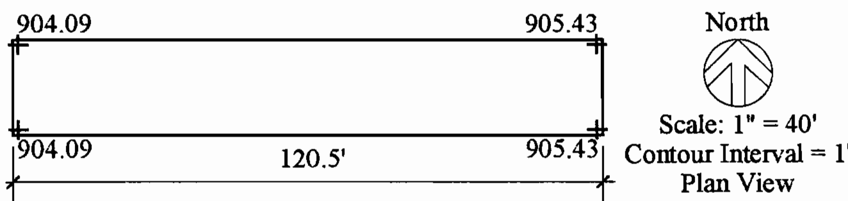


G = ☐ Non-rounded grade: ____________

Length from high end to first whole number contour line = ☐

Length between remaining whole number contour lines = ☐

28. Plot whole number contour lines on plane surface.

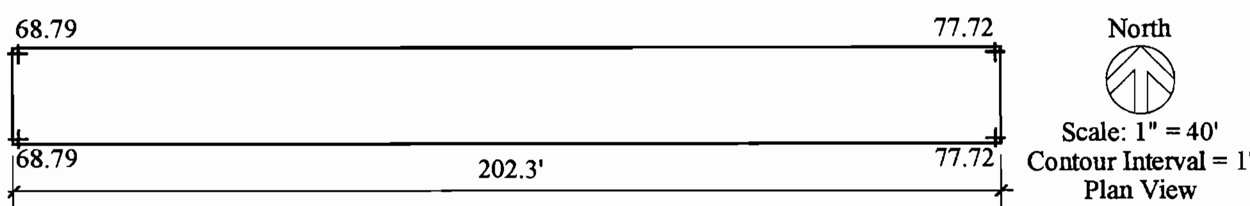


G = ☐ Non-rounded grade: ____________

Length from high end to first whole number contour line = ☐

Length between remaining whole number contour lines = ☐

29. Plot whole number contour lines on plane surface.

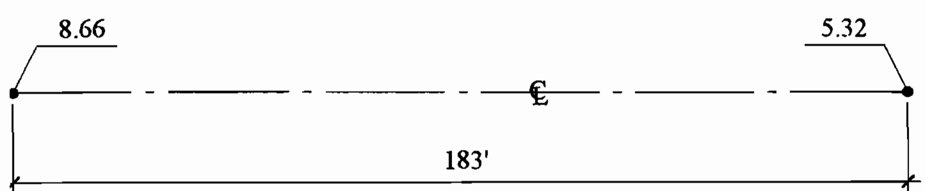


G = ☐ Non-rounded grade: ____________

Length from high end to first whole number contour line = ☐

Length between remaining whole number contour lines = ☐

30. Plot whole number contour lines along centerline.



G = ☐ Non-rounded grade: ____________

Length from high end to first whole number contour line = ☐

Length between remaining whole number contour lines = ☐

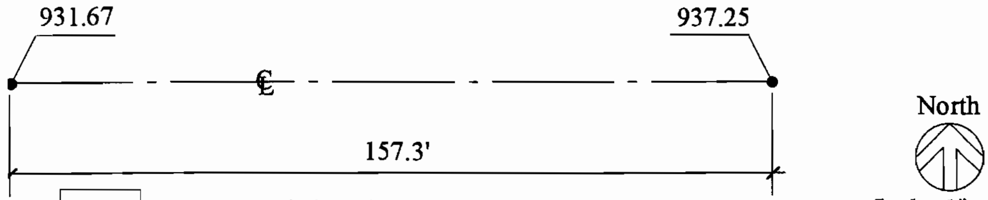
North

Scale: 1" = 40'

Contour Interval = 1'

Plan View

31. Plot whole number contour lines along centerline.



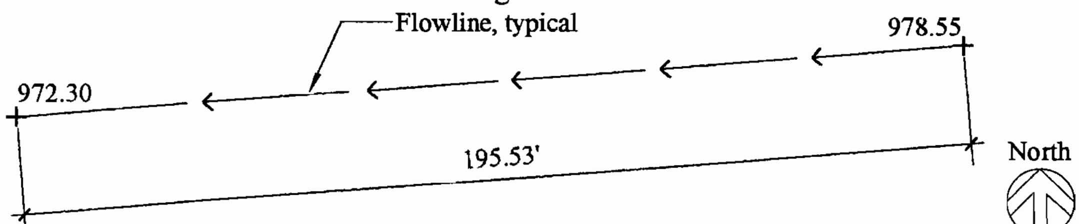
G = [ ] Non-rounded grade:___________

Length from high end to first whole number contour line = [ ]

Length between remaining whole number contour lines = [ ]

Scale: 1" = 40'
Contour Interval = 1'
Plan View

32. Plot whole number contour lines along flowline.



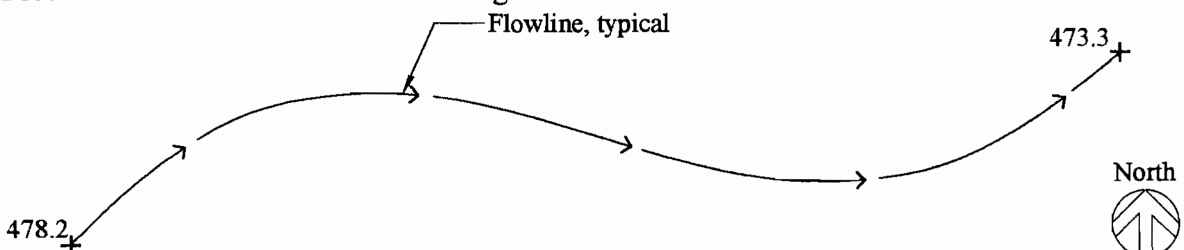
G = [ ] Non-rounded grade:___________

Length from high end to first whole number contour line = [ ]

Length between remaining whole number contour lines = [ ]

Scale: 1" = 40'
Contour Interval = 1'
Plan View

33. Plot whole number contour lines along flowline.



Length along flowline between "C" and "D" = 236.2 lineal ft.

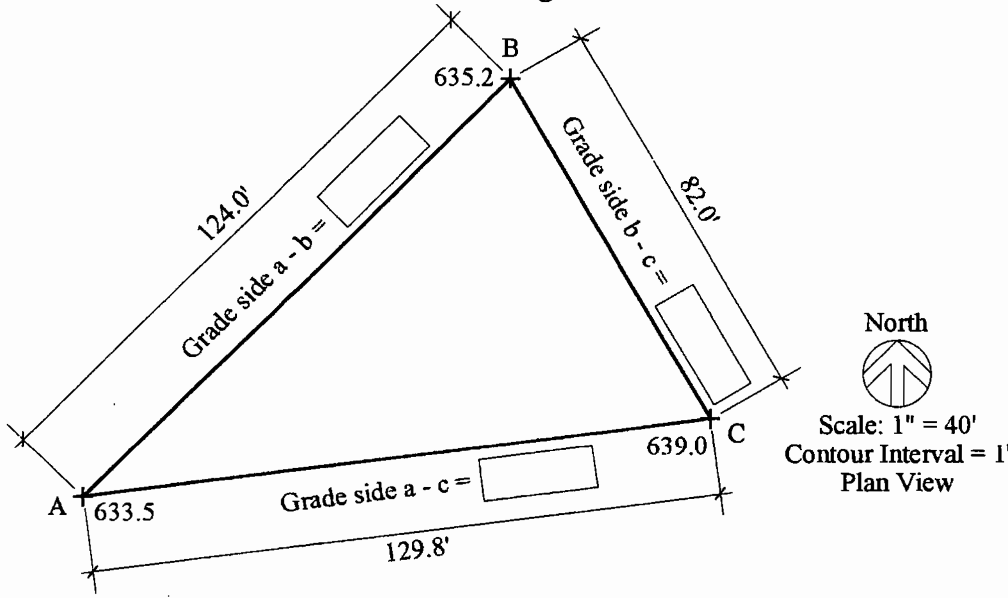
G = [ ] Non-rounded grade:___________

Length from high end to first whole number contour line = [ ]

Length between remaining whole number contour lines = [ ]

Scale: 1" = 40'
Contour Interval = 1'
Plan View

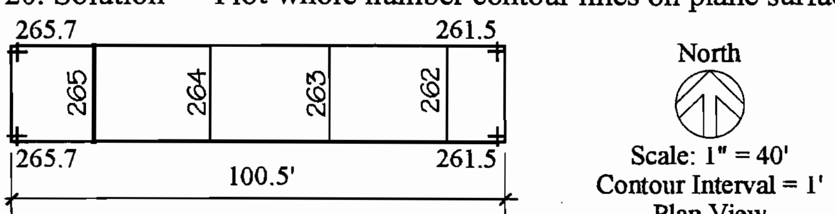
34. Plot whole number contour lines on triangle.



Problem 34 demonstrates an interesting phenomenon that results from whole number contour lines being plotted on a triangular plane surface. Can you predict the outcome?

Chapter 4, Group 2 Solutions — Plotting Whole Number Contour Lines (Problems 20 through 34)

20. Solution — Plot whole number contour lines on plane surface



G = .04 Non-rounded grade: (.041791044)

Length from high end to first whole number contour line = 16.75 ft.

Length between remaining whole number contour lines = 23.93 ft.

Calculations for problem 21:

Find difference in elevation

$$265.7 - 261.5 = 4.2 \text{ difference in elevation}$$

Find grade:

$$D = 4.2 \quad L = 100.5 \text{ feet}$$

$$G = \frac{D}{L} = \frac{4.2}{100.5} = .041791044$$

Find length to 1st contour from high end:

$D = .7 \quad G = .041791044$

$$L = \frac{D}{G} = \frac{.7}{.041791044} = 16.75 \text{ feet}$$

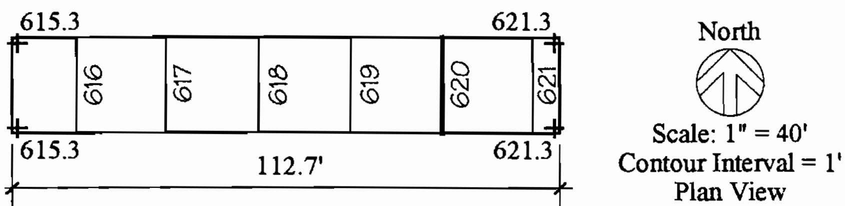
Find length between remaining contours:

$D = 1 \quad G = .041791044$

$$L = \frac{D}{G} = \frac{1}{.041791044} = 23.92857143 \text{ feet, rounds off to } 23.93 \text{ feet}$$

Or, use the reciprocal key to find the length between the remaining contours: Memory recall (.041791044), then press $1/x = 23.92857143$, rounds off to 23.93 feet

21. Solution — Plot whole number contour lines on plane surface.



G = .05 Non-rounded grade: (.053238686)

Length from high end to first whole number contour line = 5.64 ft.

Length between remaining whole number contour lines = 18.78 ft.

Calculations for problem 21:

Find difference in elevation

$621.3 - 615.3 = 6$ difference in elevation

Find grade:

$D = 6 \quad L = 112.7$ feet

$$G = \frac{D}{L} = \frac{6}{112.7} = .05328686$$

Find length to 1st contour from high end:

$D = .3 \quad G = .05328686$

$$L = \frac{D}{G} = \frac{.3}{.05328686} = 5.635 \text{ feet, rounds off to } 5.64 \text{ feet}$$

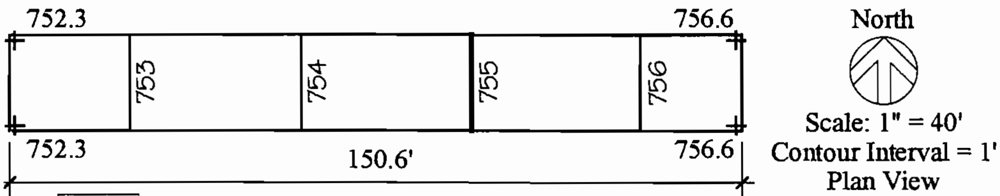
Find length between remaining contours:

$D = 1 \quad G = .05328686$

$$L = \frac{D}{G} = \frac{1}{.05328686} = 18.78333 \text{ feet, rounds off to } 18.78 \text{ feet}$$

Or, use the reciprocal key to find the length between the remaining contours: Memory recall (.053238686), then press 1/x = 18.78333 feet, rounds off to 18.78 feet

22. Solution — Plot whole number contour lines on plane surface.



G = .03 Non-rounded grade: (.028552456)

Length from high end to first whole number contour line = 21.0 ft.

Length between remaining whole number contour lines = 35.0 ft.

Calculations for problem 22:

Find grade:

$$D = 4.3 \quad L = 150.6 \text{ feet}$$

$$G = \frac{D}{L} = \frac{4.3}{150.6} = .028552456$$

Find length to 1st contour from high end:

$$D = .6 \quad G = .028552456$$

$$L = \frac{D}{G} = \frac{.6}{.028552456} = 21.01395349 \text{ feet, rounds off to } 21.01 \text{ feet}$$

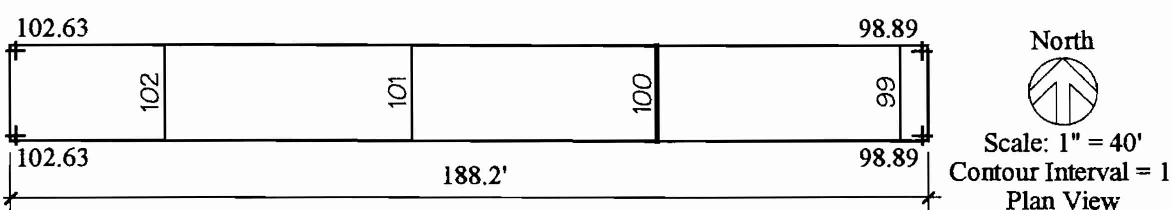
Find length between remaining contours:

$$D = 1 \quad G = .028552456$$

$$L = \frac{D}{G} = \frac{1}{.028552456} = 35.02325581 \text{ feet, rounds off to } 35.02 \text{ feet}$$

Or, using the reciprocal key to find the length between the remaining contours: Memory recall (.028552456), then press 1/x = 35.02325581 feet, rounds off to 35.02 feet

23. Solution — Plot whole number contour lines on plane surface.



G = .02 Non-rounded grade: (.019872476)

Length from high end to first whole number contour line = 31.7 ft.

Length between remaining whole number contour lines = 50.3 ft.

Calculations for problem 23:

Find grade:

$$D = 3.74 \quad L = 188.2 \text{ feet}$$

$$G = \frac{D}{L} = \frac{3.74}{188.2} = .019872476$$

Find length to 1st contour from high end:

$$D = .63 \quad G = .019872476$$

$$L = \frac{D}{G} = \frac{.63}{.019872476} = 31.70213904 \text{ feet, rounds off to } 31.7 \text{ feet}$$

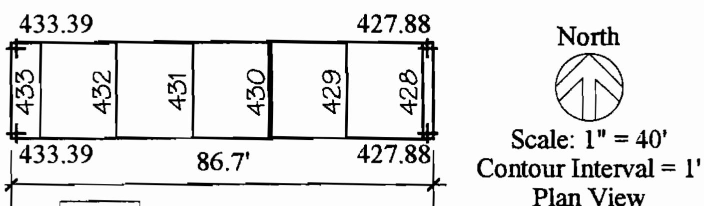
Find length between remaining contours:

$$D = 1 \quad G = .019872476$$

$$L = \frac{D}{G} = \frac{1}{.019872476} = 50.32085561 \text{ feet, rounds off to } 50.3 \text{ feet}$$

Or, use the reciprocal key to find the length between the remaining contours: Memory recall (.019872476), then press 1/x = 50.32085561 feet, rounds off to 50.3 feet

24. Solution — Plot whole number contour lines on plane surface.



G = .06 Non-rounded grade: (.063552479)

Length from high end to first whole number contour line = 6.1 ft.

Length between remaining whole number contour lines = 15.7 ft.

Calculations for problem 24:

Find grade:

$$D = 5.51 \quad L = 86.7 \text{ feet}$$

$$G = \frac{D}{L} = \frac{5.51}{86.7} = .063552479$$

Find length to 1st contour from high end:

$$D = .39 \quad G = .063552479$$

$$L = \frac{D}{G} = \frac{.39}{.063552479} = 6.1366606 \text{ feet, rounds off to } 6.1 \text{ feet}$$

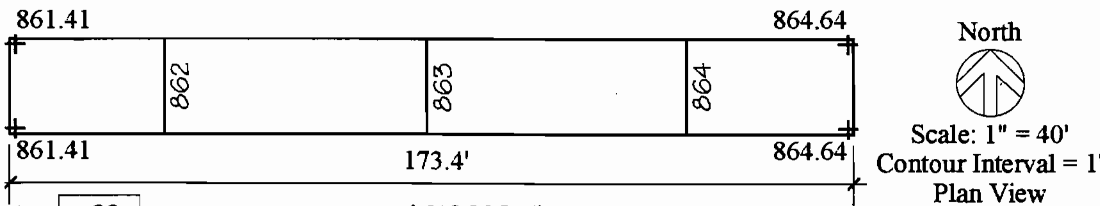
Find length between remaining contours:

$$D=1 \quad G=.063552479$$

$$L=\frac{D}{G}=\frac{1}{.063552479}=15.73502722 \text{ feet, rounds off to } 15.7 \text{ feet}$$

Or, use the reciprocal key to find the length between the remaining contours: Memory recall (.063552479), then press $1/x$ = 15.73502722 feet, rounds off to 15.7 feet

25. Solution — Plot whole number contour lines on plane surface.



G = .02 Non-rounded grade: (.01862745)

Length from high end to first whole number contour line = 34.4 ft.

Length between remaining whole number contour lines = 53.7 ft.

Calculations for problem 25:

Find grade:

$$D=3.23 \quad L=173.4 \text{ feet}$$

$$G=\frac{D}{L}=\frac{3.23}{188.2}=.01862745$$

Find length to 1st contour from high end:

$$D=.64 \quad G=.01862745$$

$$L=\frac{D}{G}=\frac{.64}{.01862745}=34.35789474 \text{ feet, rounds off to } 34.4 \text{ feet}$$

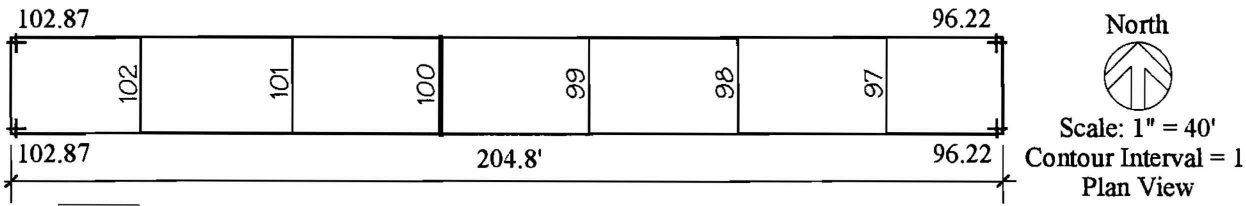
Find length between remaining contours:

$$D=1 \quad G=.01862745$$

$$L=\frac{D}{G}=\frac{1}{.01862745}=53.68421053 \text{ feet, rounds off to } 53.7 \text{ feet}$$

Or, use the reciprocal key to find the length between the remaining contours: Memory recall (.01862745), then press $1/x$ = 53.68421053 feet, rounds off to 53.7 feet

26. Solution — Plot whole number contour lines on plane surface.



G = .03 Non-rounded grade: (.032470703)

Length from high end to first whole number contour line = 26.8 ft.

Length between remaining whole number contour lines = 30.8 ft.

Calculation for problem 26:

Find grade:

$$D = 6.65 \quad L = 204.8 \text{ feet}$$

$$G = \frac{D}{L} = \frac{6.65}{204.8} = .032470703$$

Find length to 1st contour from high end:

$$D = .87 \quad G = .032470703$$

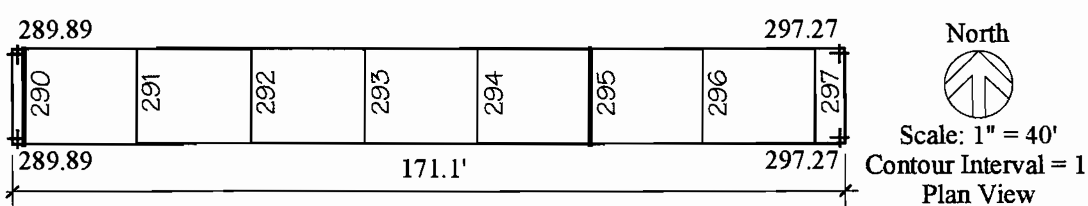
$$L = \frac{D}{G} = \frac{.87}{.032470703} = 26.79338346 \text{ feet, rounds off to 26.8 feet}$$

Find length between remaining contours:

$$D = 1 \quad G = .032470703$$

$$L = \frac{D}{G} = \frac{1}{.032470703} = 30.79699248 \text{ feet, rounds off to 30.8 feet}$$

27. Solution — Plot whole number contour lines on plane surface



G = .04 Non-rounded grade: (.04313267)

Length from high end to first whole number contour line = 6.3 ft.

Length between remaining whole number contour lines = 23.2 ft.

Calculation for problem 27:

Find grade:

$$D = 7.38 \quad L = 171.1 \text{ feet}$$

$$G = \frac{D}{L} = \frac{7.38}{171.1} = .04313267$$

Find length to 1st contour from high end:

$$D = .27 \quad G = .04313267$$

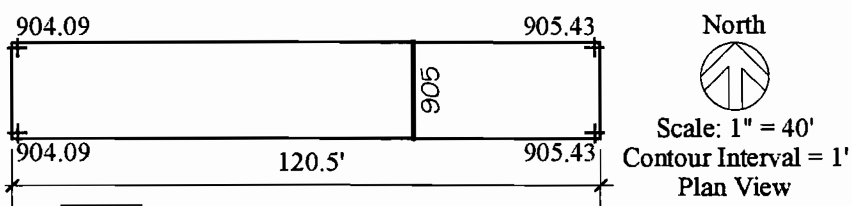
$$L = \frac{D}{G} = \frac{.27}{.04313267} = 6.259756098 \text{ feet, rounds off to 6.3 feet}$$

Find length between remaining contours:

$$D = 1 \quad G = .04313267$$

$$L = \frac{D}{G} = \frac{1}{.04313267} = 23.18428184 \text{ feet, rounds off to 23.2 feet}$$

28. Solution — Plot whole number contour lines on plane surface.



G = .01 Non-rounded grade: (.011120331)

Length from high end to first whole number contour line = 38.7 ft.

Length between remaining whole number contour lines = n/a

Calculations for problem 28:

Find grade:

$$D = 1.34 \quad L = 120.5 \text{ feet}$$

$$G = \frac{D}{L} = \frac{1.34}{120.5} = .011120331$$

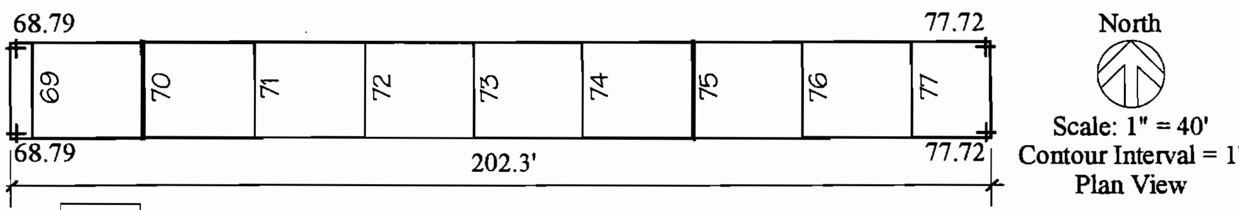
Find length to 1st contour from high end:

$$D = .43 \quad G = .011120331$$

$$L = \frac{D}{G} = \frac{.43}{.011120331} = 38.66791045 \text{ feet, rounds off to 38.7 feet}$$

Note that only one contour line, contour 905, crosses this plane surface, therefore, it is not necessary to calculate the length between remaining contours.

29. Solution — Plot whole number contour lines on plane surface.



G = .04   Non-rounded grade: (.044142362)

Length from high end to first whole number contour line = 16.3 ft.

Length between remaining whole number contour lines = 22.7 ft.

Calculations for problem 29:

Find grade:

$$D = 8.93 \quad L = 202.3 \text{ feet}$$

$$G = \frac{D}{L} = \frac{8.93}{202.3} = .044142362$$

Find length to 1st contour from high end:

$$D = .72 \quad G = .044142362$$

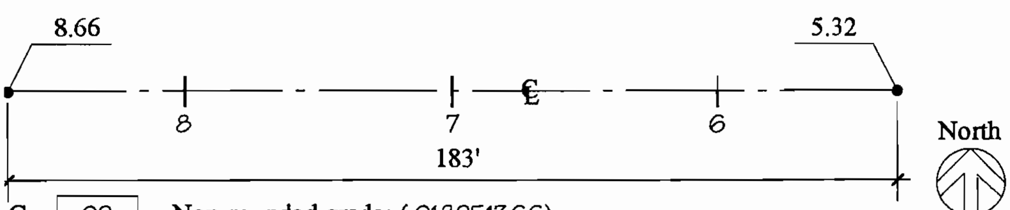
$$L = \frac{D}{G} = \frac{.72}{.044142362} = 16.1086226 \text{ feet, rounds off to 16.3 feet}$$

Find length between remaining contours:

$$D = 1 \quad G = .044142362$$

$$L = \frac{D}{G} = \frac{1}{.044142362} = 22.65397536 \text{ feet, rounds off to 22.7 feet}$$

30. Solution — Plot whole number contour lines along centerline.



G = .02   Non-rounded grade: (.018251366)

Length from high end to first whole number contour line = 36.2 ft.

Length between remaining whole number contour lines = 54.8 ft.

Scale: 1" = 40'
Contour Interval = 1'
Plan View

Calculations for problem 30:

Find grade:

$$D = 3.34 \quad L = 183 \text{ feet}$$

$$G = \frac{D}{L} = \frac{3.34}{183} = .018251366$$

Find length to 1st contour from high end:

$$D = .66 \quad G = .018251366$$

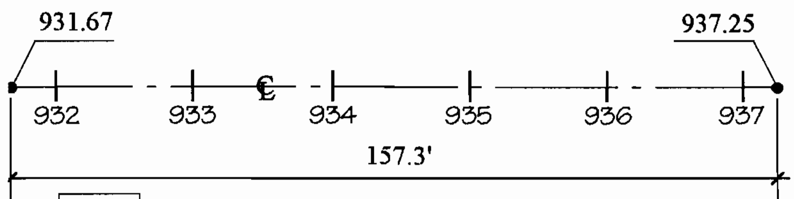
$$L = \frac{D}{G} = \frac{.66}{.018251366} = 36.16167665 \text{ feet, rounds off to 36.2 feet}$$

Find length between remaining contours:

$$D = 1 \quad G = .018251366$$

$$L = \frac{D}{G} = \frac{1}{.018251366} = 54.79041916 \text{ feet, rounds off to 54.8 feet}$$

31. Solution — Plot whole number contour lines along centerline.



North

Scale: 1" = 40'
Contour Interval = 1'
Plan View

G = .04 Non-rounded grade: (.035473617)

Length from high end to first whole number contour line = 7.0 ft.

Length between remaining whole number contour lines = 28.2 ft.

Calculations for problem 31:

Find grade:

$$D = 5.58 \quad L = 157.3 \text{ feet}$$

$$G = \frac{D}{L} = \frac{5.58}{157.3} = .035473617$$

Find length to 1st contour from high end:

$$D = .25 \quad G = .035473617$$

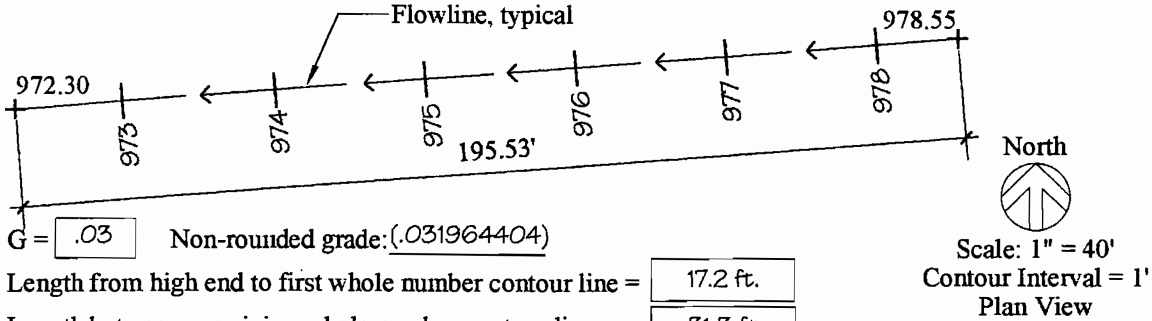
$$L = \frac{D}{G} = \frac{.25}{.035473617} = 7.047491039 \text{ feet, rounds off to 7.0 feet}$$

Find length between remaining contours:

$$D = 1 \quad G = .035473617$$

$$L = \frac{D}{G} = \frac{1}{.035473617} = 28.18996416 \text{ feet, rounds off to 28.2 feet}$$

32. Solution — Plot whole number contour lines along centerline.



G = .03 Non-rounded grade: (.031964404)

Length from high end to first whole number contour line = 17.2 ft.

Length between remaining whole number contour lines = 31.3 ft.

Calculations for problem 32:

Find grade:

$$D = 6.25 \quad L = 195.53 \text{ feet}$$

$$G = \frac{D}{L} = \frac{6.25}{195.53} = .031964404$$

Find length to 1st contour from high end:

$$D = .55 \quad G = .031964404$$

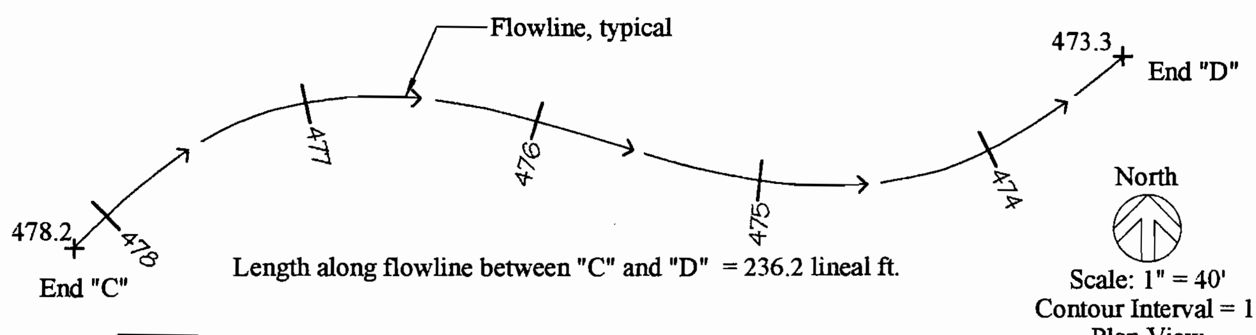
$$L = \frac{D}{G} = \frac{.55}{.031964404} = 17.20664 \text{ feet, rounds off to } 17.2 \text{ feet}$$

Find length between remaining contours:

$$D = 1 \quad G = .031964404$$

$$L = \frac{D}{G} = \frac{1}{.031964404} = 31.2848 \text{ feet, rounds off to } 31.3 \text{ feet}$$

33. Solution — Plot whole number contour lines along flowline.



G = .02 Non-rounded grade: (.020745131)

Length from high end to first whole number contour line = 9.6 ft.

Length between remaining whole number contour lines = 48.2 ft.

Calculations for problem 33:

Find grade:

$D = 4.9 \quad L = 236.2$ lineal feet

$$G = \frac{D}{L} = \frac{4.9}{236.2} = .020745131$$

Find length to 1st contour from high end:

$D = .2 \quad G = .020745131$

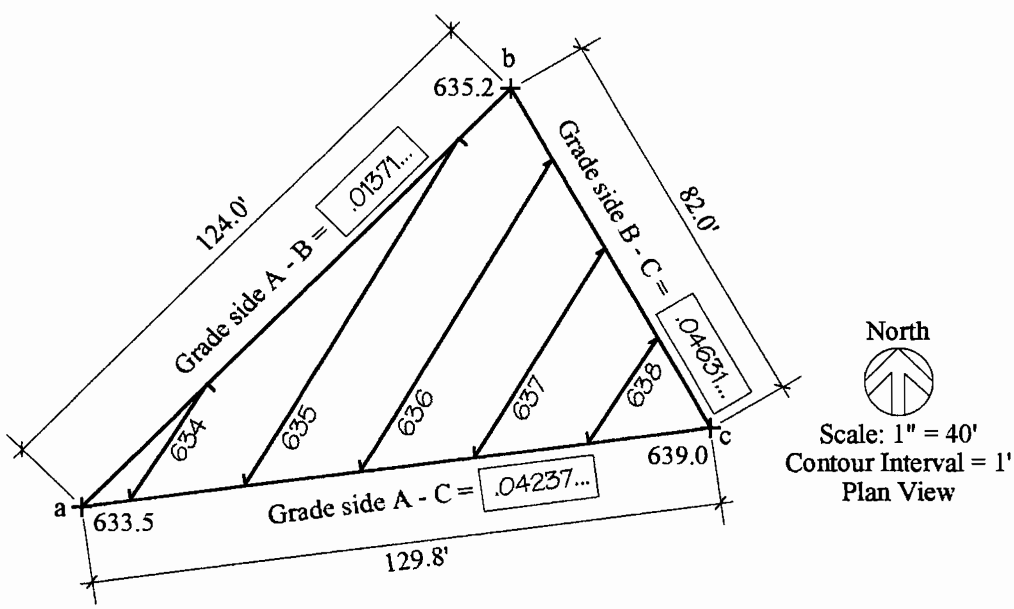
$$L = \frac{D}{G} = \frac{.2}{.020745131} = 9.640816327 \text{ feet, rounds off to } 9.6 \text{ feet}$$

Find length between remaining contours:

$D = 1 \quad G = .020745131$

$$L = \frac{D}{G} = \frac{1}{.020745131} = 48.20408163 \text{ feet, rounds off to } 48.2 \text{ feet}$$

34. Solution — Plot whole number contour lines on triangle.



Calculations for problem 34:

Find grade of side A - B:

$D = 1.7 \quad L = 124.0$ feet

$$G = \frac{D}{L} = \frac{1.7}{124.0} = .013709677$$

Find length to 1st contour from high end:

$$D = .2 \quad G = .013709677$$

$$L = \frac{D}{G} = \frac{.2}{.013709677} = 14.58823529 \text{ feet, rounds off to } 14.6 \text{ feet}$$

Find length between remaining contours:

$$D = 1 \quad G = .013709677$$

$$L = \frac{D}{G} = \frac{1}{.013709677} = 72.94117647 \text{ feet, rounds off to } 72.9 \text{ feet}$$

Find grade of side B - C:

$$D = 3.8 \quad L = 82.0 \text{ feet}$$

$$G = \frac{D}{L} = \frac{3.8}{82.0} = .046341463$$

The elevation at corner c is a whole number (39).

Find length between remaining contours:

$$D = 1 \quad G = .046341463$$

$$L = \frac{D}{G} = \frac{1}{.046341463} = 21.57894737 \text{ feet, rounds off to } 21.6 \text{ feet}$$

Find grade of side A - C:

$$D = 5.5 \quad L = 129.8 \text{ feet}$$

$$G = \frac{D}{L} = \frac{5.5}{129.8} = .042372881$$

The elevation at corner c is a whole number (39).

Find length between remaining contours:

$$D = 1 \quad G = .042372881$$

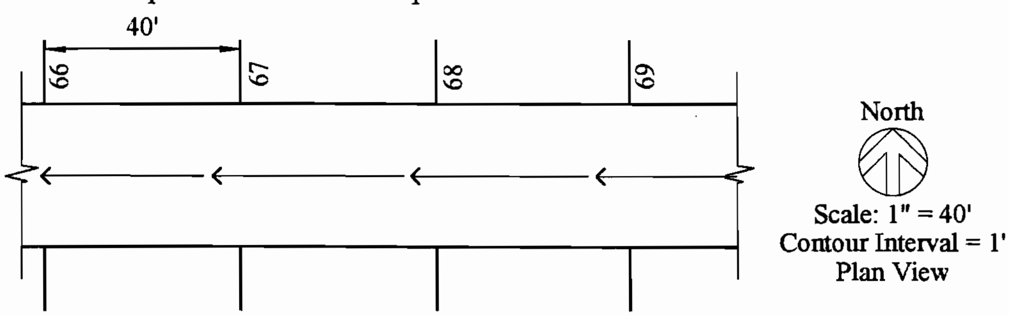
$$L = \frac{D}{G} = \frac{1}{.042372881} = 23.6 \text{ feet}$$

Were you able to predict the fact that when the contour lines are plotted, they plot *parallel to one another?* Interestingly, the contours will remain parallel regardless of how the corner elevations are changed.

Chapter 4, Group 3 Exercises — Calculating Height or Depth of a Site Element and Cross Slope (Problems 35 through 43)

The following problems concentrate on finding the height of the crown of a road, the height of a curb, or the height of a wall, or the depth of a ditch, or the cross slopes of various surfaces. Follow the instructions given with each problem.

35. Find the depth of the ditch and plot contours.

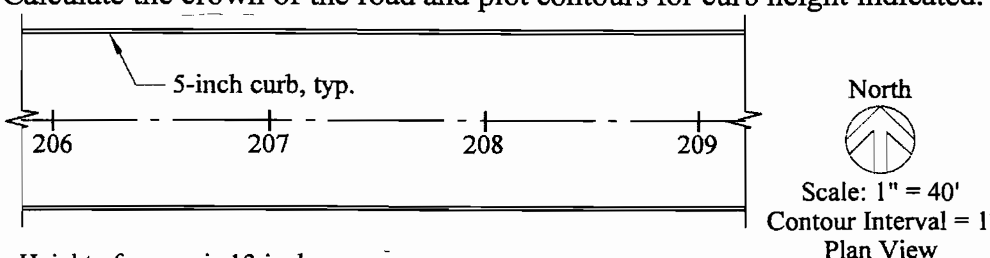


Depth of ditch is 28 inches.

Grade = ☐ Non-rounded grade: ______

Length of run = ☐

36. Calculate the crown of the road and plot contours for curb height indicated.



Height of crown is 13 inches.

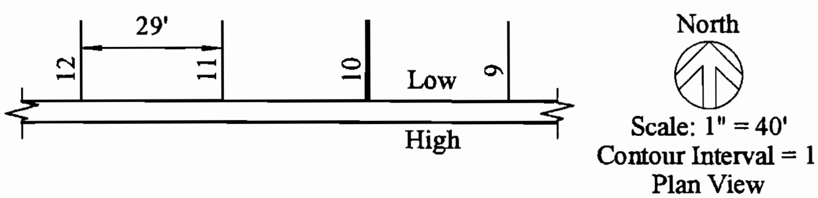
Grade = ☐ Non-rounded grade: ______

Length of crown run = ☐

Height of curb is 5 inches

Length of curb run = ☐

37. Calculate the offset of contour 12 on the retaining wall.

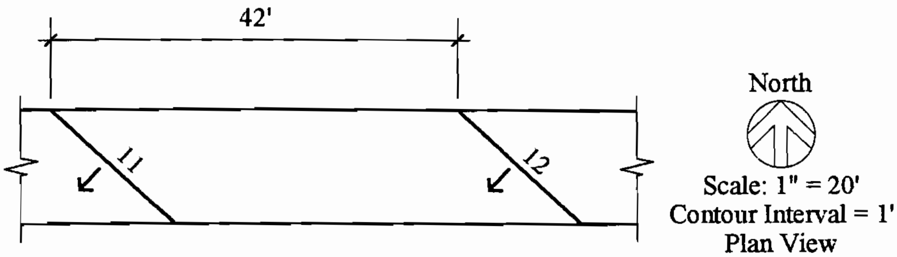


Height of wall is 22 inches. Calculate, plot, and dimension contour 12 on the south (high) side of the wall.

Grade = ☐ Non-rounded grade: ______

Length of run = ☐

38. Calculate and show correct relationship of contours 11 and 12 adjacent to walk on north and south sides. *Note scale change.* (Suggestion: to determine which way the contours deflect off the walk, think of the walk as a *flat-topped ridge* in its relationship to the adjacent non-paved surface. Remember, in the ridge signature, contours always point downhill.)



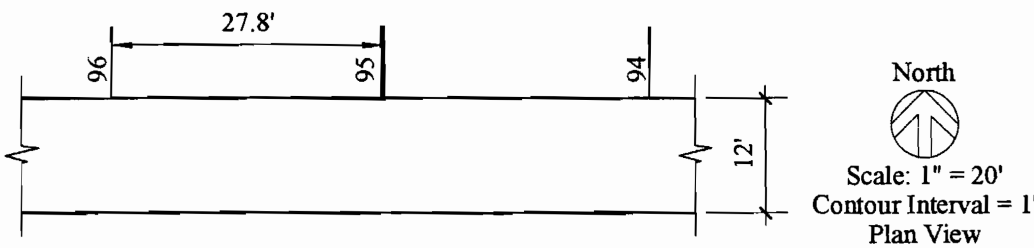
Finish surface of walk is 1" above adjacent finish grade.

Grade = ☐ Non-rounded grade: ________

Length of run = ☐

Reminder: Use the cross slope formula: $Df = \frac{(CS)(W)}{LG}$

39. Calculate and plot contours to reflect the stipulated cross slope on walk.

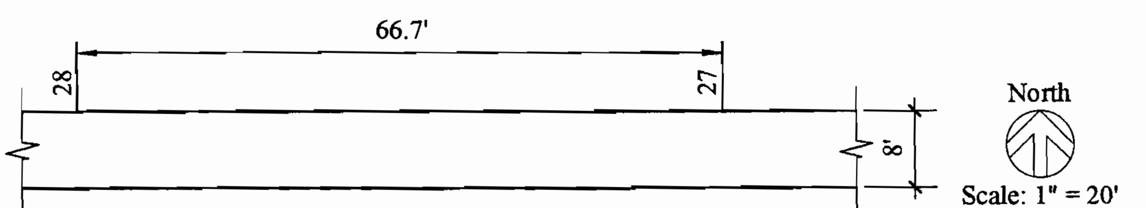


Cross slope of walk is 2%; runoff drains to south side.

Grade = ☐ Non-rounded grade: ______

Deflection = ☐

40. Calculate and plot contours to reflect the stipulated cross slope on walk.



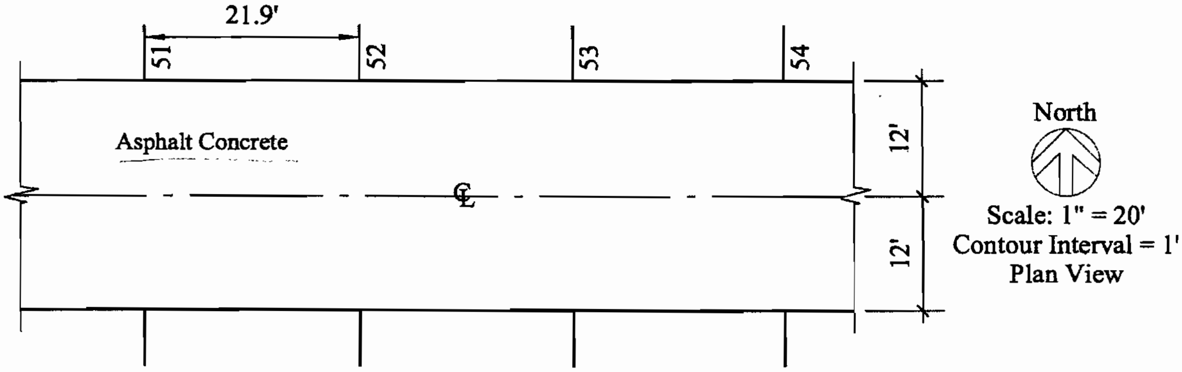
Contour Interval = 1'
Plan View

Cross slope of walk is 2%; runoff drains to north side.

Grade = ☐ Non-rounded grade: ______

Deflection = ☐

41. Calculate and plot contours to reflect the stipulated cross slope on the asphalt concrete road.

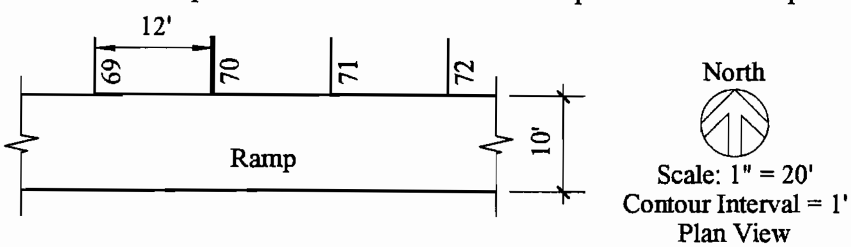


Cross slope about the center line is 2%; runoff drains to shoulders.

Grade = ☐ Non-rounded grade:________

Deflection at centerline = ☐

42. Calculate and plot contours to reflect the stipulated cross slope on ramp.

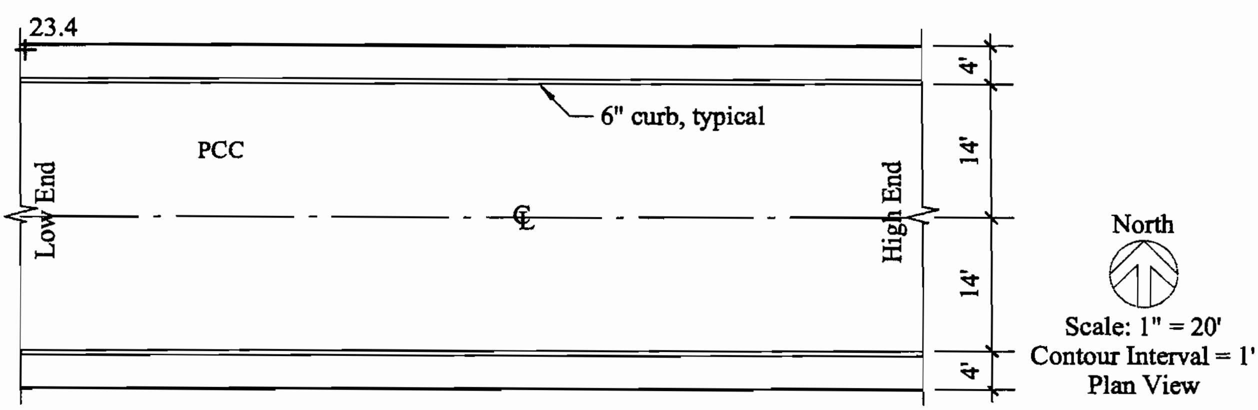


Cross slope of ramp is 2%; runoff drains to north side.

Grade = ☐ Non-rounded grade:________

Deflection = ☐

43. Calculate and plot contours to reflect the stipulated cross slopes on sidewalk and portland cement concrete road with 6" concrete curbs.



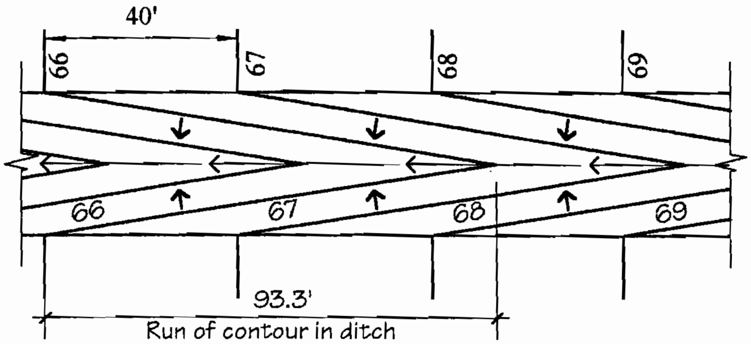
Longitudinal grade is 4.6%; cross slope of sidewalk is 1.5%; cross slope about the centerline is 4%; 6 inch concrete curbs both sides; all runoff drains to gutters at base of curbs.

Deflection at sidewalk = ☐

Deflection at centerline = ☐

Chapter Four, Group 4 Solutions — Calculating Height or Depth and Cross Slope
(Problems 35 through 43)

35. Solution — Find the depth of the ditch and plot contours.



North

Scale: 1" = 40'
Contour Interval = 1'
Plan View

Depth of ditch is 28 inches.

Grade = .025   Non-rounded grade: (.025)

Length of run = 93.3 ft.

Calculations for problem 35:

Find grade:

$D = 1 \quad L = 40$ feet between contours 66 and 67

$G = \dfrac{D}{L} = \dfrac{1}{40} = .025$ or, using the reciprocal key: Enter 40, then press $1/X = .025$

Convert 28 inches to decimal feet:

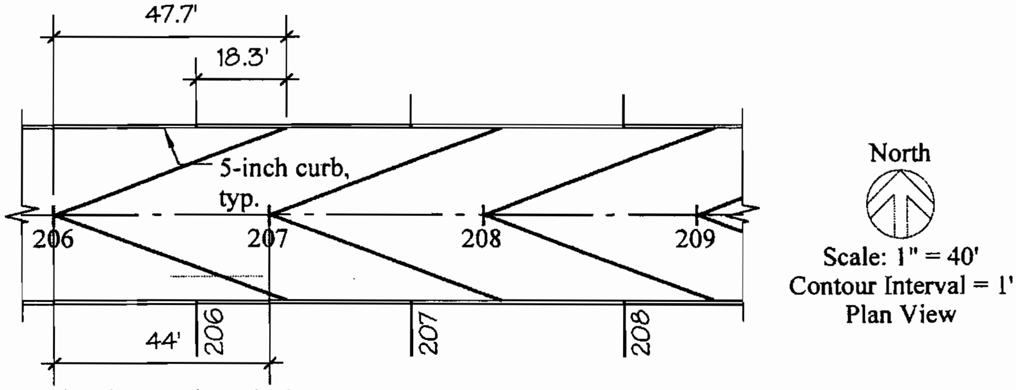
$$\frac{28 \text{ inches}}{12 \text{ inches}} = 2.3333 \text{ feet}$$

Find length of run:

$D = 2.3333 \quad G = .025$

$L = \dfrac{D}{G} = \dfrac{2.333}{.025} = 93.3333$ feet, rounds off to 93.3 feet, the length of run of contour in ditch

36. Solution — Calculate the crown of the road and plot contours for curb height indicated.



Height of crown is 13 inches.

Grade = .02 Non-rounded grade: (.022727272)

Length of crown run = 47.7 ft.

Height of curb is 5 inches

Length of curb run = 18.3 ft.

Calculations for problem 36:

Find grade:

$D = 1 \quad L = 44$ feet point-to-point between contours 206 and 207

$G = \dfrac{D}{L} = \dfrac{1}{44} = .022727272$, rounds off to .02 or, using the reciprocal key: Enter 44, then press $1/X = .022727272$

Calculate length of the run of the contours depicting the crown based on a crown height of 13-inches — Convert 13 inches to decimal feet:

$$\frac{13 \text{ inches}}{12 \text{ inches}} = 1.0833333 \text{ foot, rounds off to } 1.1 \text{ foot}$$

Calculate length of run:

$D = 1.0833333 \quad G = .022727272$

$L = \dfrac{D}{G} = \dfrac{1.08333333}{.022727272} = 47.66666818$ feet, rounds off to 46.7 feet, the length of run of the contour at the crown of the road

47.7

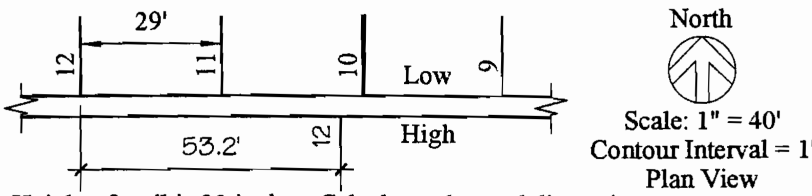
Calculate length of the run of the contour depicting the curb based on a curb height of 5-inches — Convert 5 inches to decimal feet:

$$\frac{5 \text{ inches}}{12 \text{ inches}} = .4166666 \text{ foot, rounds off to } .4 \text{ foot}$$

$D = .4166666 \quad G = .022727272$

$L = \frac{D}{G} = \frac{.416666}{.022727272} = 18.33333392$ feet, rounds off to 18.3 feet, the length of run of contour on curb face

37. Solution — Calculate the offset of contour 12 on the retaining wall.



Height of wall is 22 inches. Calculate, plot, and dimension contour 12 on the south (high) side of the wall.

Grade = .03 Non-rounded grade: (.034482758)

Length of run = 53.2 ft.

Calculations for problem 37:

Find grade:

$D = 1 \quad L = 29$ feet between contours 11 and 12

$G = \frac{D}{L} = \frac{1}{29} = .034482758$, rounds off to .03 or, using the reciprocal key: Enter 29, then press $1/X = .034482758$

Calculate length of the run of the contours on the face of the wall depicting a wall height of 22 inches —

Convert ~~13~~ 22 inches to decimal feet:

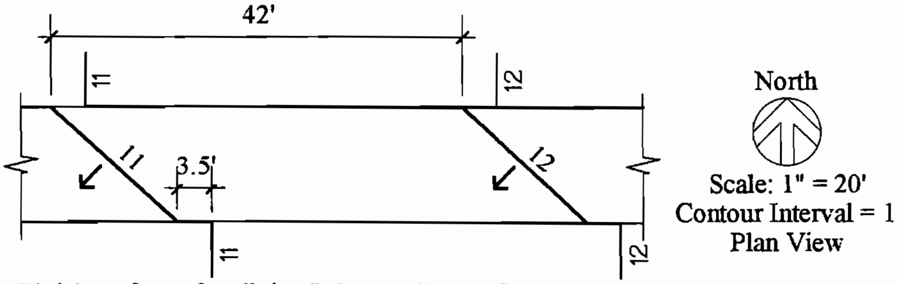
$\frac{22 \text{ inches}}{12 \text{ inches}} = 1.833333$ feet, rounds off to 1.8 feet

Calculate length of run:

$D = 1.8333333 \quad G = .034482758$

$L = \frac{D}{G} = \frac{1.83333333}{.034482758} = 53.16666667$ feet, rounds off to 53.2 feet, the length of run of the contour on the face of the wall

38. Solution — Calculate and show correct relationship of contours 11 and 12 adjacent to walk.



Finish surface of walk is 1" above adjacent finish grade.

Grade = .02 Non-rounded grade: (.023809523)

Length of run = 3.5 ft.

Calculations for problem 38:

Find grade:

$D = 1 \quad L = 42$ feet between contours 11 and 12

$G = \frac{D}{L} = \frac{1}{42} = .023809523$, rounds off to .02 or, using the reciprocal key: Enter 42, then press 1/X = .023809523

Calculate length of the run of the contours depicting a walk that is 1 inch above the adjacent non-paved surface —

Convert 1 inch to decimal feet:

$\frac{1 \text{ inch}}{12 \text{ inches}} = .0833333$ feet, rounds off to .08 feet

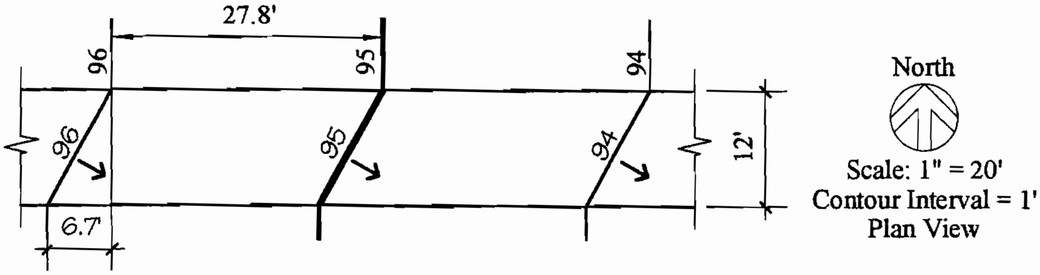
Calculate length of run:

$D = .08333333 \quad G = .023809523$

$L = \frac{D}{G} = \frac{.08333333}{.023809523} = 3.5$ feet, the length of run of the contours at the edge of the walk

Notice that the contours on the walk *deflect downhill* from those adjacent to the walk. Therefore, it can be said that the resulting contour signature imitates a stylized flat-topped ridge.

39. Solution — Calculate and plot contours to reflect the stipulated cross slope on walk.



Cross slope of walk is 2%; runoff drains to south side.

Grade = .04 Non-rounded grade: (.035971223)

Deflection = 6.7 ft.

Sample calculations for problem 39

Find the longitudinal grade of the walk:

$D = 1 \quad L = 27.8$ feet

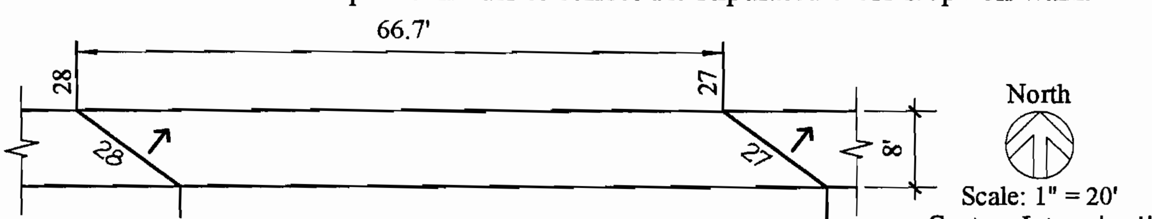
$G = \frac{D}{L} = \frac{1}{27.8} = .035971223$ or, using the reciprocal key: Enter 27.8, then press 1/X = .035971223

Calculate the cross slope on the walk and plot contours:

$CS = .02 \quad W = 12 \quad LG = .035971223$

$Df = \frac{(CS)\,(W)}{LG} = \frac{(.02)\,(12)}{.035971223} = 6.672$ feet, rounds off to 6.7 feet

40. Solution — Calculate and plot contours to reflect the stipulated cross slope on walk.



Cross slope of walk is 2%; runoff drains to north side.

Grade = .02 Non-rounded grade: (.014992503)

Deflection = 10.7 ft.

Sample calculations for problem 40

Find the longitudinal grade of the walk:

$D = 1 \quad L = 66.7$ feet

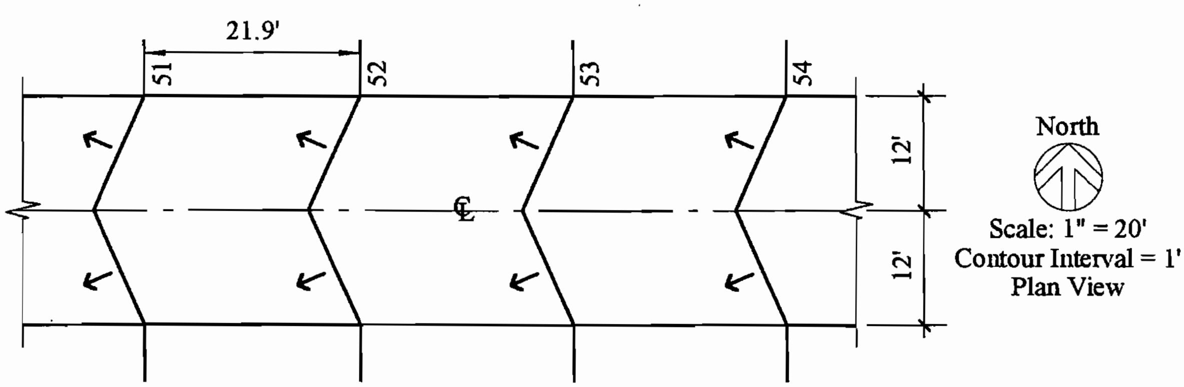
$$G = \frac{D}{L} = \frac{1}{66.7} = .014992503\text{, rounds off to .02}$$

Calculate the cross slope on the walk and plot contours:

$CS = .02 \quad W = 8 \quad LG = .014992503$

$$Df = \frac{(CS)\ (W)}{LG} = \frac{(.02)\,(8)}{.014992503} = 10.672\text{ feet, rounds off to 10.7 feet}$$

41. Solution — Calculate and plot contours to reflect the stipulated cross slope on road.



Cross slope about the center line is 2%; runoff drains to shoulders.

Grade = .05 Non-rounded grade: (.0456621)

Deflection at centerline = 5.3 ft.

Sample calculations for problem 41

Find the longitudinal grade of the walk:

$D = 1 \quad L = 21.9\text{ feet}$

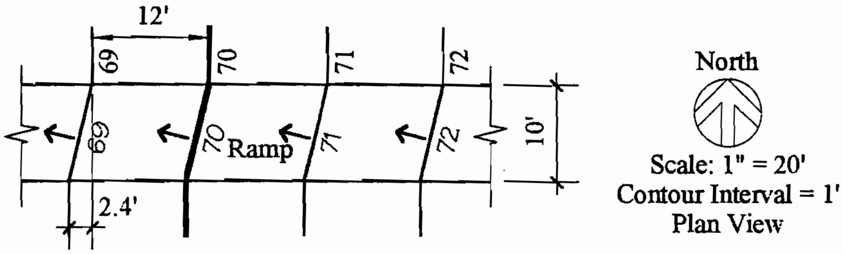
$$G = \frac{D}{L} = \frac{1}{21.9} = .0456621\text{, rounds off to .05}$$

Calculate the cross slope on the walk and plot contours:

$CS = .02 \quad W = 12 \quad LG = .0456621$

$$Df = \frac{(CS)\ (W)}{LG} = \frac{(.02)\,(12)}{.0456621} = 5.256\text{ feet, rounds off to 5.3 feet}$$

42. Solution — Calculate and plot contours to reflect the stipulated cross slope on ramp.



Cross slope of ramp is 2%; runoff drains to north side.

Grade = .08 Non-rounded grade: (.08333333)

Deflection = 2.4 ft.

Sample calculations for problem 41

Find the longitudinal grade of the walk:

$$D = 1 \quad L = 12 \text{ feet}$$

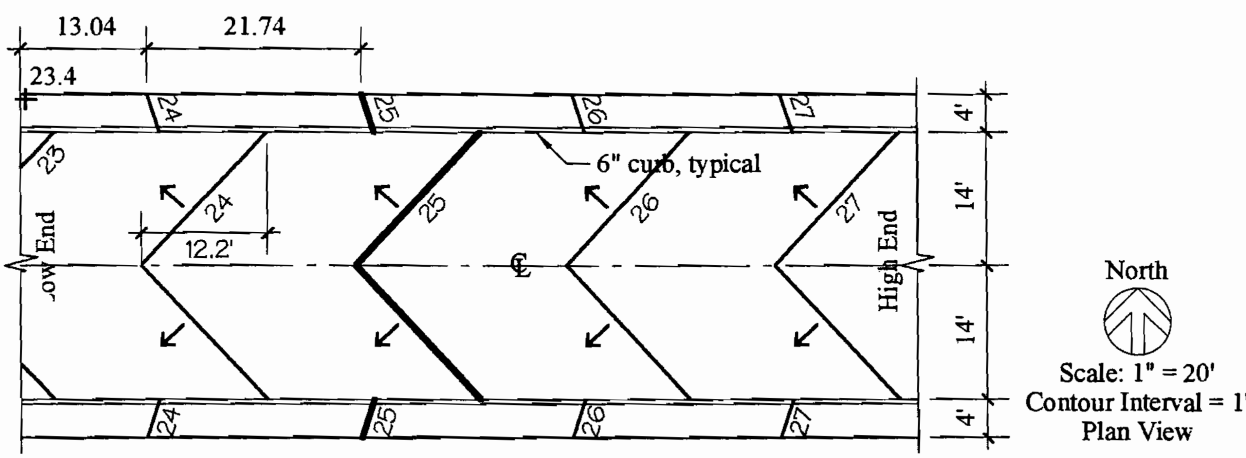
$$G = \frac{D}{L} = \frac{1}{12} = .083333333, \text{ rounds off to } .08$$

Calculate the cross slope on the walk and plot contours:

$$CS = .02 \quad W = 10 \quad LG = .083333333$$

$$Df = \frac{(CS)\,(W)}{LG} = \frac{(.02)\,(10)}{.083333333} = 2.4 \text{ feet}$$

43. Solution — Calculate and plot contours to reflect the stipulated cross slopes on sidewalk and road with 6" concrete curbs.



Longitudinal grade is 4.6%; cross slope of sidewalk is 1.5%; cross slope about the centerline is 4%; 6 inch concrete curbs both sides; all runoff drains to gutters at base of curbs.

Deflection at sidewalk = 1.3 ft.

Deflection at centerline = 12.2 ft.

Problem 43 demonstrates a gambit often used on the exam: only one spot elevation has been provided. To solve problems of this type, *always begin at the point of known elevation.* It is also helpful to make a quick schematic sketch to help understand how the contours will be plotted on both sidewalk and road surface. Here is the recommended order of work with the sample calculations:

Step 1. Note elevation 23.4 at the northwest corner of the road and sidewalk plan. Plot the points along the north edge of the sidewalk where the contours cross.

Length to 1st contour *from low end:*

Having the point of known elevation at the *low end* of the plane surface makes this problem even more challenging because, unlike working from the high end, you must *subtract* to determine the difference in elevation between the known elevation and the next higher contour line. Find difference in elevation between 23.4 and contour 24:

$$D = 24 - 23.4 = .6$$

Find length to 1st contour:

$$L = \frac{D}{G} = \frac{.6}{.046} = 13.04347826 \text{ feet, rounds off to 13 feet}$$

Find length between remaining contours:

$$L = \frac{D}{G} = \frac{1}{.046} = 21.73913043 \text{ feet, rounds off to 21.7 feet}$$

This completes the plot of whole number contours on the north edge of the sidewalk. The next step will be to calculate the contour deflections for the required cross slope on the sidewalk and the road.

Step 2. Calculate the cross slope on the sidewalk and plot the contours.

$$Df = \frac{(CS)(W)}{LG} = \frac{(.015)(4)}{.046} = 1.3 \text{ feet}$$

Step 3. Find points along face of curb where contours on road will meet curb.

Step 4. Calculate the cross slope for the road (be sure to use the half-width of the road — 14 feet — for the cross slope calculation).

$$Df = \frac{(CS)(W)}{LG} = \frac{(.04)(14)}{.046} = 12.17391304 \text{ feet, rounds off to 12.2 feet}$$

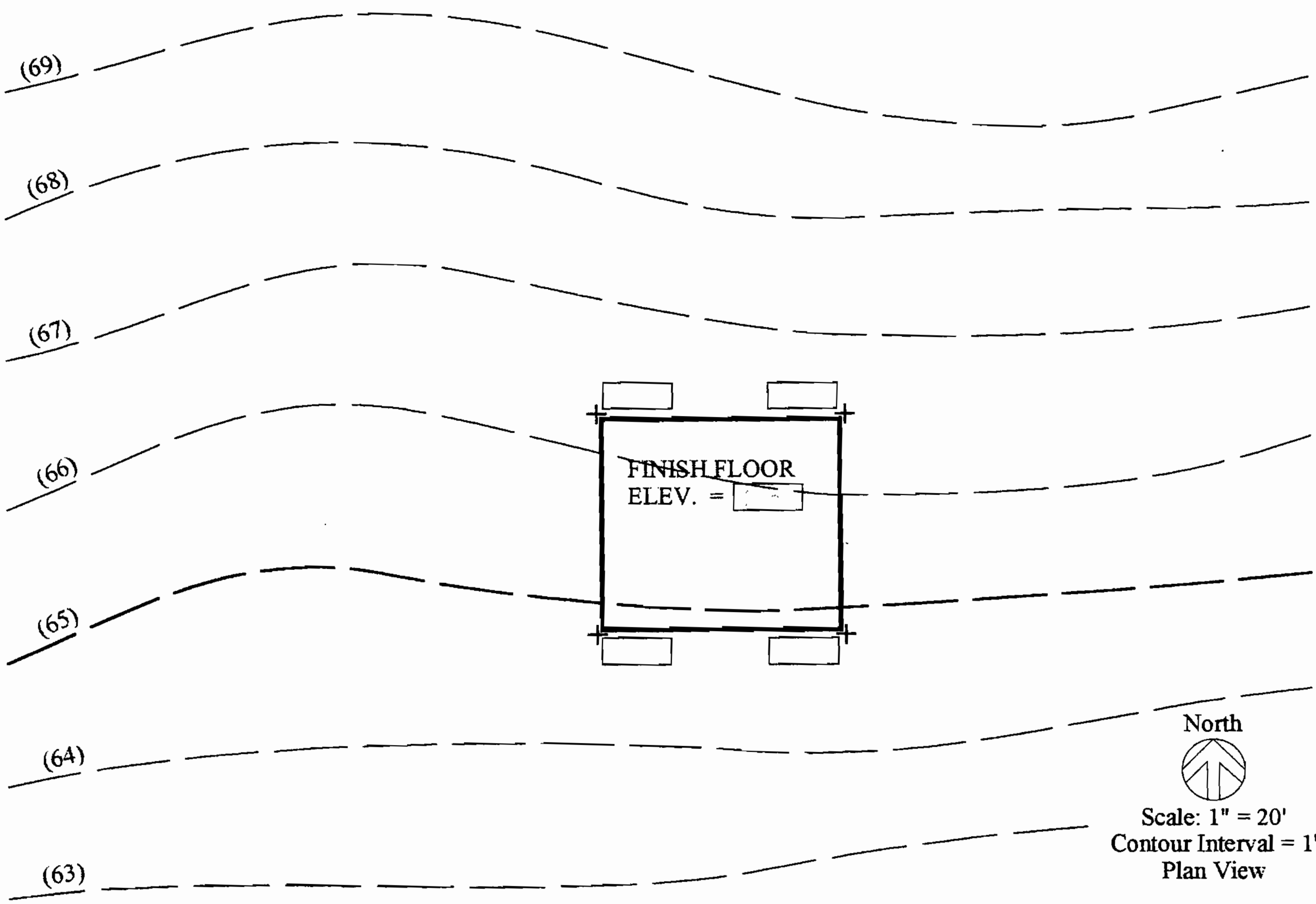
Step 5. Plot the remaining contours and number all. Add flow arrows.

Chapter Four, Group 4 Problems — Designing Horseshoe Swales (Problems 44 through 48)

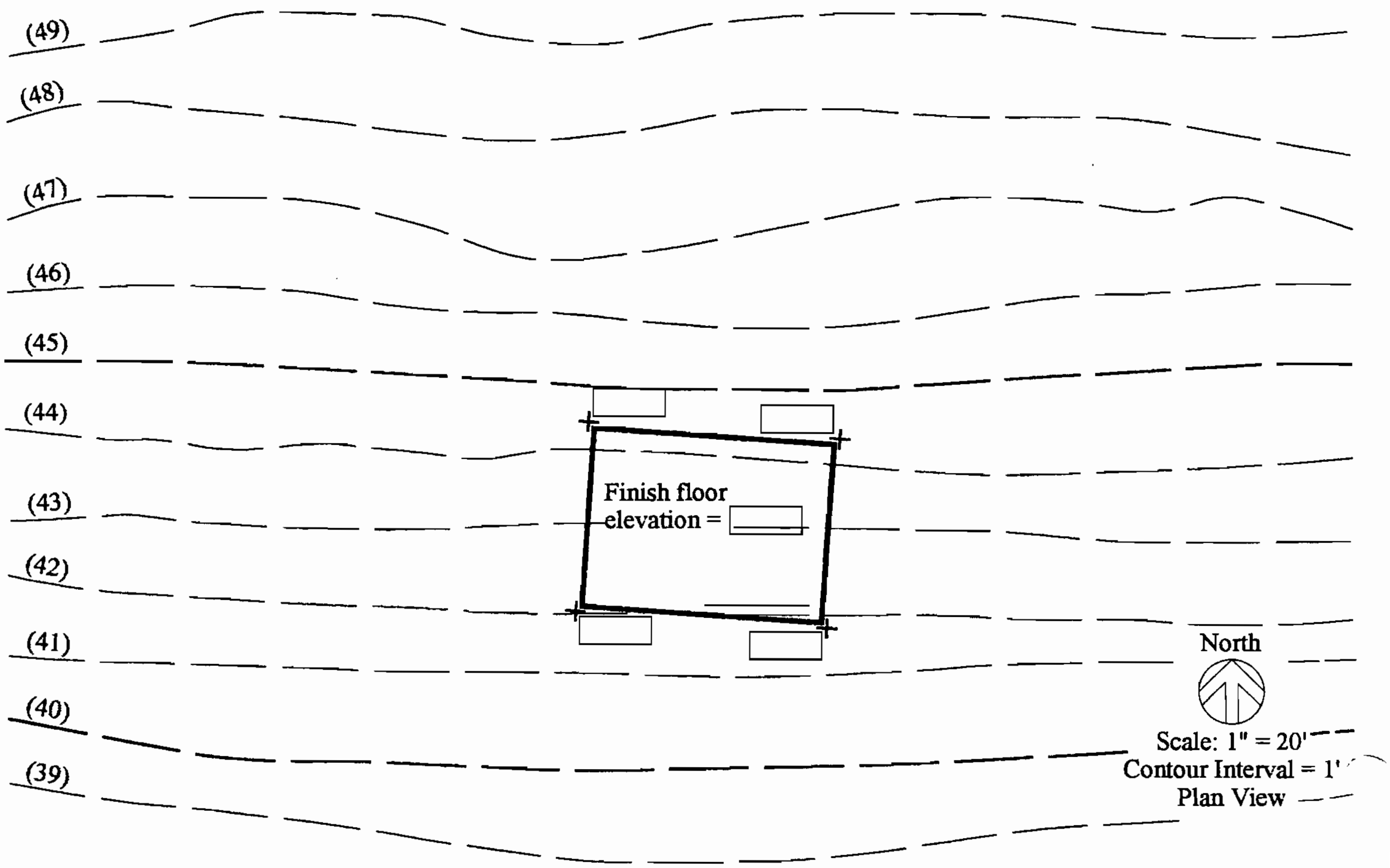
The following problems require the design of horseshoe swales of various types to protect a site feature from runoff. The five horseshoe swale problems in this group share the following requirements:

- Maximum slope shall be 5:1
- Minimum flowline grade shall be 2% (50 feet or less between contours)
- Maximum flowline grade shall be 10% (10 feet or more between contours)
- Where a building is to be protected (level pad), the building slab shall be a standard CLARB style slab
- In the case of a sloping pad, it shall be at grade (there are no curbs or other break in grade)
- Show grades to the nearest tenth or hundredth, as appropriate, to adequately convey solution

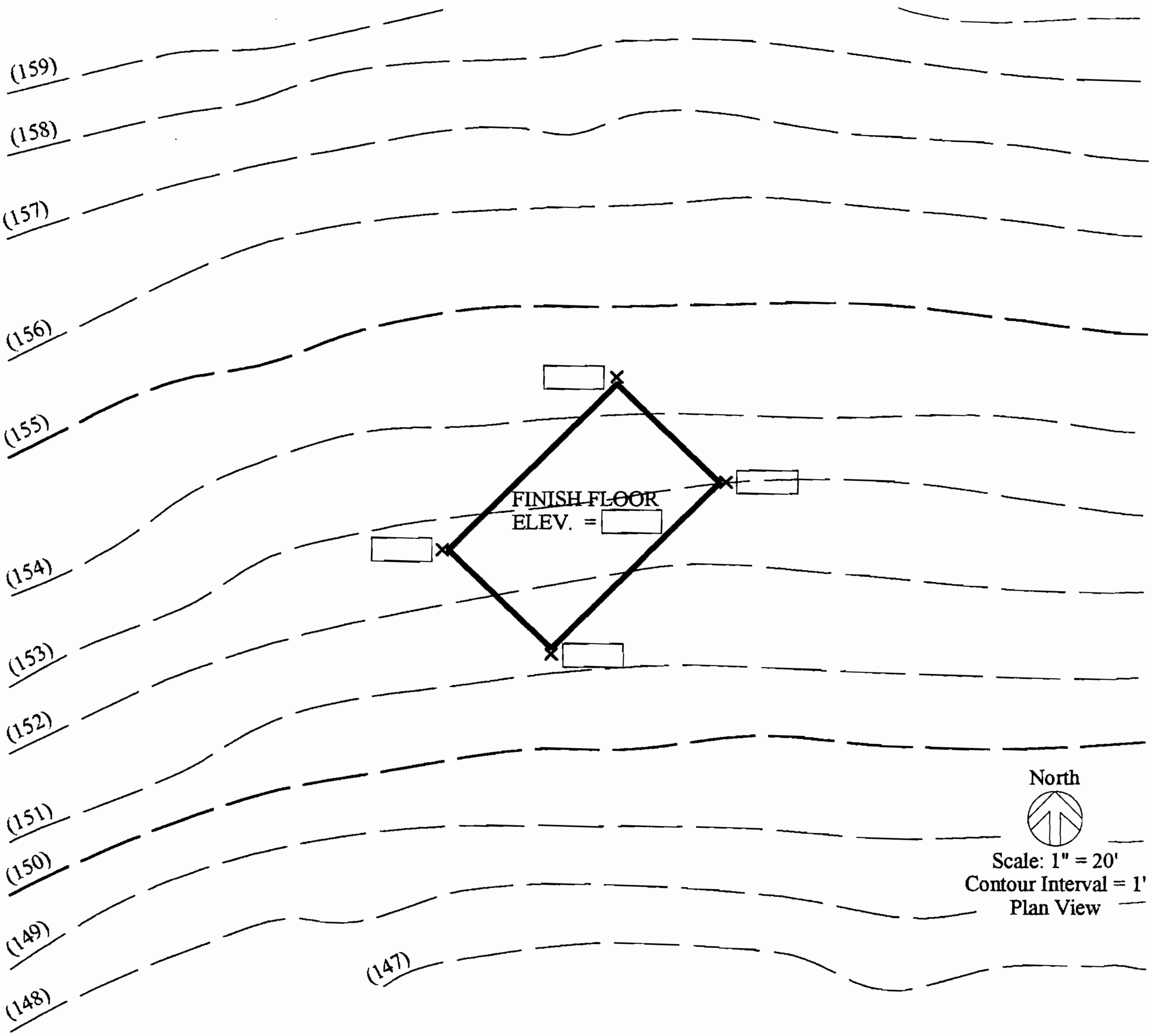
44. Design horseshoe swale to protect level building slab.



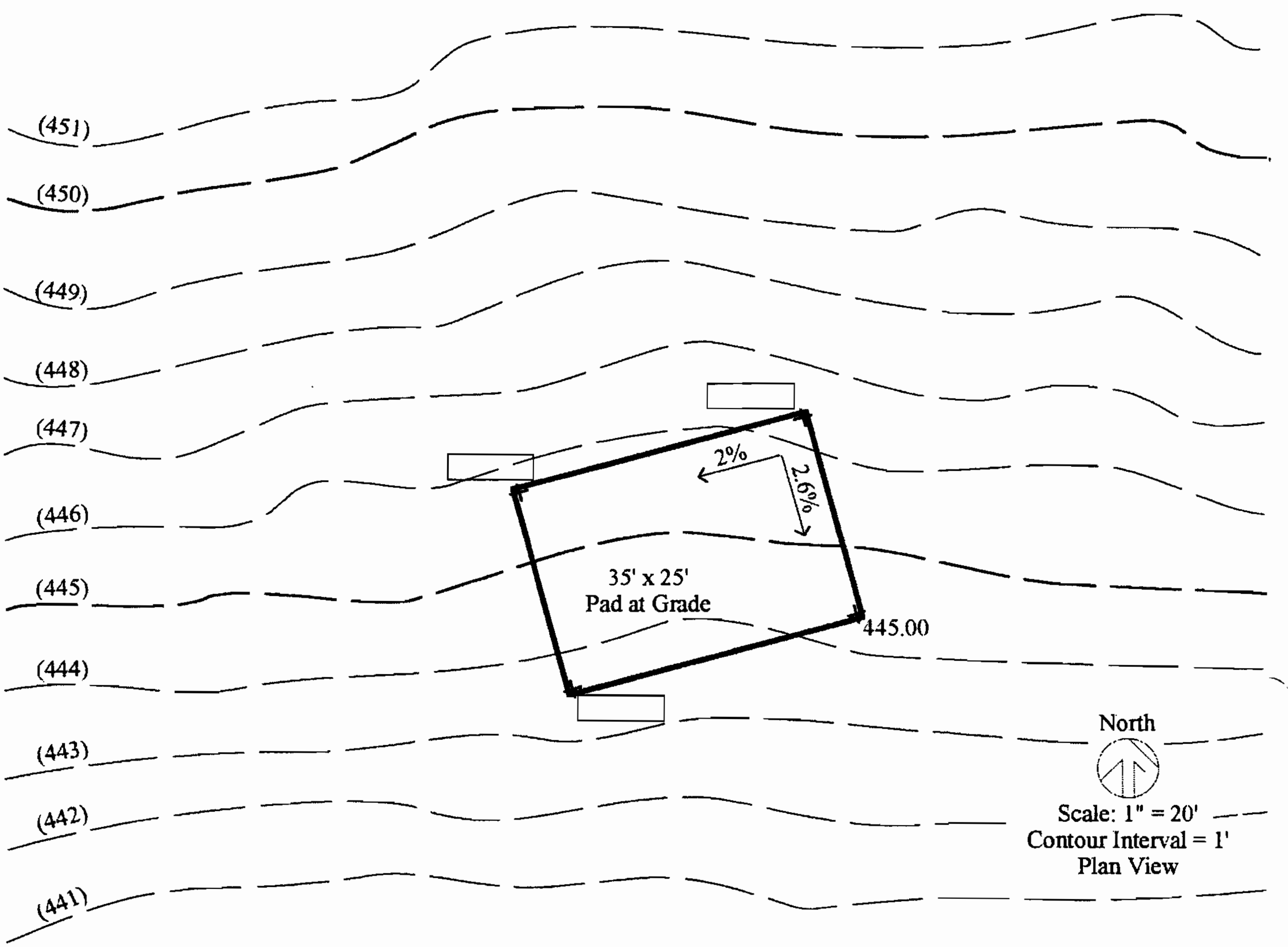
45. Design horseshoe swale to protect level building slab.



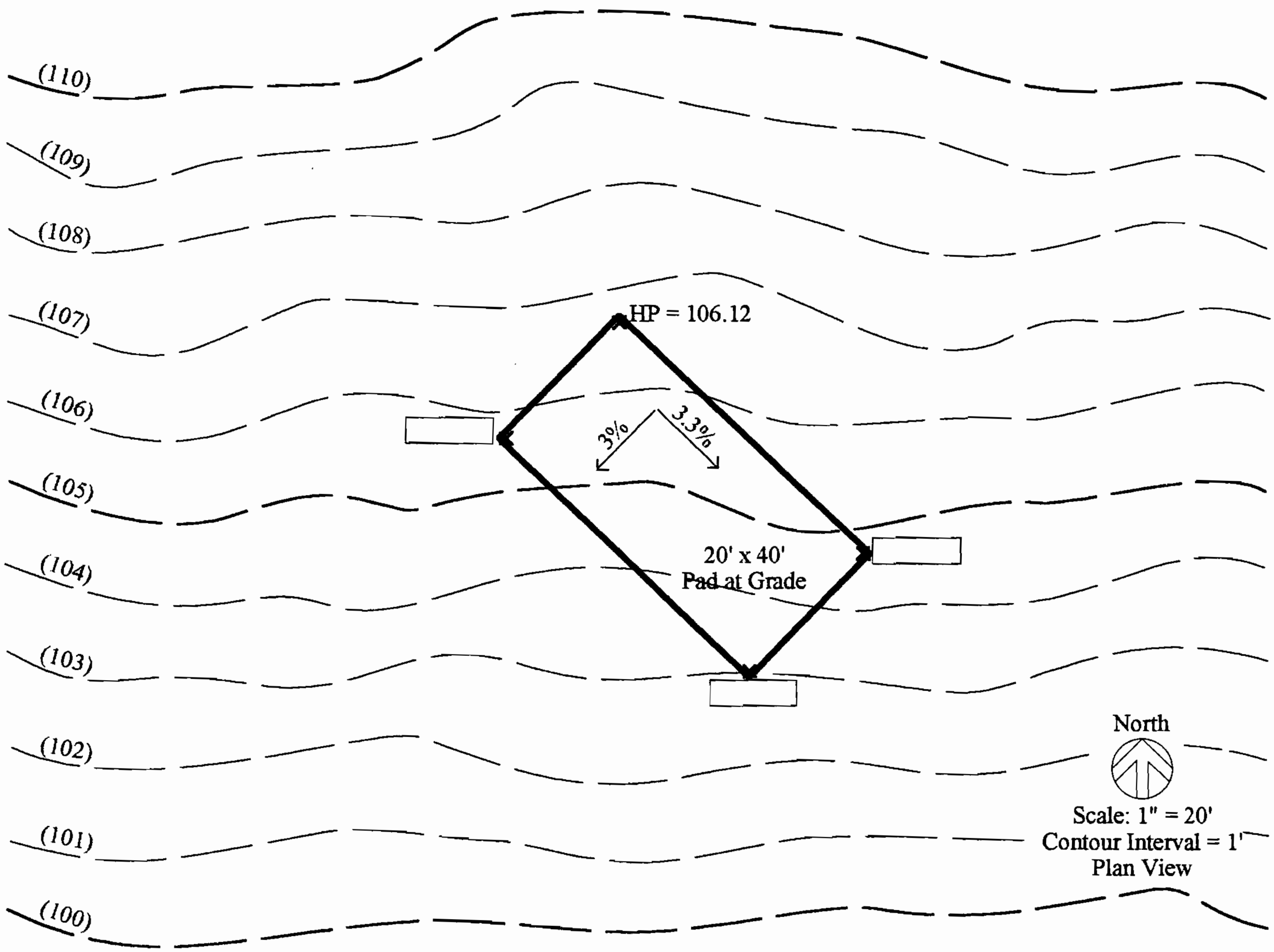
46. Design horseshoe swale to protect level building slab.



47. Design horseshoe swale to protect sloping pad.



48. Design horseshoe swale to protect sloping pad.

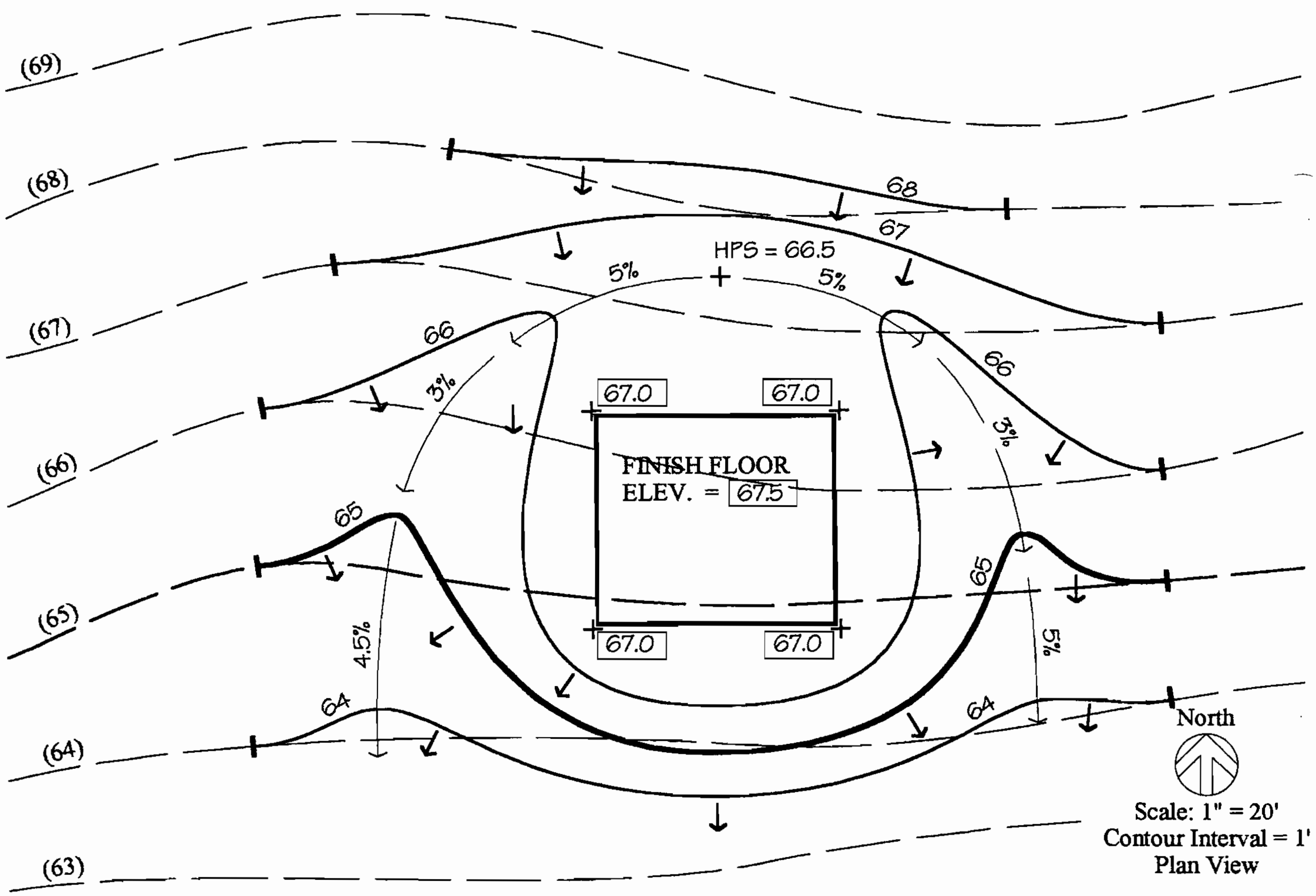


Chapter 4, Group 4 Solutions — Designing Horseshoe Swales (Problems 44 through 48)

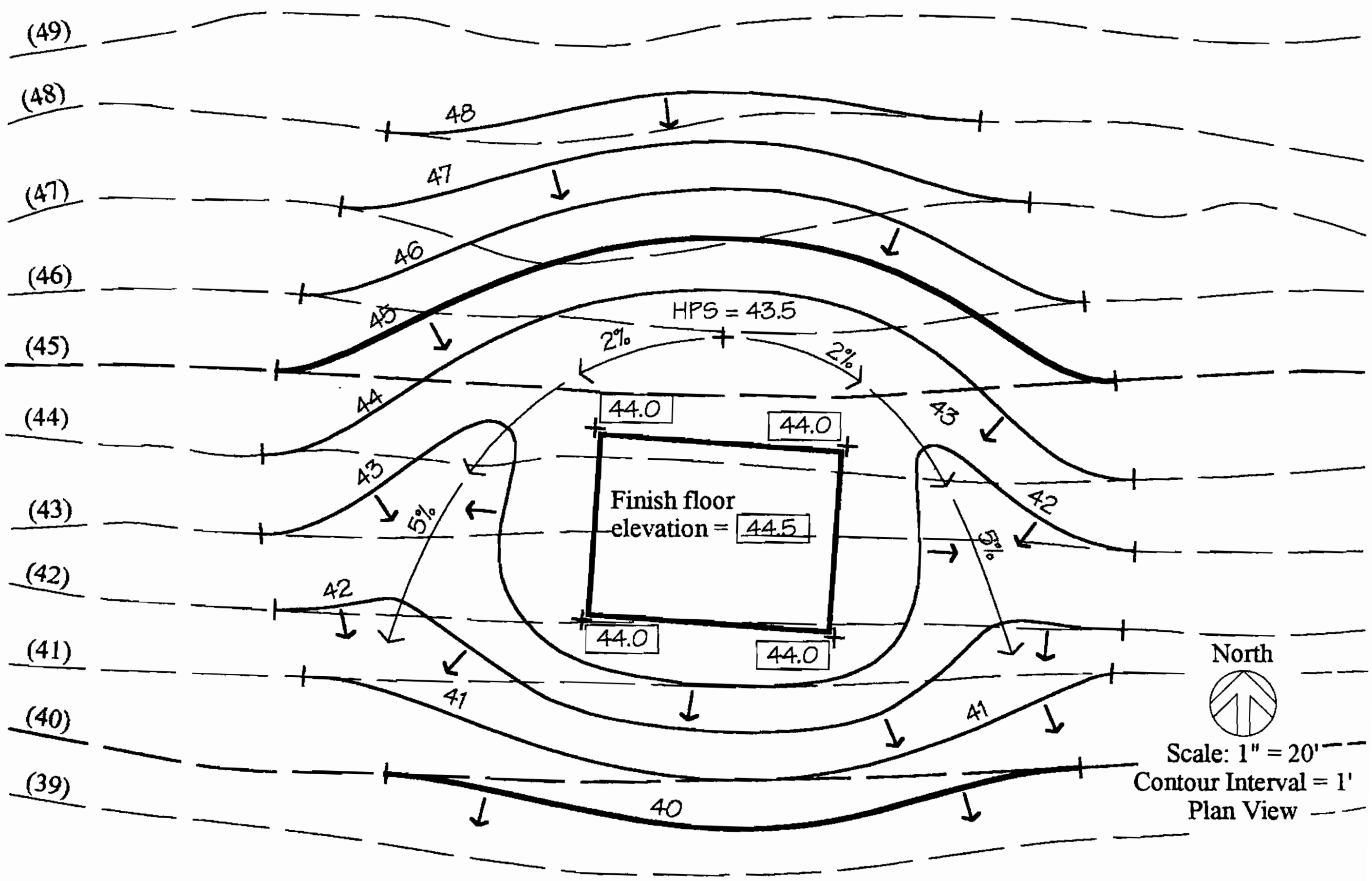
A note about the solutions: Each solution represents one of an infinite variety of possible correct solutions. There will always be qualitative differences between various solutions, and therefore ways any design can be improved. The following solutions may, or may not, be optimum. In an office practice setting, you may have the luxury of spending whatever time it takes to fine-tune and tweak contours until the law of diminishing returns dictates it's time to "put it to bed." This luxury of time doesn't exist in the world of the LARE where the only goal is to produce a correct solution as quickly as possible. If there is any one qualitative goal you need to strive for, it is economy and efficiency — that is, a solution that disturbs as little of the site as possible while fulfilling the requirements of the problem.

The flowline grades and flow arrows shown on the solution below are optional. They are provided here and on the solutions that follow for informational purposes. Flow arrows can be helpful to the examinee as a check to confirm that runoff is being directed as intended.

44. Solution — Design horseshoe swale to protect level building slab.

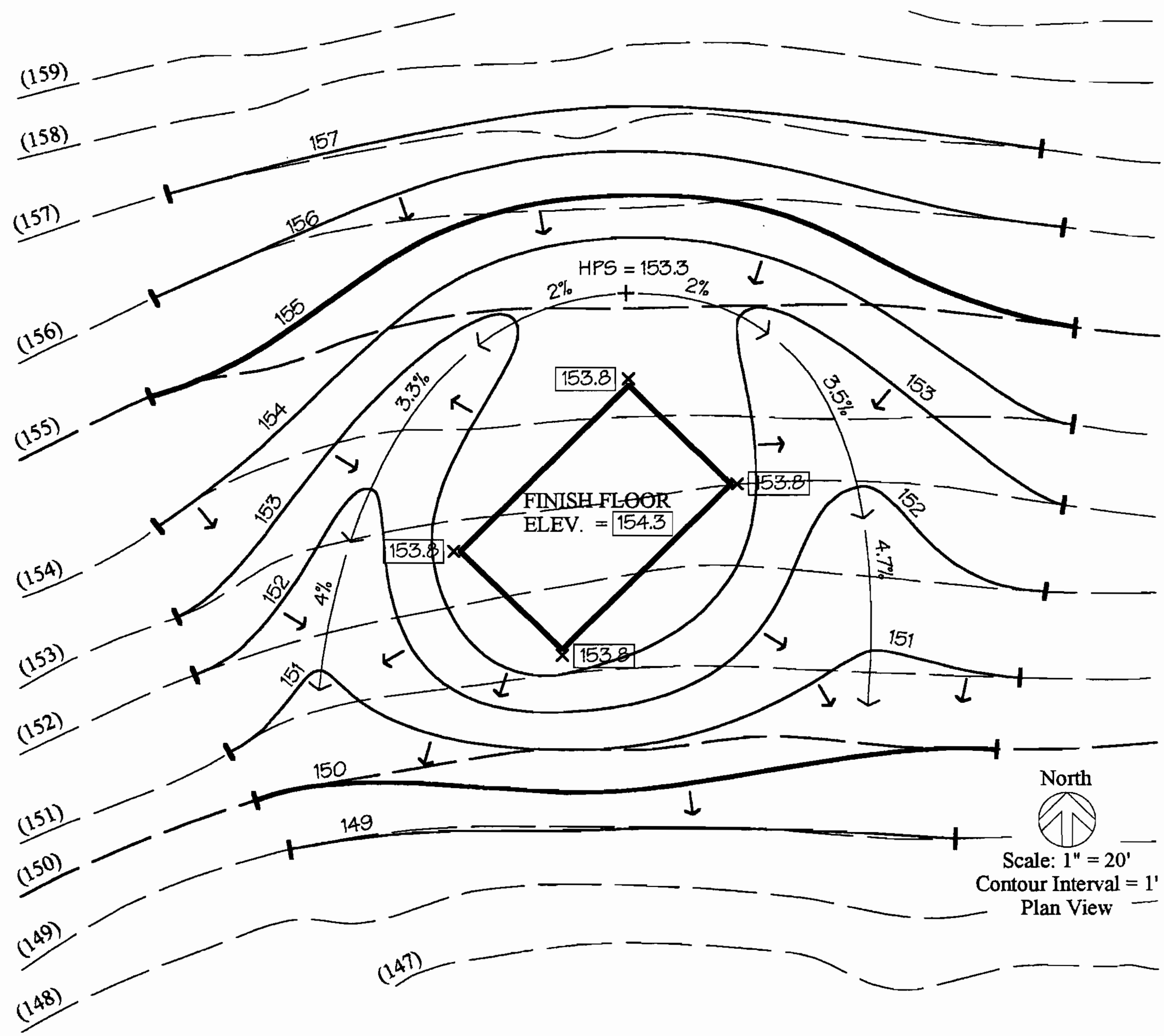


45. Solution — Design horseshoe swale to protect level building slab.

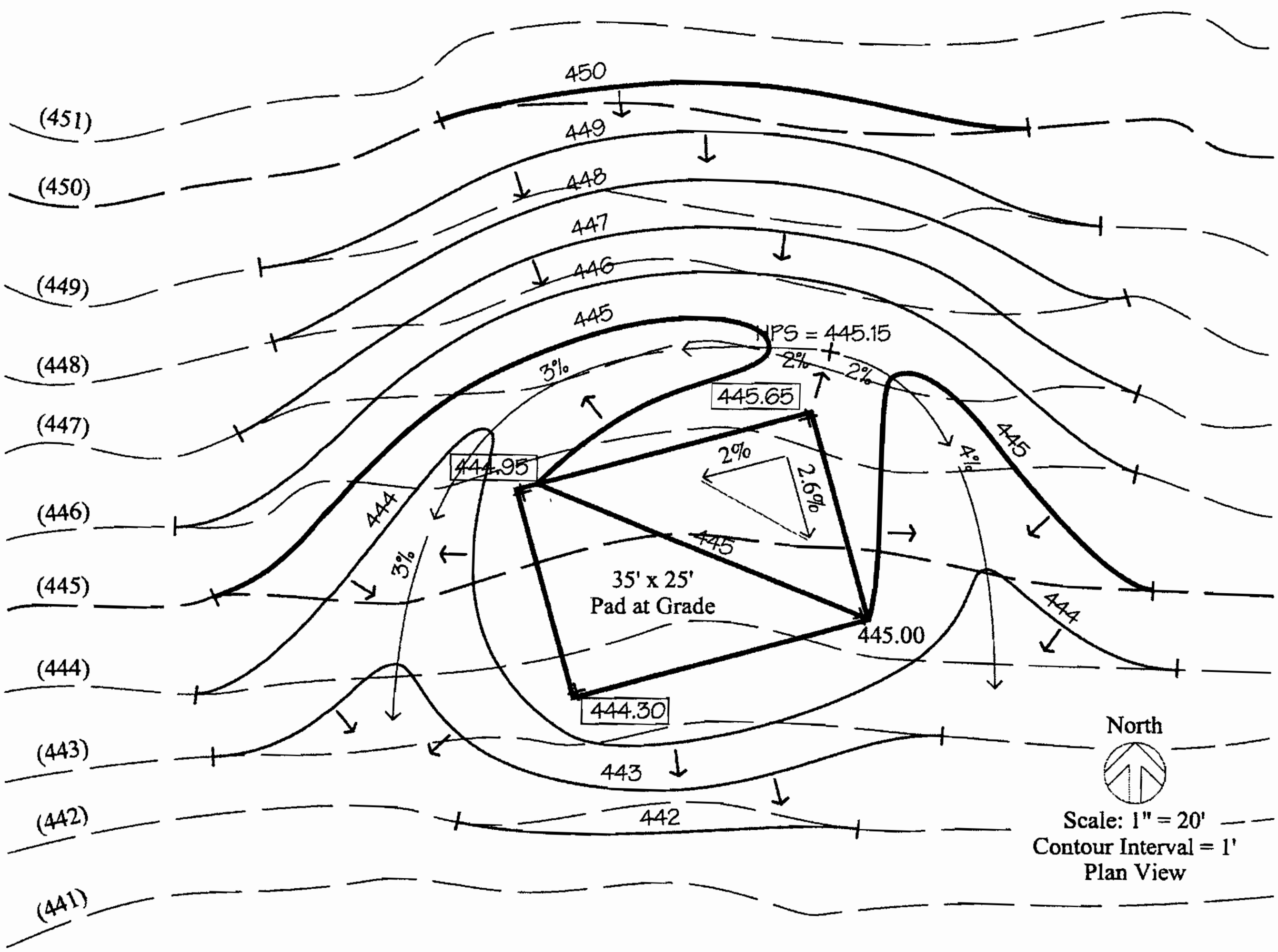


Notice on this solution that the point where the first whole number contour line below the high point swale crosses the flowline (contour line 42) could have been placed somewhat closer to the high point swale, and that so doing would have improved the 'graphic appearance' of the swale while making the flowline steeper. From an exam standpoint, the graphic appearance of having a well-defined swale is a positive quality. Here, the area at the north of the building appears to be flat, although it really isn't. Placing the flowline grades on the flowline communicates to the exam scorers the fact that an acceptable 6-inch deep swale has been developed. From a functional standpoint, this solution works well because positive drainage is provided while maintaining a flatter, more useable space at the north side of the building, while the steeper portions of the swale are farther removed. As will be seen on several of the solutions that follow, it isn't always possible to keep the flowline grade as flat as 2% because of the graphic appearance issue.

46. Solution — Design horseshoe swale to protect level building slab.



47. Solution — Design horseshoe swale to protect sloping pad.



The first step is to plot whole number contour line 445 on the pad. Once that has been done, the next step is to draw the flowline, followed by determining the point of attack. Next, the location of the high point swale is established. Subtracting .5 from the elevation at the northeast corner of the pad determines the high point swale elevation.

$$445.65 - .5 = 445.15$$

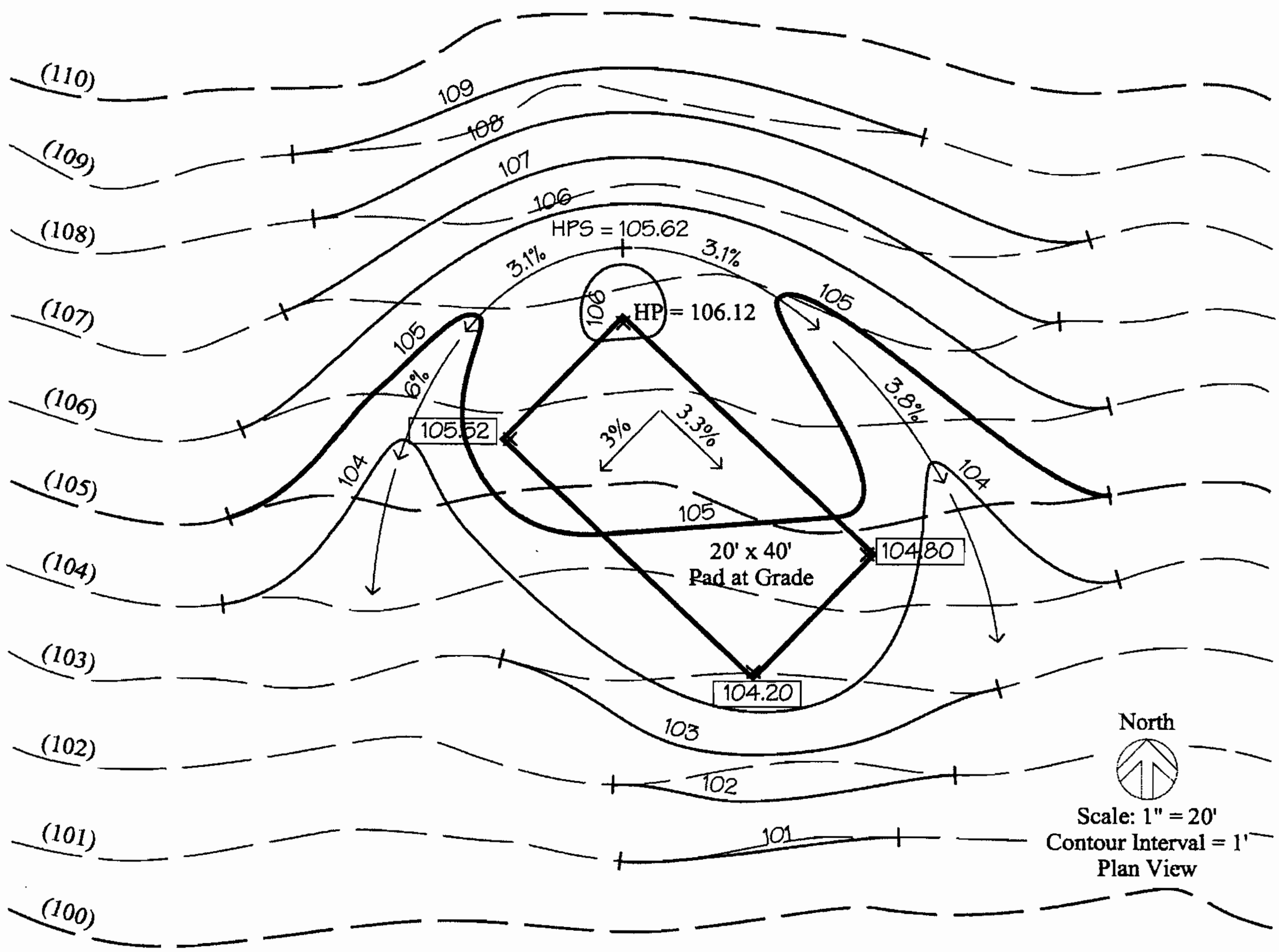
Now find the length to contour 445, which is the first contour below the high point swale based on a flowline grade of 2%.

$$D = .15 \quad G = .02$$

$$L = \frac{D}{G} = \frac{.15}{.02} = 7.5 \text{ feet}$$

There is an advantage to calculating the length based on a 2% flowline grade by default: doing so insures that the minimum requirement has been met. Of course, contour 445 could be moved closer to the high point swale, thus creating a slope greater than 2%, but it could not be moved further away without raising the high point swale, which would have the consequence of a swale that is not at least 6 inches deep.

48. Solution — Design horseshoe swale to protect sloping pad.



This problem features a key difference from the previous swale problems and solutions. Note that the corner elevation is 106.12, which is only slightly higher than contour 106. Therefore, contour 106 must cross the corner of the pad and *close on itself* as shown in the solution. Drawing a section through this portion of the solution would reveal that contour line 106 appears in *three* places; first on the plane surface, second in the area between the north corner of the plane surface and the high point swale, and third at the backslope of the swale just north of the high point swale. This is often the case when working with sloping plane surfaces where the highest corner elevation is just below the next higher whole number contour line.

As the cliché says, practice make perfect. This is certainly true in the design of horseshoe swales, or any other swale configuration for that matter. As you continue to design swales, you'll find they become increasingly easier and that the process will become more intuitive and natural.

Chapter 5:
Drainage Basics And Exercises

Chapter 5 is all about drainage and stormwater management. It focuses on those aspects of the subject that you're likely to be tested for knowledge of in Section E of the LARE

What you'll learn: This chapter begins with a review of the aspects of hydraulic theory that are relevant to Section E. It then goes on to look at setting invert elevations, calculating cover over drainlines, and the design of headwalls and endwalls.

SECTION E AND HYDRAULIC THEORY

Section E does not require an extensive understanding of hydraulic theory, but you'll benefit from at least a rudimentary knowledge of fluid behavior. Those who plan to sit for Section B will want to delve more deeply into hydraulic theory, and those who plan to sit for Section D will want to review the Rational Method.

THE VERNACULAR OF DRAINAGE DESIGN

Drainage design has its own unique vocabulary of terms that are used in connection with the design of drainage systems. Some drainage terms are synonymous and are used interchangeably. Some terms are used to describe what may appear to be the same thing, for example, drain inlet and catch basin appear to be used interchangeably. Are they different, and if so, how? All of this can lead to confusion. Here are some of the more common terms, with brief definitions.

Drainage Structure: Any of a number of physical structures that are interconnected by pipes to comprise a drainage system. This includes manholes and a wide variety of drain inlets (see below).

Drain Inlet: Any structure that collects surface runoff and directs it into a drainline. There are many possible variations on the basic concept of a drain inlet, such as area drain, atrium drain, curb inlet, combined curb and grate inlet, drop inlet, manhole grate inlet, and so on. On the LARE, drain inlets tend to be placed within paved areas where the accumulation of debris is less than it would be on a non-paved surface.

Catch Basin: A drain inlet that has provision for catching and retaining sediment and debris to keep it from entering a drainage system. Catch basins require periodic maintenance to remove collected sediment. On the LARE, catch basins tend to be placed in non-paved areas.

Drop Inlet: Any drain inlet that connects directly to a drainline that does not have provision for collecting sediment.

Area Drain: A small-scale drop inlet that connects directly to a drainline that does not have provision for collecting sediment.

Pipe: The root term for any conduit that conducts water from one place to another. Other terms that are used more or less interchangeably are: storm drain, storm sewer, and drainline. On the exam, the term pipe is the most commonly used term, and the most common pipe material is concrete.

Slope: The terms grade and slope are used interchangeably. Slope is the preferred term in the context of drainage systems. In calling out the slope of a drainline, look for the letter 'S' to denote slope.

Pipe diameter: Diameter of a pipe. Figure 5-1 shows the width of a pipe, which is its diameter.

Rim Elevation: The elevation at the top of a drainage structure is referred to as the Rim Elevation (usually abbreviated Rim El. on the LARE), or Top of Catch Basin (abbreviated T.C.B., or C.B. El.).

Invert Elevation: The term invert elevation refers to the bottom-most point inside a pipe or the lowest point in an open channel. (See Figure 5-2a.) It is usually abbreviated Inv. El. on the LARE. If an elevation is noted or required at the point where stormwater *enters* a drainage structure, it will be noted as Inv. In (as in invert elevation in). At the point where the stormwater *exits* the drainage structure, it will be noted as Inv. Out (as in invert elevation out). Reference may also be made on the plan to a Manhole (abbreviated M.H.), which will also have an invert elevation in and an invert elevation out.

Identification of Pipes: Pipes are customarily identified with capital letters, as in Pipe A, Pipe B, and so on. Generally, labels identifying a given pipe are centered over or under the pipe. Besides the label, CLARB almost always gives the pipe's length from point-to-point in lineal feet. For example: "Pipe B — 150 LF". For existing pipes, the size is usually given as well.

STORMWATER MANAGEMENT AND SECTION E OF THE LARE

For Section E, the amount of hydraulic design knowledge needed is minimal. The chief "hydraulic" concern is compensating for head loss within a drainage structure — in other words, negating the loss of velocity that results from turbulence within a drainage structure. This negation is achieved by *setting the invert elevation out of a structure some amount lower than the invert elevation in,* which has the effect of re-accelerating the flow of water out of the structure, thereby canceling out for the potential head loss. Although the information presented below is a gross simplification of far more complex calculations that would customarily be performed to design a high performance drainage system, what is presented is appropriate for the exam.

ACCURACY AND ROUNDING OFF IN DRAINAGE PROBLEMS

The degree of accuracy required for drainage problems is generally greater than for other grading problems because the level of precision in a drainage system is greater than for other aspects of landscape construction, such as paving. As pointed out in the first chapter, drainlines may be laid with a slope of as little as one-half of one percent (0.005), which is the slope expressed to the nearest 1/1000th. (Note that when the slope is less than 1%, it must be expressed to the nearest 1/1000th.)

Figures 5-1 and 5-2 illustrate the hydraulic properties of a circular pipe in cross section and longitudinal section views:

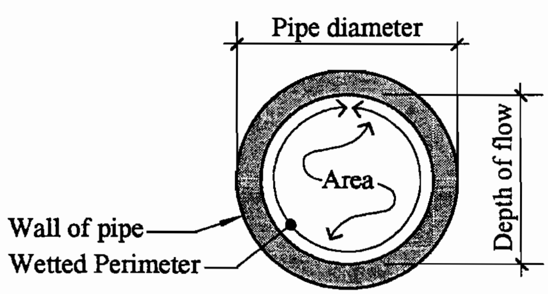


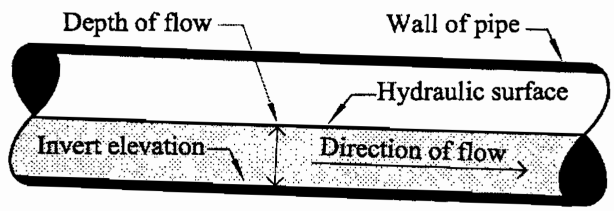
Figure 5-1. Cross-section of Circular Pipe Designed to Flow Full

Area: The cross-sectional area of a pipe, which, depending on slope, determines the theoretical flow capacity of the pipe.

Wetted perimeter: That portion of the inside circumference of the pipe that comes in contact with stormwater as shown in Figure 5-1.

Depth of flow: Depth of the water in the pipe; the depth vertically between the water surface and invert elevation of the pipe as shown in Figures 5-1 and 5-2.

Hydraulic surface: Surface of the stormwater under steady-state flow conditions where there is nothing present to disturb the movement of the water, as shown in Figures 5-2a and 5-2b.



Longitudinal Section of Pipe Flowing Half-Full

Figure 5-2a. Hydraulic Surface

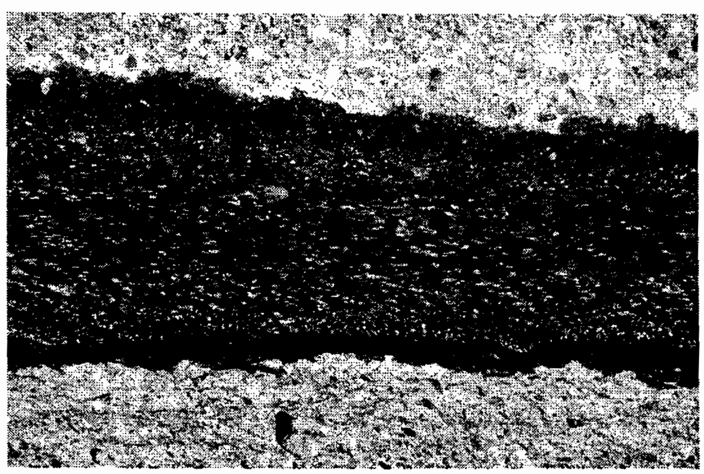
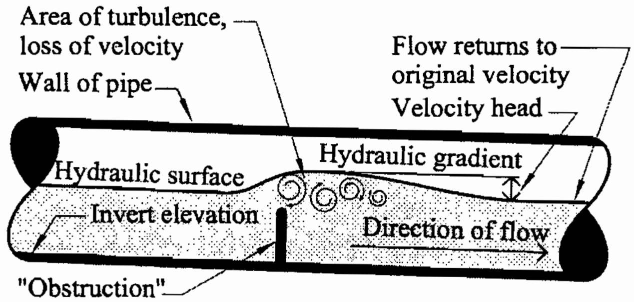


Figure 5-2 b. Photograph showing Hydraulic Surface—
Water Running in Concrete Channel at a Constant Velocity

Hydraulic gradient: Surface of the water under flow conditions where something has caused turbulence within the pipe or channel. Although the example shown in Figure 5-3a is extreme, it demonstrates what happens when an obstruction is placed into the path of flow. Figures 5-3b and 5-3c are actual photographs taken of an open concrete channel that demonstrate hydraulic gradient. In Figure 5-3b, rebar has become exposed in the bottom of the concrete channel, which has disrupted the flow of water. Since stormwater cannot be compressed, the mean velocity of the stormwater is reduced, which in turn causes the water level to rise in the pipe. This elevated level is referred to as hydraulic gradient. The effect of this loss of velocity is clearly visible in Figure 5-3c.



Longitudinal Section of Pipe Flowing Half-Full

Figure 5-3a. Hydraulic Gradient

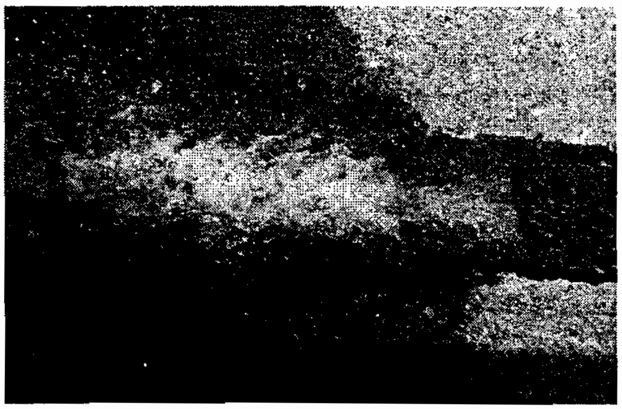


Figure 5-3b. Hydraulic Gradient — Close Up of Exposed Rebar in Channel Disrupting Flow (flow from right to left)

Figure 5-3c. Hydraulic Gradient — Shot shows Loss of Velocity (flow from right to left)

Velocity: Velocity is the mean velocity across the entire cross-section of a pipe. Figure 5-4 shows a *hypothetical* velocity-measuring device that demonstrates that the velocity of flow varies across the cross-section of the pipe.

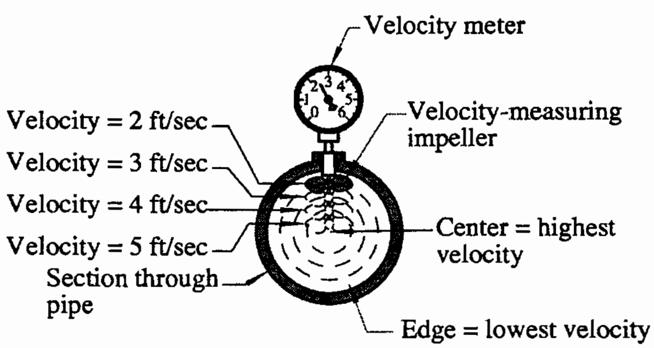


Figure 5-4. Hypothetical Velocity Measuring Device

Notice that the velocity is greatest in the center of the pipe, lowest at the edges, where resistance caused by friction imposed by the wall of the pipe acts to slow the flow. These differences in velocity occur because water, like all fluids, has poor resistance to shear. The sum of the velocities in aggregate across the section is referred to as *mean velocity,* and is expressed in cubic feet per second (cs/f). In order to calculate an approximation of mean velocity, a formula known as Manning's formula is used. Although an in-depth discussion of this formula is beyond the scope of this book, you should be aware of its existence and the role it plays. (For those familiar with irrigation design, Manning's formula is also used to create the friction loss tables used for sizing irrigation pipes.)

Velocity head: The gravitational acceleration of stormwater in the pipe. It is the net difference between the hydraulic surface and the hydraulic gradient as shown in Figure 5-3. Notice here that an obstruction has been placed within the flow pattern to demonstrate hydraulic gradient and the effect loss of velocity has on flow.

Invert elevation: The lowest point on the inside of a pipe, or the bottom-most point in a channel, as shown in Figure 5-5.

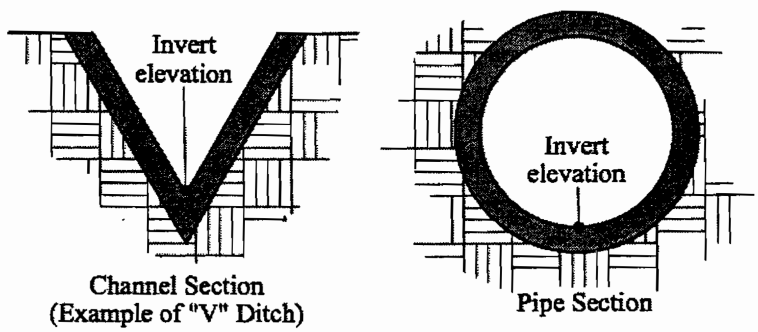


Figure 5-5. Invert Elevation of Pipe and Channels

BASIC PRINCIPLES OF DRAINAGE

Because stormwater management deals mostly with the flow of stormwater through pipes (as opposed to open channels), pipes are the focus of the following discussion. Knowledge of hydraulic properties of ditches, swales and other open channel sections have not been tested in Section E.

Compensating for Head Loss: Figures 5-6 and 5-7 show the two typical drain inlet conditions that are likely to be encountered on the exam.

Condition 1 — Same Size Pipe In and Out: The drain inlet shown in Figure 5-6 has a 12-inch drain-line going into and coming out of the drainage structure.

Rule for Condition 1, same pipe in and out: Lower the invert elevation out by 1-inch, or .083 (which may be rounded off to simply 0.08). **CAUTION**: One of the most common errors examinees make in doing head loss calculations is to subtract *point eight* (0.8) from the diameter of the pipe going into the drainage structure rather than the correct point *zero* eight (0.08). In the example shown in Figure 5-6, 0.08 is subtracted from the Invert Elevation In of 97 yielding an invert elevation out of 96.92. *

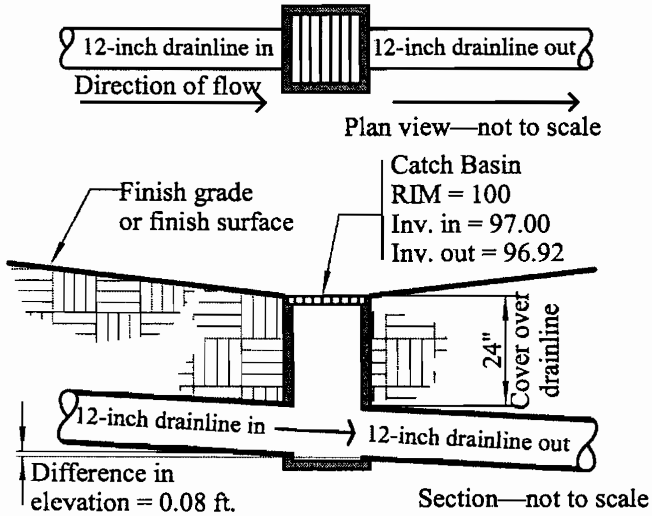


Figure 5-6. Condition 1—Setting Invert Elevation for Same Size Pipe In and Pipe Out

Condition 2 — Larger Size Pipe Out: The drain inlet shown in Figure 5-7 has a 12-inch drainline going into the structure, and an 18-inch coming out. Note that the drainline out will always be larger, never smaller, for the obvious reason that the runoff collected by the drainage structure is *added* to the flow coming in.

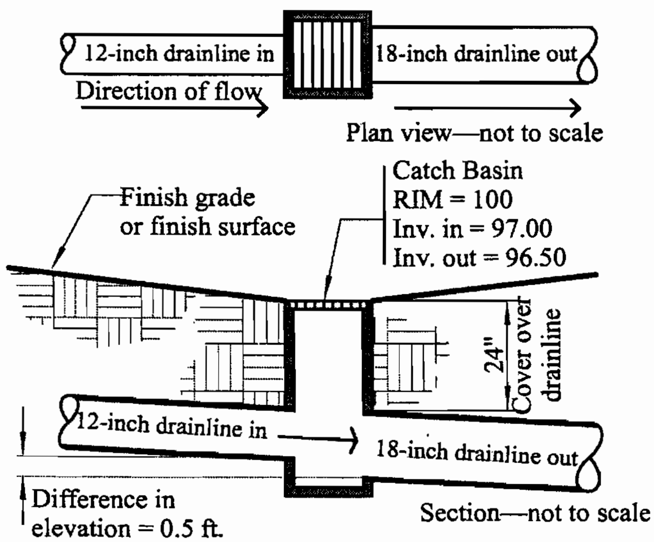


Figure 5-7. Condition 2—Setting Invert Elevation for Larger Size Pipe Out

The rule for larger size out condition: Lower the invert elevation out by the difference between the two pipe sizes. In the example shown in figure 5-7, the difference is 6-inches, or .5. Therefore, .5 is simply subtracted from the invert elevation in to arrive at the invert elevation out. Note that an additional one-inch *is not* subtracted — only the difference between the two sizes is subtracted.

Setting invert elevations is a simple process when you work step-by-step through each problem methodically. Begin by looking for given elevations and pipe slope information. In solving invert elevation problems, this given elevation is virtually always the starting point from which to work, regardless of whether it is at the first inlet (high point) of the system, or the outlet (low point) of the system. Elevations will most likely be found somewhere on the problem sheet itself — if not there, look for it in the problem statement. This starting elevation will almost always be an invert elevation, and it will appear at either the high end or the low end of a run of pipe, but almost never within the run.

Staying oriented in terms of up versus down is crucial. Although losing your orientation may seem highly unlikely (water never runs uphill, right?), it is appallingly easy to do exactly this when you're deeply engrossed in solving the problem. Remember that when starting at the highest point in the system, differences in elevation are subtracted from that which is higher; when starting at the lowest point, they are added to that which is lower.

Some exam problems have a two-pipes-in, one-pipe-out, configuration. The exiting pipe will always be larger than those entering the structure. The pipes entering may be the same size, or different sizes. If they are the *same* size, treat them as if there was only one pipe coming in (e.g., simply find the difference between the pipe size in and pipe size out as shown in Figure 5-7 and use that difference as the difference between the invert in and the invert out). Where the two incoming pipes are of *different* sizes, use the difference in size between the *larger* of the two incoming pipes and the size of the exiting pipe as the difference between the invert in and the invert out.

A question often arises as to how deep an invert elevation can go. Some exams have required surprisingly deep invert elevations. To avoid an "excessive solution," go only as deep as necessary to solve the problem and secure the required cover over the drainline (see the next section). (In the real world, deep invert elevations are undesirable because they require costly deep excavation and even shoring — although the cost is not an issue on Section E, an "excessive" solution may be.)

Be sure that pipe slopes do not fall below the required minimum of .5% (.005)

Do the exercises at the end of the chapter to gain experience in calculating invert elevations.

COVER OVER DRAINLINES — HOW TO CALCULATE

Providing sufficient cover over a drainline, or verifying that existing cover is adequate, is a key skill area that you should expect to be tested on. Cover-over-drainline problems frequently require also setting invert elevations as explained above. Work through the following example, then practice on the cover-over-drainline exercises at the end of the chapter. The examinee should always make a point of checking the problem statement carefully for cover requirements. Most often, the requirement will be for 24-inches of cover, but on recent exams it has also been 18-inches, and as little as 12-inches.

In working with cover over drainline problems, the total difference between the pipe invert elevation is always the sum of the required cover *plus* the pipe size. The sum of the pipe size and cover is the number that will be added to the invert elevation to establish the surface elevation, or the rim elevation if the problem involves a drain inlet. Thus, if the required cover is 24-inches and the pipe diameter is 12-inches, the total difference in elevation between the invert elevation and the elevation at the surface will be 3-feet. If the required cover is 18-inches, the total difference will be 2.5-feet, and so on. Note that the size of the drainline is a nominal dimension — the wall thickness of the pipe is disregarded.

Invert Elevations at Drain Inlets: A basic rule in designing subsurface drainage systems is that the cover-over-drainline requirement must be *applied at the point where a drainline enters or exits a drain inlet.* For example, if the required cover is two-feet and the drainline is 12-inches, the invert elevation of the drain inlet must be at least three-feet below the rim elevation. It can be lower, but never higher. With a rim elevation of 100, the invert elevation in can be no higher than 97 — it can be lower though. Remarkably, in spite of the obviousness of this point, a fair number of examinees overlook it. Figure 5-8 shows a typical condition. Contour line 230 crosses over a 12-inch drainline between a drain inlet and an endwall. The requirement is for 24-inches minimum of cover over the drainline. To determine whether this requirement has been met requires a very simple difference in elevation calculation, as illustrated.

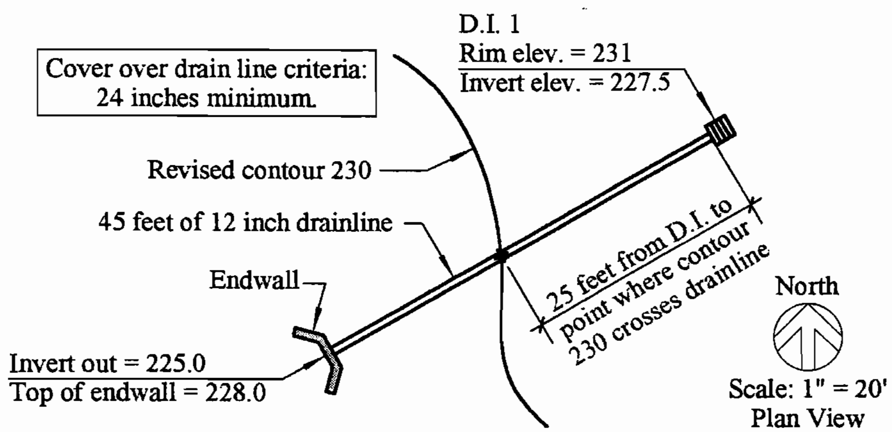


Figure 5-8. Determine Cover Over Drainline at Contour 230

As always, when the slope (grade) has not been given, it must be calculated, as is the case here. The slope will be based on the difference in elevation between the invert elevation out at the drain inlet and the invert elevation out at the endwall, and the 45-foot length of the drainline as given on the figure 5-8.

Find the overall difference in elevation:

$$D = 227.5 - 225.0 = 2.5 \text{ difference in elevation}$$

Then, find the grade:

$$D = 2.5 \quad L = 45 \text{ feet}$$

$$G = \frac{D}{L} = \frac{2.5}{45} = .055555555; \text{ rounds off to } .056$$

The next step will be to determine the invert elevation of the pipe at the point where contour 230 crosses. Here, there are two choices: 1) work from the D.I. down, or, 2) work form the endwall up. Since the dimension of 25-feet has been provided from the D.I. to the contour crossing point, working from the D.I. down to the contour will be used in this example.

Find the difference in elevation between the D.I. and contour 230:

$$D = G\,L = (.056)\,(25) = 1.4 \text{ difference in elevation}$$

Subtract the difference elevation, 1.4, from the invert elevation out, 227.5, at the drain inlet to find the invert elevation at the exact point where contour 230 crosses as follows:

$$227.5 - 1.4 = 226.1 \text{ (elevation)}$$

Consequently, the invert elevation at contour 230 is 226.1. To determine whether the cover is sufficient, simply add three-feet (the sum of the required two-feet of cover, plus 12-inch pipe diameter, equals 3-feet), to the invert elevation of 226.1 as follows:

$$226.1 + 3 = 229.1 \text{ (elevation)}$$

The calculated invert elevation of 229.1 is lower than 230, therefore, the cover over the drainline at the point where contour 230 crosses is sufficient, with .9 to spare. Review the section shown in Figure 5-9.

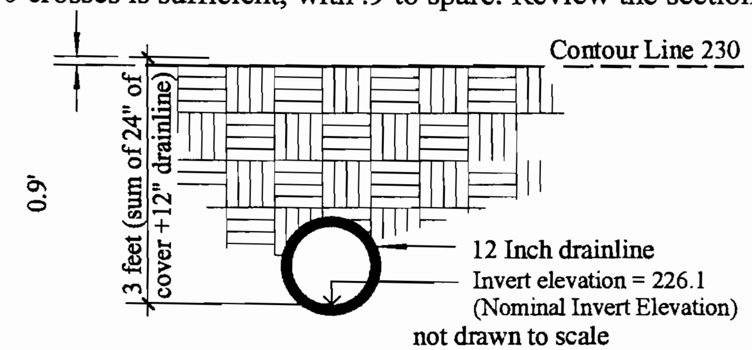


Figure 5-9. Section Through Drainline at Contour 230

How to Increase Cover Over Drainlines

If the calculated invert elevation plus the sum of the required cover and pipe diameter in the example above had revealed that cover over the drainline was not sufficient, there are several strategies that could be used to increase cover. The easiest and most direct way is to simply move contour line 230 *down-slope* toward the endwall. This will have the effect of forming a moderate ridge over the drainline. This is illustrated in Figure 5-10.

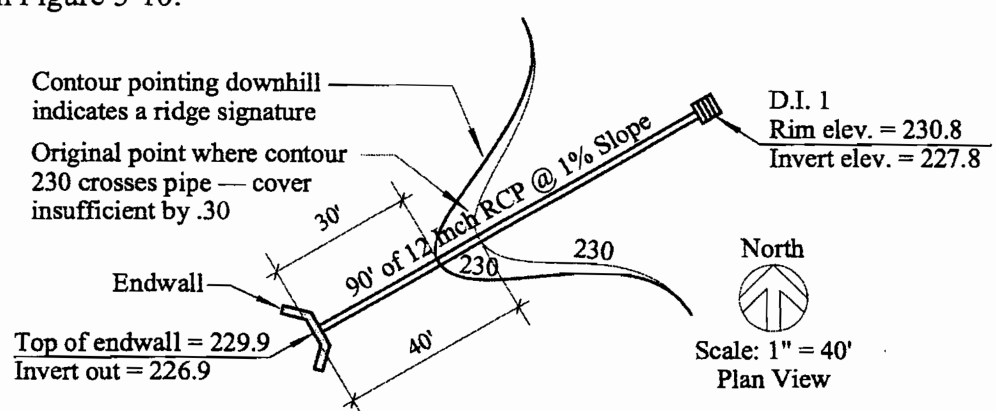


Figure 5-10. Adjusting Contour 230 to Increase Cover Over Drainline

In fact, contour 230 could be moved all the way to the endwall, where it would tie into its backside. While this strategy may not be aesthetically attractive, it does produce an effective quick fix. And, since aesthetics are not a consideration in Section E, this approach is advantageous from a timesaving standpoint.

A second strategy is to lower one or both of the invert elevations. If the choice is to lower the invert elevation at the drain inlet, be sure the slope of the drainline doesn't fall below the stipulated minimum slope — usually .005. Lowering the invert elevation out at the endwall is another option if done with care — a flowline grade of at least 2% should be maintained from the invert out at the endwall to the next lower whole number contour line below the endwall. Either lowering the invert elevation out at the drain inlet, or lowering the invert elevation out at the endwall is pretty much a trial and error process. For example, lower one or both of the invert elevations and test to see if the cover requirement has been met. If your guess comes up short, you'll need to repeat the process until the result is satisfactory. Consequently, moving the contour line downslope toward the endwall will likely be a quicker alternative, but only if the length the contour must be moved *is calculated.* What we're after is the length in feet the contour line must be deflected to meet the coverage requirement. To find this number, the length formula will be used. Here's an example. Consider a drainline with a grade of 1% flowing from a drain inlet. It has been revealed that there is a cover shortfall of .25-feet. Using the length formula, substitute in the difference in elevation — the amount of the shortfall — and the slope of the drainline.

$$D = .25 \quad G = .01$$

$$L = \frac{D}{G} = \frac{.25}{.01} = 25 \text{ feet}$$

Therefore, moving — or deflecting — the contour line 25-feet down-slope from the original position will correct the cover shortfall. Try this technique on the exercises that address cover over drainlines at the end of the chapter. Several of the solutions will accommodate using this technique. As is usually the case, experience will improve your instinct for optimizing contour placement.

CONTOUR REVISIONS AT ENDWALLS AND HEADWALLS

Figure 5-11 illustrates a typical endwall. (Although an endwall is shown, the external appearance of both are essentially identical.)

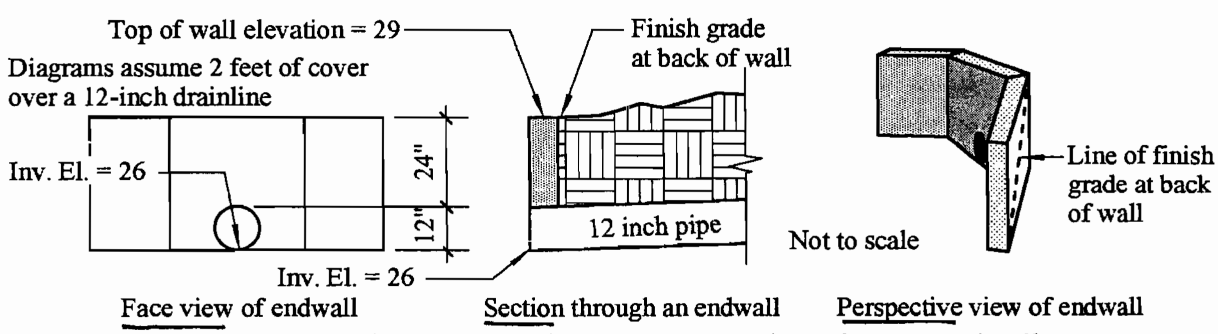


Figure 5-11. Elevation, Section, and Perspective View of Endwall

Figure 5-12 illustrates why an endwall is desirable, and what can happen at the point of discharge if it isn't provided.

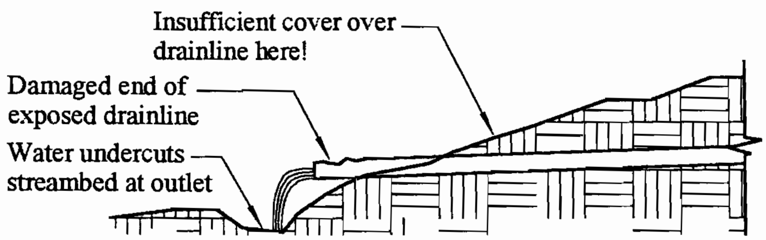


Figure 5-12. Typical Condition Without Benefit an Endwall

When you think of a headwall, or an endwall, think of the word "wall" that's part of both terms. Endwalls and headwalls are in reality specialized retaining wall structures that are specifically designed to protect drainlines by adding cover equal to their overall height. Because they are walls, the contour lines in their immediate vicinity must be revised. Figure 5-13 illustrates a typical example of the sort of contour manipulation that is required at an endwall. One way to remember this contour signature is to think of it as resembling an abstract spider, complete with its legs symmetrically splayed out. When manipulating contours at a headwall or endwall, pay attention to the spacing between the contours where they meet the wall: the problem statement will almost always require a maximum allowable slope expressed as a ratio, such as 3:1 or 5:1. Try to stay as close to the required ratio as possible. However, you'll often find that doing so is difficult, or sometimes even impossible in the immediate vicinity of the wall itself. In such cases, do the best you can. Or, try moving a contour to the end of the wall, like contour 27 in Figure 5-13. It's also permissible to bring one contour around to the front face of the wall, as contour 26 does. And finally, remember that like all retaining walls, an equal number of contours must go into, and come out of, the wall.

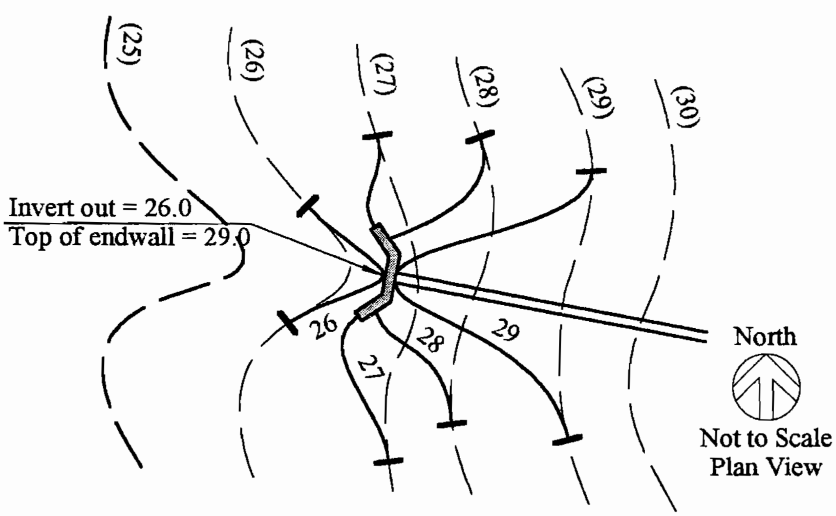


Figure 5-13. Typical Contour Modification at Endwall

Freeboard

Freeboard is defined as an allowance of additional wall or curb height above an adjacent finish grade elevation. It is provided to reduce the tendency for soil behind the wall to be washed over a wall or curb as the result of rainfall, irrigation, or wash-down. For instance, if the finish surface elevation in a planter is 100, the top of the enclosing wall might be 6-inches higher, or elevation 100.5. In the case of an endwall or headwall, freeboard might be added to the top of wall to prevent the soil behind the wall from washing over the top of the wall.

Should freeboard be provided on the exam? This is something of a catch-22. Although freeboard has never been explicitly required on the exam, providing it could be viewed as an implicit requirement — that is, providing freeboard is what a licensed landscape architect would do. In fact, most landscape architects routinely provided freeboard on everything from walk surfaces to planter walls to endwalls and headwalls. The problem is that it's difficult to predict how the Master Grader will react to this interpretation. The easy answer is not to provide it. However, if in your mind, you believe it should be added when it's not explicitly required, protect yourself from being guilty of an excessive solution by simply adding a brief note to the effect that freeboard has been intentionally added (e.g., 6-inch freeboard intentionally added). This should avoid the possibility of being penalized for an excessive solution while, on the other hand, avoiding the possibility of being penalized for not doing what a licensed landscape architect would do. The top of endwall elevation shown in Figure 5-13 has been set at exactly three-feet above the invert elevation out, meaning that freeboard *has not* been added.

CHARACTERISTICS OF RAINFALL

According to the *Data Book for Civil Engineers: Design,* by Elwyn E. Seeley, rainfall has these characteristics:

1. Intense storms generally cover small areas and are of short duration.

2. Longer duration storms usually cover larger areas and fall at lower intensities.

3. While intense storms of varying duration occur from time to time over most portions of the earth, they are not necessarily more frequent in areas having high total annual rainfall.

4. The magnitude and intensity of storms are inversely related to their average frequency of occurrence.

5. Exception: Atypical combinations of high intensity and long duration storms may cause significant erosion damage and may result in major flooding.

Time of Concentration (abbreviated TOC): The time of concentration for a watershed area is theoretically the time it would take runoff from the most distant point within the area to flow to the point of discharge. When the duration of a storm matches the time of concentration, the entire watershed area is simultaneously contributing runoff to the point of discharge.

RETENTION PONDS — HOW TO IMPLEMENT A POND AND A DAM

A recent trend seen in Section E has been the implementation of a retention pond. There are two ways CLARB has presented retention problems:

1) The problem statement includes a "graphic convention" that the examinee is required to place in an appropriate location on the solution. The graphic convention usually consists of a simple crosshatched circle of the required the size of the pond. In some cases the graphic convention will also include a dam.

2) In this scenario, the examinee is required to *show the grading* for the construction of a pond having a specified surface area and a basic earthen dam. This section focuses on the steps to take to design a pond and to a simple earthen dam. The first ingredient for both is a swale. An example pond and dam grading

solution is shown below in Figures 5-14a through 5-14e. The requirements for this example are a pond with an average depth of 2-feet, an approximate surface area of 2,000-square feet and a dam face slope ratio not to exceed 5:1.

Step 1. Select area for the pond and dam. Look for a natural swale contour signature. See Figure 5-14a.

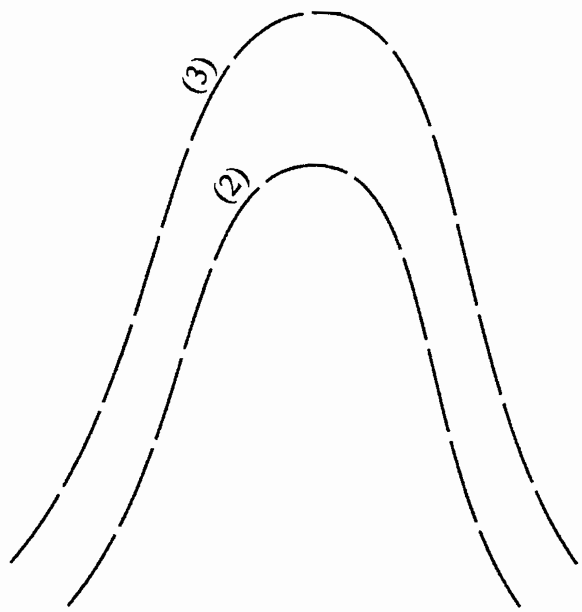


Figure 5-14a, Swale Signature Necessary for the Development of a Retention Pond and Dam

Step 2. Identify and draw in a flowline, then draw a construction line perpendicular to the flowline as shown in Figure 5-14b.

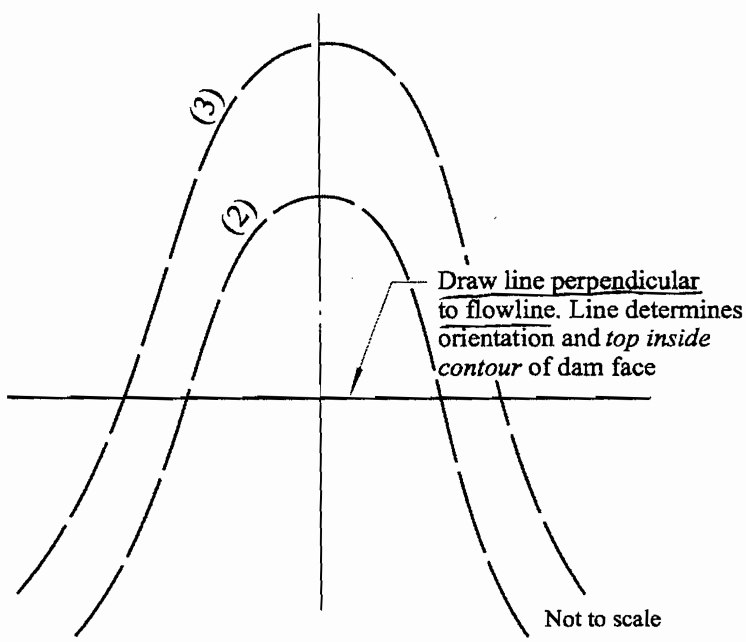


Figure 5-14b, Establishing the Flowline and Top Inside Face of Dam

This line will represent the inside top face of the dam. Consider the location of this line as adjustable. Move it down to increase the size of the pond; move it up to decrease the size of the pond.

Step 3. Finalize pond size by measuring the area formed by the highest contour and the top-inside face of the dam as shown in Figure 5-14c. Use the information provided below to estimate the area of the pond using your best judgment. It is highly likely that the exam scorers will grant reasonable latitude in your estimation of size since you're not expected to have the means to establish an exact pond size.

There are several ways in which the problem statement may stipulate pond size and depth. For example, it might be written thusly: "Locate a dam to create a retention pond that has an average depth of at least 2-feet over a surface area of 1/2-acre." The statement is self-explanatory. In this example, the pond size requirement has been stated in acres, but it could also be stated as a square footage as in the example.

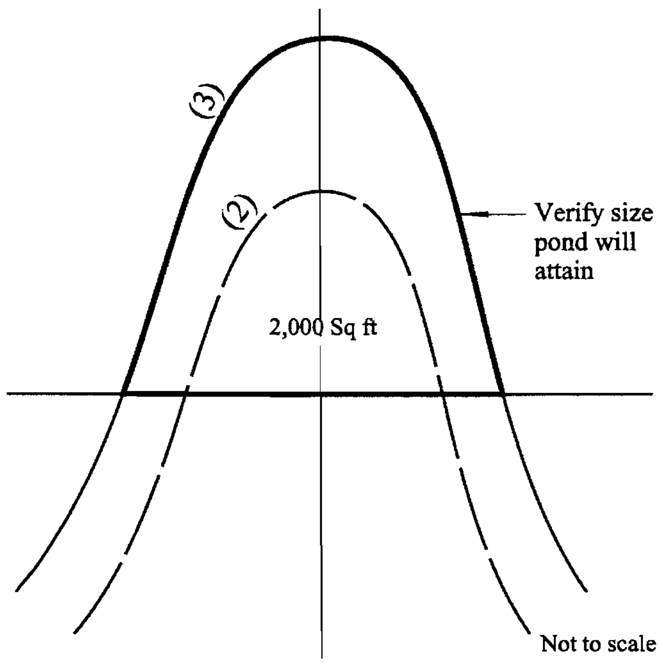


Figure 5-14c, Establishing Pond Size Needed

To approximate the size needed for the pond, you need to have a feeling for the size of an acre or a given number of square feet. Here are some basic *acre facts* to know. Most importantly you should memorize that there are 43,560-feet in an acre.

An acre represented as a square will be approximately 209-feet on each side (208.71 to be exact). This is found by calculating the square root of 43,560. Calculating the square root for *parts of an acre* yields the following sizes of squares:

- ¾ of an acre is 180-feet on each side
- ½ acre is 148-feet on each side
- ¼ acre is 104 feet on each side

However, since the pond shapes you'll be working with are more apt to be circular than geometric, it may be even more useful to visualize each of these acre figures as a circular form:

- one-acre in size has a radius of approximately 117.7-feet
- ¾ acre a radius of 102-feet
- ½ acre a radius of 83.3-feet
- ¼ acre a radius of 58.9-feet

This relationship can also be stated in mathematical terms. However, to do the calculation in a timely manner, you'll need a calculator capable of calculating square roots. The formula for finding radius where you know the area of a circle is:

$$radius = \sqrt{\frac{A}{3.142}}$$

Where:
A is the area of the circle.
3.142 is pi

The problem statement will always provide a so-called graphic convention showing how the retention pond to be drawn graphically. For instance, an amorphous semi-circular shape labeled "Graphic Convention for Delineating Retention Pond (Not to Scale)," and a note stating that the shape shown "may be altered" (obviously you're expected to alter it to fit your solution).

Step 4. Draw contour construction lines as shown in Figure 5-14d. Keep in mind the required slope ratio (5:1 in this example meaning that the lines must be at least 5-feet apart) and that the construction line you drew in Step 2 represents the *inside-top of the dam.* The number of lines needed to achieve a given average pond depth is as follows:

- If the pond is to have an average depth of 1-foot, the dam must be 1-foot high, which means you will draw a total of 2-lines.
- If the pond is to have an average depth of 2-feet, the dam must be 2-feet high, which means you will draw a total of 4-lines.
- If the pond is to have an average depth of 3-feet, the dam must be 3-feet high, which means you will draw a total of 6-lines.

It is highly unlikely that you will ever be asked to design a dam of more than three-feet in height.

Once the lines have been drawn, number them as shown in Figure 5-14d. Note that the two mid-lines are the highest lines, and that they represent the top of the dam.

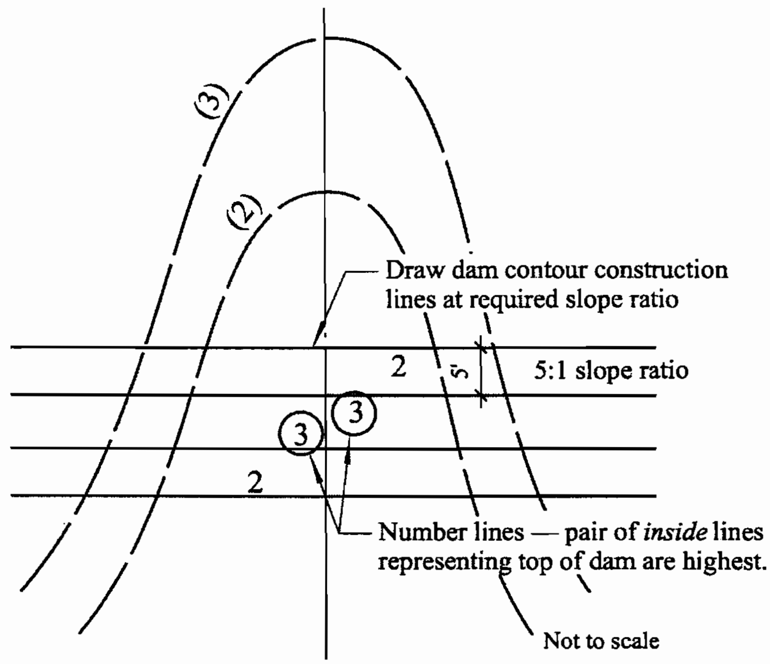


Figure 5-14d, Laying Out Contours

Step 5 Lightly draw in a schematic representation of the contours as shown in Figure 5-14e. Note that the top two contours join the highest existing contours, and the next contours down join the next lower contours and so on. Drawing these contour lines schematically will help you keep them straight when you hard line your solution.

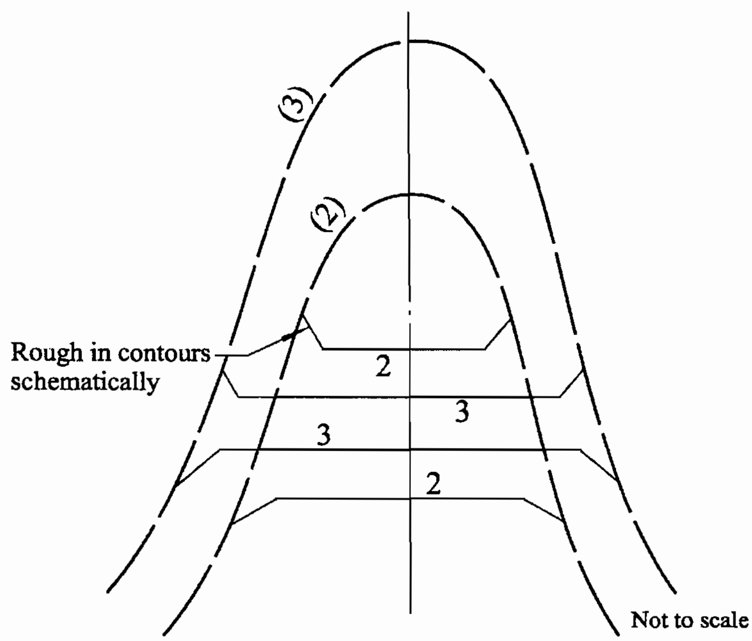


Figure 5-14e, Contours Shown in Their Final Locations Schematically

Step 6. Hard line the contours drawn in the previous step. Number the revised contours and delineate the area of the pond with the stipulated graphic convention as shown in Figure 5-14f.

Review the placement of the revised contour lines. Notice that they are placed perpendicular to the flow-line of the swale, and that the same number of contour lines appears on the inside and outside faces of the dam. Add any other information needed to communicate your solution, such as a recapitulation of the average depth and size of the pond as shown.

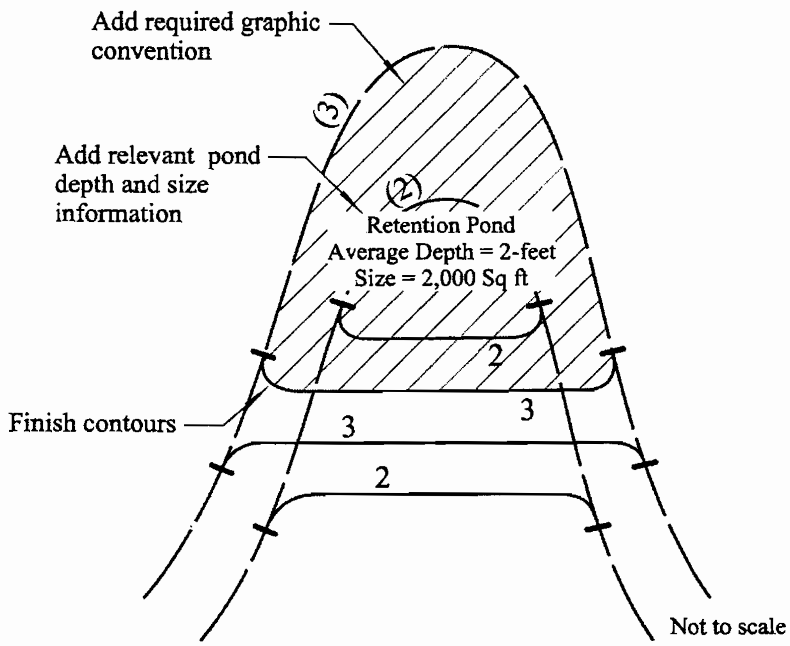


Figure 5-14f, Dam Signature for Detention/Retention Basin

WETLANDS

Recent LARE exam administrations have featured an increasing emphasis on wetlands and their role in stormwater management. Although many of the issues concerning wetlands are tested for in other sections of the exam (especially Section B), Section E vignettes are most likely to focus on *physically locating some sort of constructed wetland.* For example, the examinee may be required to locate a constructed wetland of a specified size as a water quality pond, or to intercept and treat possibly polluted runoff before it enters a lake or river.

The following wetlands overview is offered here to provide a general understanding of the subject. It is doubtful that any of this information would ever be tested for directly in Section E, but it could be tested for indirectly, or some of the terminology could conceivably appear in a problem statement.

Types of Wetlands

Generally speaking, there are two primary types of wetlands: natural and constructed (constructed wetlands are manmade). In addition, a third type, a hybrid of the two, is possible when a natural wetland is to be enhanced or physically expanded. Although the material presented in *Section B, Objective Aspects of Grading and Drainage and Irrigation Design* focuses on constructed wetlands, most of the concepts and terminology presented applies to both. The Environmental Protection Agency's (EPA) Web site is highly recommended for additional information on wetlands. Find it at:
< http://www.epa.gov/owow/wetlands/>

For a comprehensive list of wetland related publications in pdf format, visit:

< http://www.epa.gov/owow/wetlands/facts/contents.html>

Definitions of Wetlands

Wetlands are lands where saturation with water is the dominant factor determining the nature of soil development and the types of plant and animal communities living in the soil and on its surface (Cowardin, December 1979). Wetlands vary widely because of regional and local differences in soils, topography, climate, hydrology, water chemistry, vegetation, and other factors, including human disturbance. Indeed, wetlands are found from the tundra to the tropics and on every continent except Antarctica.

For regulatory purposes under the Clean Water Act, the term wetlands means "those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support…a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs and similar areas." [Excerpted from the EPA Regulations listed at 40 CFR 230.3(t)]

Although wetlands are often wet, a wetland might not be wet year-round. In fact, some of the most important wetlands are only seasonally wet. Wetlands are the link between the land and water. They are transition zones where the flow of water, the cycling of nutrients, and the energy of the sun meet to produce a unique ecosystem characterized by hydrology, soils, and vegetation — making these areas very important features of a watershed. Using a watershed-based approach to wetland protection ensures that the whole system, including land, air, and water resources, is protected.

Wetland Categories

Wetlands found in the United States fall into four general categories — marshes, swamps, bogs, and fens. Marshes are wetlands dominated by soft-stemmed vegetation, while swamps have mostly woody plants. Bogs are freshwater wetlands, often formed in old glacial lakes, characterized by spongy peat deposits, evergreen trees and shrubs, and a floor covered by a thick carpet of sphagnum moss. Fens are freshwater peat-forming wetlands covered mostly by grasses, sedges, reeds, and wildflowers.

Coastal wetlands — Coastal wetlands, in the United States, as their name suggests, are found along the Atlantic, Pacific, Alaskan, and Gulf coasts. They are closely linked to our nation's estuaries, where seawater mixes with fresh water to form an environment of varying salinities. The salt water and the fluctuating water levels (due to tidal action) combine to create a rather difficult environment for most plants. Consequently, many shallow coastal areas are unvegetated mudflats or sand flats. Some plants, however, have successfully adapted to this environment. Certain grasses and grass-like plants that adapt to the saline conditions form the tidal salt marshes that are found along the Atlantic, Gulf, and Pacific coasts. Mangrove swamps, with salt-loving shrubs or trees, are common in tropical climates, such as in southern Florida and Puerto Rico. Some tidal freshwater wetlands form beyond the upper edges of tidal salt marshes where the influence of salt water ends.

Inland wetlands — Inland wetlands are most common on floodplains along rivers and streams (riparian wetlands), in isolated depressions surrounded by dry land (for example, playas, basins, and "potholes"), along the margins of lakes and ponds, and in other low-lying areas where the groundwater intercepts the soil surface or where precipitation sufficiently saturates the soil (vernal pools and bogs). Inland wetlands include marshes and wet meadows dominated by herbaceous plants, swamps dominated by shrubs, and wooded swamps dominated by trees.

Certain types of inland wetlands are common to particular regions of the country:

- Bogs and fens of the northeastern and north-central states and Alaska
- Wet meadows or wet prairies in the Midwest
- Inland saline and alkaline marshes and riparian wetlands of the arid and semiarid west
- Prairie potholes of Iowa, Minnesota and the Dakotas
- Alpine meadows of the west
- Playa lakes of the southwest and Great Plains
- Bottomland hardwood swamps of the south
- Pocosins and Carolina Bays of the southeast coastal states
- Tundra wetlands of Alaska.

Many of these wetlands are seasonal (meaning they are dry one or more season every year), and, particularly in the arid and semiarid West, may be wet only periodically. The quantity of water present, and the timing of its presence, in part determine the functions of a wetland and its role in the environment. Even wetlands that appear dry at times for significant parts of the year — such as vernal pools — often provide critical habitat for wildlife adapted to breeding exclusively in these areas.

Benefits of Wetlands

Often referred to as "nurseries of life," wetlands provide habitat for thousands of species of aquatic and terrestrial plants and animals. Although wetlands are best known for being home to water lilies, turtles, frogs, snakes, alligators, and crocodiles, they also provide important habitat for waterfowl, fish, and mammals. Migrating birds use wetlands to rest and feed during their cross-continental journeys and as nesting sites when they are at home. As a result, wetland loss has a serious impact on these species. Habitat degradation since the 1970s has been a leading cause of species extinction.

Wetlands do more than provide habitat for plants and animals in the watershed. When rivers overflow, wetlands help to absorb and slow floodwaters. This ability to control floods can alleviate property damage and loss and can even save lives. Wetlands also absorb excess nutrients, sediment, and other pollutants before they reach rivers, lakes, and other waterbodies. In summary:

- Wetlands provide homes for a wider diversity of wildlife than any other habitat type.
- Wetlands serve as a floodwater retention area, reducing risk of flood damage to inhabited areas.

- Wetlands located adjacent to oceans or inland lakes buffer shore areas against damaging storm-induced waves.

- The plants found in wetlands filter and purify water.

- Wetlands trap polluted runoff waters, absorbing sediments and excess nutrients.

- Wetlands act as groundwater recharge areas, replenishing existing aquifers.

Wetland Terms and Definitions

BOD: In the book *Constructed Wetlands in the Sustainable Landscape* by Craig S. Campbell and Michael H. Ogden (John Wiley and Sons, Inc.), BOD is defined as *Biological Oxygen Demand* and also as Bio*chemical* Oxygen Demand.

Here are some common textbook definitions of Biological Oxygen Demand:

1. A measure of the pollution load on the receiving water body.

2. A measure of the organic compounds in wastewater that require oxidation in order to become stable (e.g., BOD removal).

3. A measure of the amount of Oxygen required to oxidize, and to thus stabilize, the organic materials in polluted water.

Numbers 1 and 2 infer a measurement of organic materials in wastewater, while 3 suggests the amount of oxygen that is needed to complete the oxidation process.

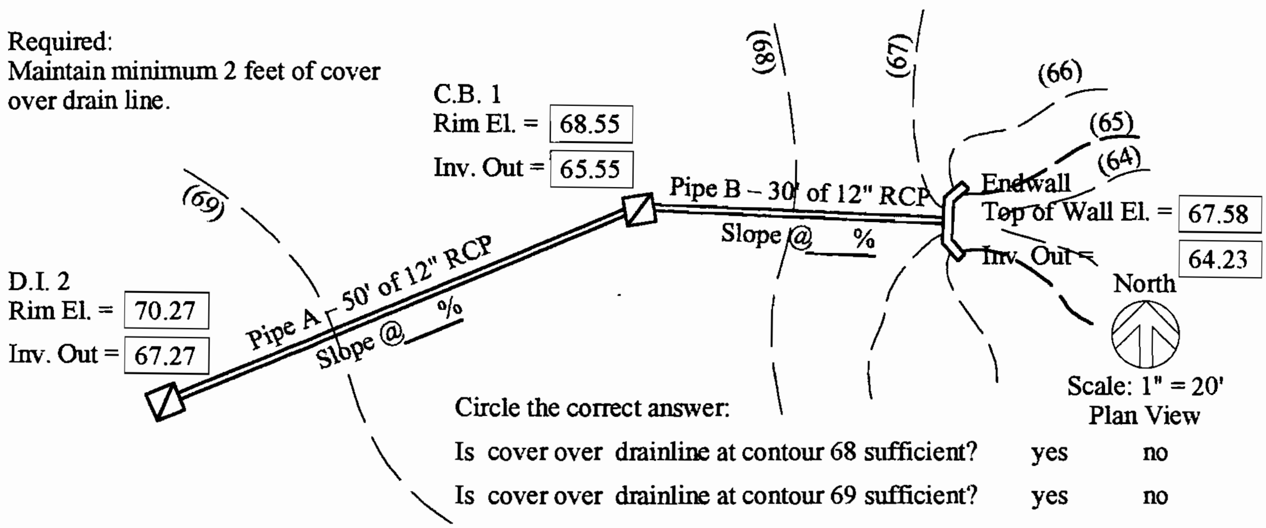
HLR: Hydraulic Loading Rate. Refers to the quantity of effluent in gallons per day delivered to a constructed wetland.

HRT: Hydraulic Residence Time. Represents the time it takes a single molecule of water to move from its point of introduction to its point of discharge in a wetland.

SS or **TSS:** Suspended Solids or Total Suspended Solids. This represents the organic and inorganic solid particles in wastewater.

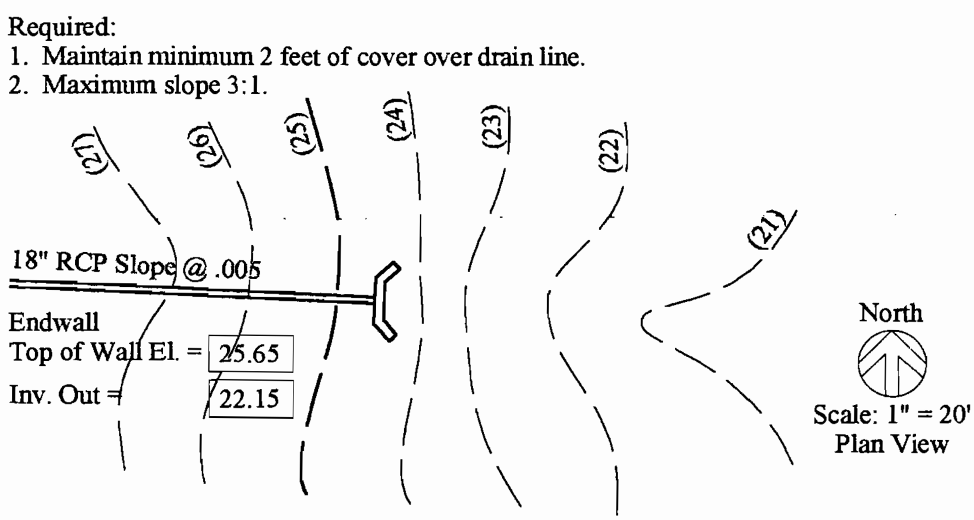
N: Nitrogen. Nitrogen can be a pollutant if discharged into rivers and lakes; on the other hand, if properly managed, it is also is a valuable plant nutrient resource.
TKN: Total Kjeldahl Nitrogen. Kjeldahl Nitrogen refers to a method of chemical analysis used to determine *protein nitrogen in biological materials,* the so-called Kjeldahl method. As pointed out above, agriculture can be a major source of nitrogen pollution. In both fresh water and wastewater, the forms of nitrogen of greatest concern are, in order of decreasing oxidation state, nitrate nitrogen ($NO3$), nitrite nitrogen ($NO2$), ammonia nitrogen ($NH4$), and organic nitrogen. The sum of all these nitrogen forms together is called "total nitrogen."

8. Answer the questions concerning cover over contours 68 and 69. If either, or both, contours have insufficient cover, revise the existing contours to correct the condition.



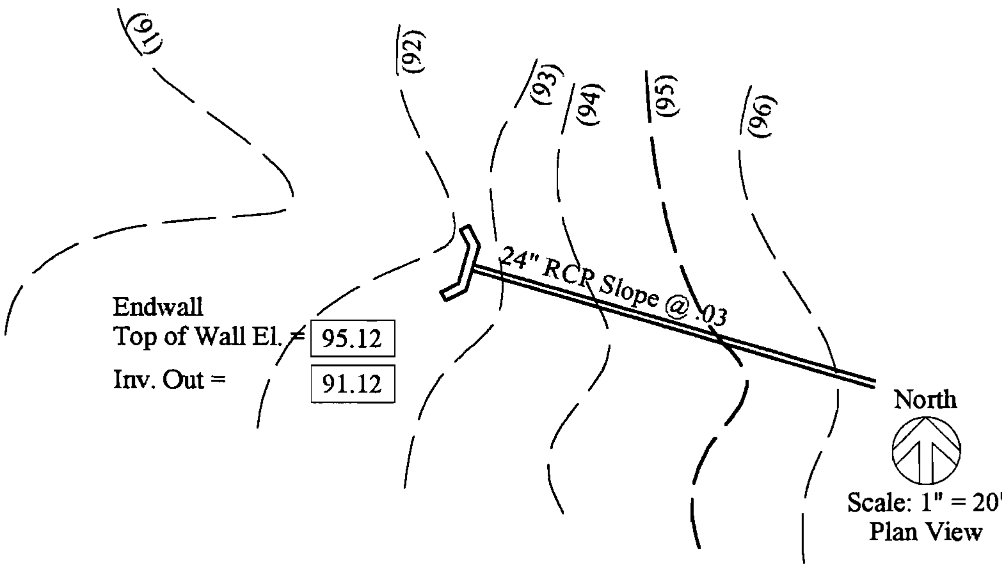
Problem 8

9. Manipulate existing contour lines as necessary to site new endwall and ensure that there is sufficient cover over 18-inch RCP drainline.



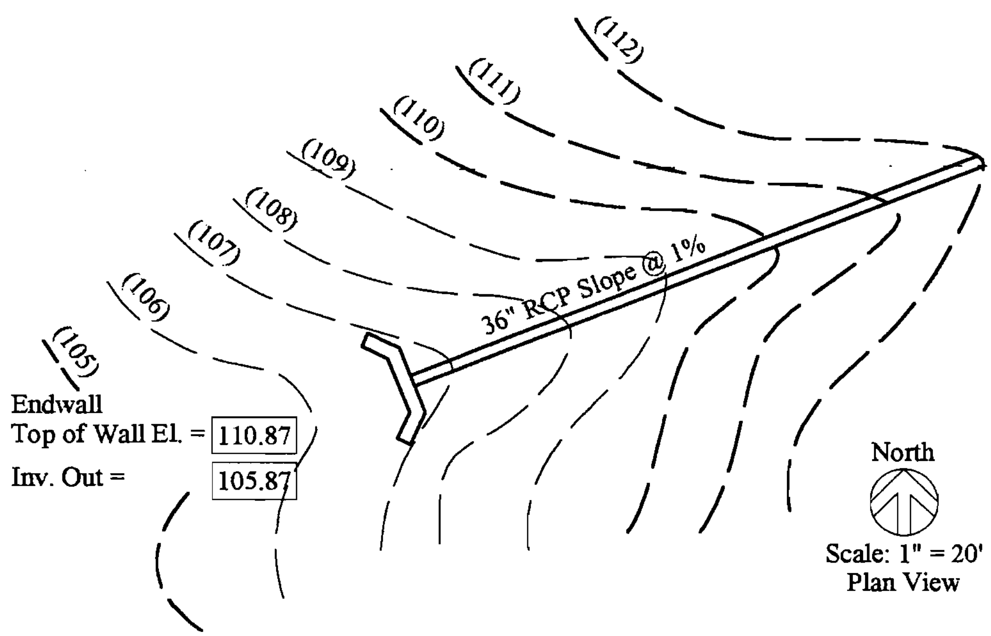
Problem 9

10. Manipulate existing contour lines as necessary to site new endwall and ensure that there is sufficient cover over the 24-inch reinforced concrete pipe (RCP) drainline.



Problem 10

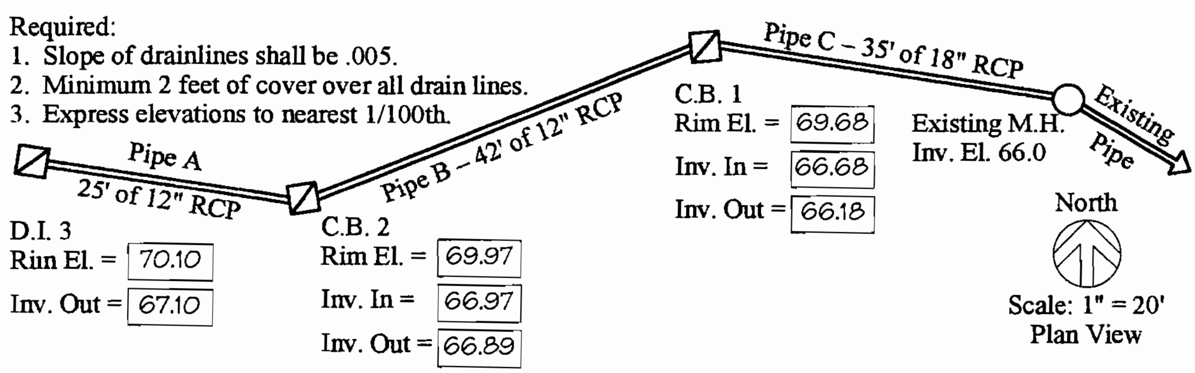
11. Manipulate existing contour lines as necessary to site new endwall and ensure that there is sufficient cover over 36" RCP drainline.



Problem 11

Chapter 5 Exercises, Group 1 Solutions — Setting Invert Elevations, Providing Cover Over Drainlines, and Grading Headwalls and Endwalls (Problems 1 through 11)

1. Solution — Set the invert elevation and rim elevations of the drain inlet and catch basins.



Problem 1 Solution

This solution must begin at the manhole, the sole point of known elevation (invert elevation of 66.0). Proceed by finding the difference in elevation between the manhole invert elevation of 66.0 and C.B. 1, which is located 35-feet upstream at a grade of .5%:

$G = .005; \quad L = 35$ feet

$D = G\,L = (.005)\,(35) = .175$ is the difference in elevation

Because all pipes are *sloping up* from the manhole, the differences in elevation calculations will be added cumulatively:

$.175 + 66.0 = 66.175$; rounds off to an elevation of 66.18

In order to calculate the cover over the drainline, it is necessary to add the size of the pipe to the required cover. With a pipe size of 12-inches and-24 inches of cover, the total is 3-feet, or 36-inches. Therefore, to find the rim elevation at C.B. 1, add 3-feet to the invert elevation in or, alternately, add 3.5-feet to the invert elevation out (the resulting elevation is the same because the head loss adjustment from a 12-inch pipe to an 18-inch pipe lowers the invert out by .5-feet — see the next paragraph).

Using the invert elevation in:

$3 + 66.68 = 69.68$

or using the invert elevation out:

$3.5 + 66.18 = 69.68$

Note that pipe C is 18-inches in diameter while pipe B is 12-inches in diameter. To compensate for head loss, the difference between the two sizes, .5, will be added to the invert elevation out at C.B. 1 to establish the invert elevation in:

$$66.18 + .5 = 66.68 \text{ is the invert elevation out at CB 1}$$

Moving from C.B. 1 to C.B. 2, the length of pipe B is 42-feet at a slope of .5%:

$$D = G\,L = (.005)\,(42) = .21 \text{ difference in elevation}$$

Add .21 to the invert elevation in at C.B. 1 to find the invert elevation out at C.B. 2:

$$.21 + 66.68 = 66.89$$

To find the rim elevation at C.B. 2, add 3-feet to the invert elevation in:

$$3 + 66.68 = 69.68$$

Since pipe B and pipe A are both 12-inches in diameter, .08 will be added to the invert elevation out to find the invert elevation in to compensate for head loss:

$$66.97 + 3 = 69.97$$

Moving from C.B. 2 to D.I. 3, the length of pipe C is 25-feet at a slope of .5%:

$$D = G\,L = (.005)\,(25) = .125 \text{ difference in elevation; rounds off to } .13$$

Add .13 to the invert elevation in at C.B. 2 to find the invert elevation out at D.I. 3:

$$.13 + 66.68 = 67.10$$

To find the rim elevation at D.I. 3, add 3-feet to the invert elevation out:

$$3 + 67.10 = 70.10$$

This completes the solution for problem 1. By working through the problem logically and sequentially, developing a correct solution is simple and straightforward.

The following invert elevation problems utilize the same problem-solving process as problem 1.

2. Solution — Set the invert elevation and rim elevations of the drain inlet and catch basins and the invert elevations at endwall and top of endwall.

Wetlands Protection

The federal government protects wetlands through regulations (for example, Section 404 of the Clean Water Act), economic incentives and disincentives (for example, tax deductions for selling or donating wetlands to a qualified organization and the "Swampbuster" provisions of the Food Security Act), cooperative programs, and acquisition (for example, establishing national wildlife refuges).

Beyond the federal level, a number of states have enacted laws to regulate activities in wetlands, and some counties and towns have adopted local wetlands protection ordinances or have changed the way development is permitted. Most coastal states have significantly reduced losses of coastal wetlands through protective laws. Few states, however, have laws specifically regulating activities in inland wetlands, although some states and local governments have non-regulatory programs that help protect wetlands.

Recently, partnerships to manage whole watersheds have developed among federal, state, tribal, and local governments, nonprofit organizations, and private landowners. The goal of these partnerships is to implement comprehensive, integrated watershed protection approaches. A watershed approach recognizes the inter-connectedness of water, land, and wetlands resources and results in more complete solutions that address more of the factors causing wetland degradation. The government achieves the restoration of former or degraded wetlands under the Clean Water Act Section 404 program as well as through watershed protection initiatives.

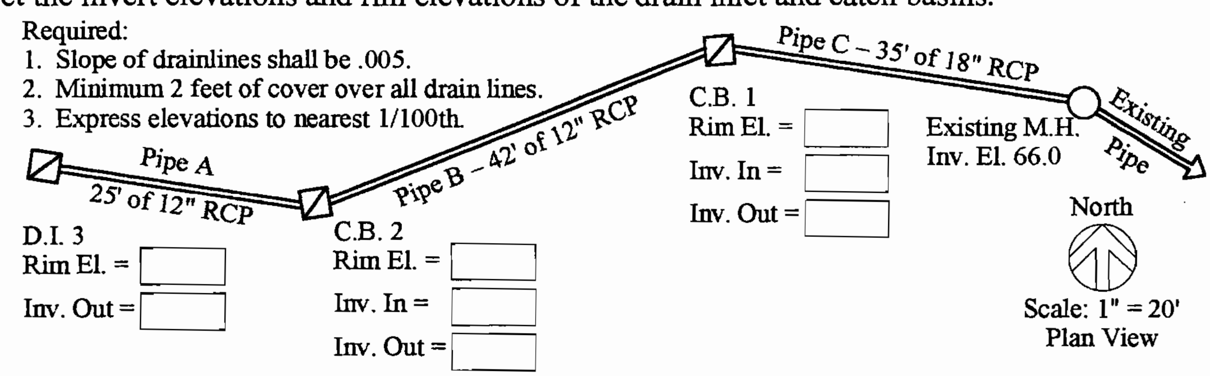
Effectiveness of Wetlands

How effective wetlands are at removing pollutants from wastewater? Very! The following statement, loosely quoted from *Constructed Wetlands in the Sustainable Landscape,* provides a sense of the results that a well designed, constructed, and maintained wetland can achieve: "A wetland…is capable of removing soluble and solid organic compounds, total suspended solids (TSS), nitrogen, phosphorus, metals, hydrocarbons, organic pollutants, pathogenic bacteria and viruses."

CHAPTER FIVE EXERCISES

Group 1 — Setting Invert Elevations, Providing Cover Over Drainlines, and Grading Headwalls and Endwalls

1. Set the invert elevations and rim elevations of the drain inlet and catch basins.

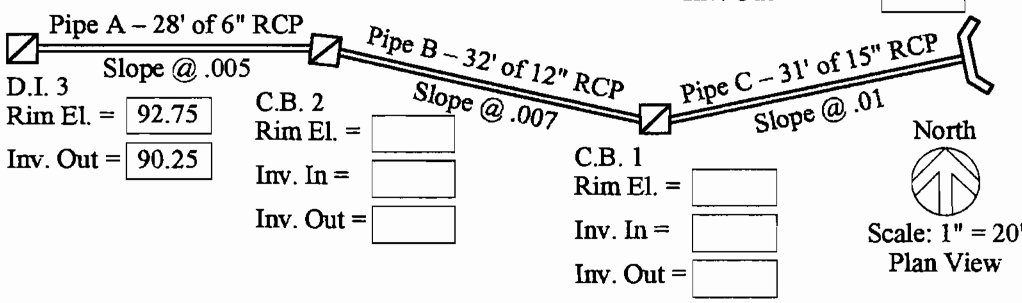


Problem 1

2. Set the invert elevations and rim elevations of the drain inlet and catch basins and invert at endwall and top of endwall.

Required:
1. Slope of drainlines shall be as indicated on the plan.
2. Minimum 2 feet of cover over all drain lines.
3. Express elevations to nearest 1/100th.
4. Top of endwall shall be set at 4 feet above invert out.

Endwall
Top of Wall El. = ____
Inv. Out = ____



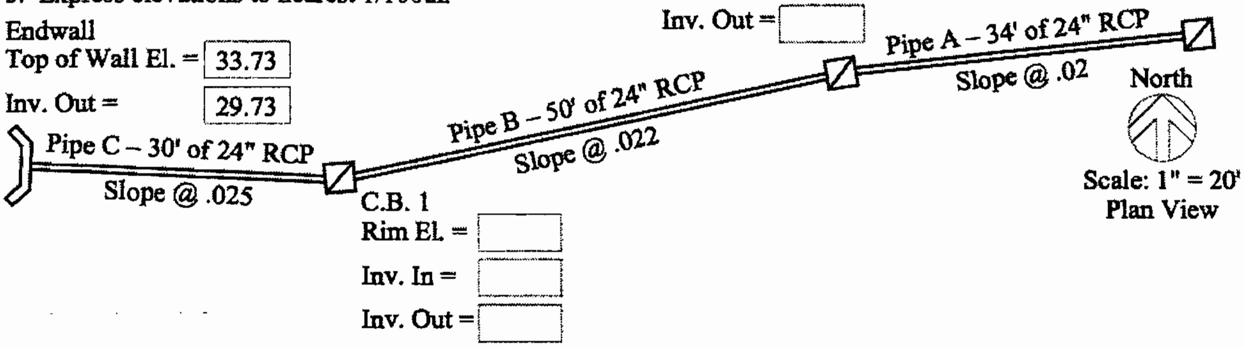
Problem 2

3. Set the invert elevations and rim elevations of the drain inlet and catch basins.

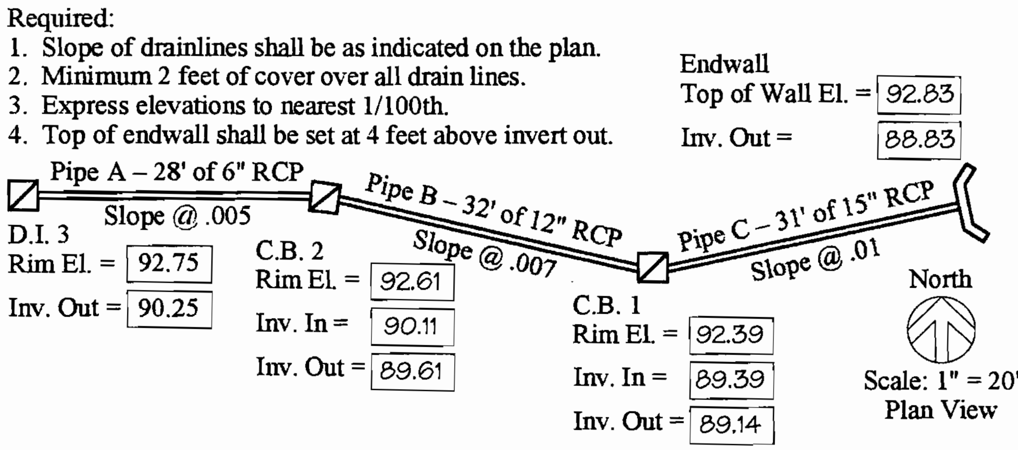
Required:
1. Slope of drainlines shall be as indicated on the plan.
2. Minimum 2 feet of cover over all drain lines.
3. Express elevations to nearest 1/100th.

C.B. 2
Rim El. = ____
Inv. In = ____
Inv. Out = ____

D.I. 3
Rim El. = ____
Inv. Out = ____



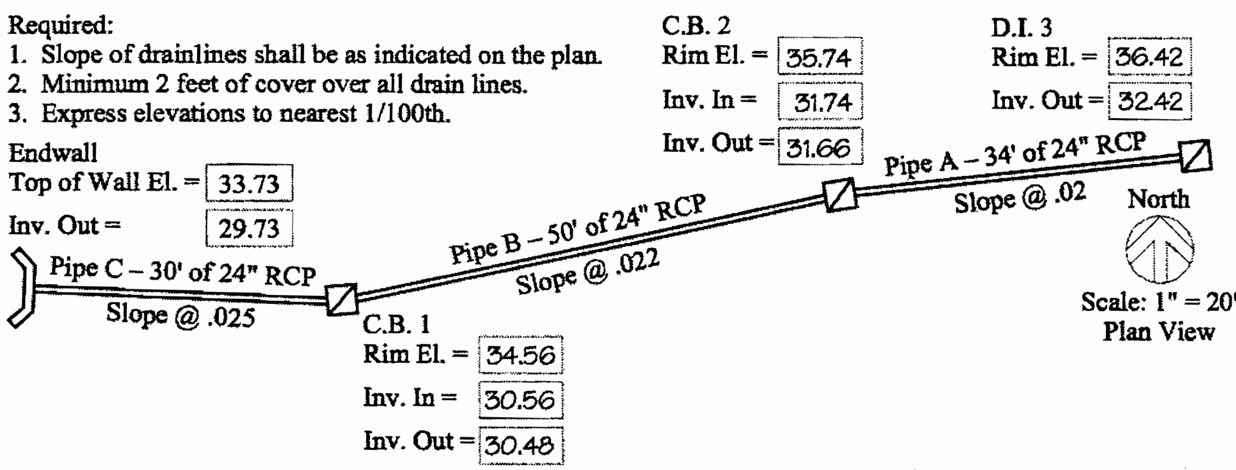
Problem 3



Problem 2 Solution

Problem 2 begins at the known invert elevation out of 90.25 at the endwall. The solution is developed in the same manner as in the previous invert elevation problem.

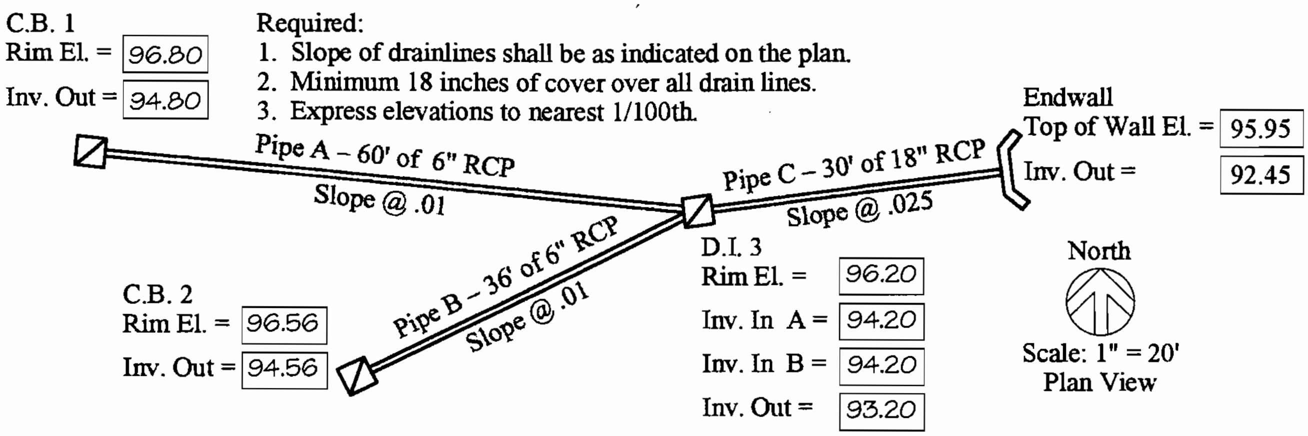
3. Solution — Set the invert elevations and rim elevations of the drain inlet and catch basins.



Problem 3 Solution

Problem 3 begins at the known invert elevation out of 29.73 at the endwall. The solution is developed in the same manner as in the previous invert elevation problems by adding the difference in elevation calculated at each pipe segment, then making the appropriate adjustment at each drain inlet or catch basin. In this example, the entire process is additive, because you're working upstream.

4. Solution — Set the invert elevations and rim elevations of drain inlet and catch basins and invert elevation at endwall and top of endwall elevation.



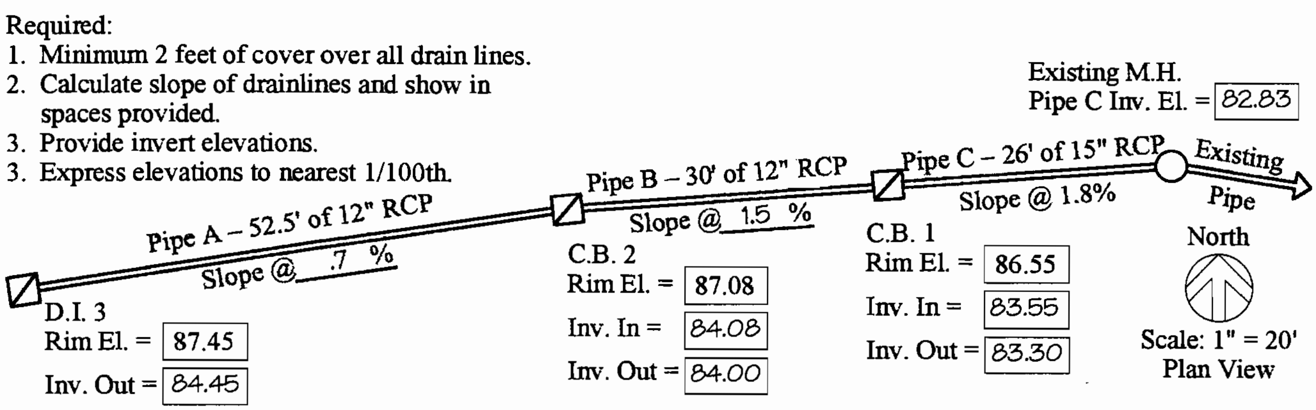
Problem 4 Solution

Problem 4 begins at the known invert elevation out of 92.45 at the endwall. The solution is developed in the same manner as in the previous invert elevation problems.

Problem 4 also features the condition described above where two pipes of the same size enter a drain inlet. Note that the difference in size between both pipes A and B, and pipe C, is 12-inches. Therefore, 12-inches is applied to compensate for head loss:

$$93.20 + 1 = 94.20$$

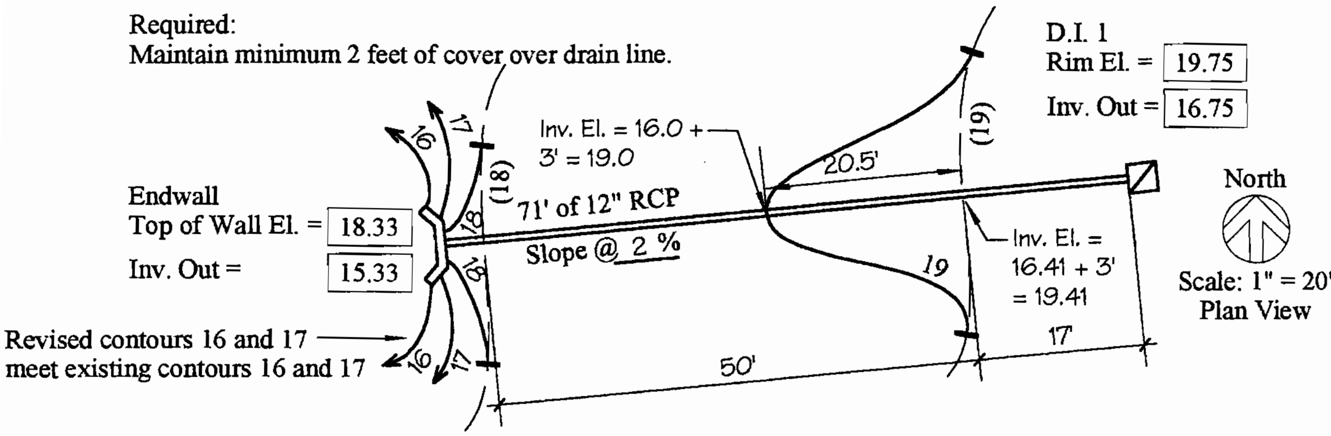
5. Solution — Set invert elevations of drain inlet, catch basins and manhole, and determine slopes of pipes A and B.



Problem 5 Solution

Problem 5 begins at the known rim elevation of 87.45 at D.I. 3, requiring that 3-feet be subtracted to determine the invert elevation out. The solution is developed in the same manner as before.

6. Solution — Manipulate contours as necessary to ensure required cover over 12-inch RCP drainline; determine slope of pipe.



Problem 6 Solution

The first step is to determine the slope of the pipe. Begin by finding the difference in elevation between the invert elevation out at the endwall and the invert elevation out at D.I. 1:

$$16.75 - 15.33 = 1.42$$

Then, using the grade formula, find the slope of the pipe:

$$G = \frac{D}{L} = \frac{1.42}{71} = .02$$

Note that the space for slope of the pipe provides a percentage sign (grade expressed as 2%). On problems of this type, the goal is to determine whether the cover over the drainline where contour lines, or other fixed points of known elevation, meets the requirements. For problem 6, the required cover is 2-feet. Since the pipe size is 12-inches, the total difference in elevation between the invert elevation and the surface is 3-feet.

To determine if the cover is sufficient at contour 19, scale from any known invert elevation. In this case, D.I. 1 will be used. Its invert elevation out is 16.75, and the length to contour 19 is 17-feet. (The endwall could also have been used, since it also has a known invert elevation.) Using the difference formula, find the invert elevation at contour 19:

$$G = .02 \quad L = 17 \text{ feet}$$

$$D = G\,L = (.02)\,(17) = .34 \text{ difference in elevation}$$

Since contour 19 is down stream from D.I. 1, the difference in elevation will be subtracted to find the invert elevation where contour 19 crosses the drainline:

$$16.75 - .34 = 16.41$$

Next add 3-feet (the cover plus the pipe size) to 16.41 to determine if the cover is sufficient:

$$16.41 + 3 = 19.41$$

The answer reveals that the cover is not sufficient, by a shortfall of .41 (the difference between 19 and 19.41). Therefore, it will be necessary to manipulate contour 19 toward the endwall (down slope) some amount to secure the needed cover. As explained above, the quickest way to do this is to use the length formula to determine exactly how far contour 19 must be moved. Substitute in the amount of the shortfall and the grade:

$$D = .41 \quad G = .02$$

$$L = \frac{D}{G} = \frac{.41}{.02} = 20.5 \text{ feet}$$

Scale 20.5-feet down slope from contour 19 and place a tick mark. That is the point that contour 19 must deflect to as shown above. Optional: test this solution to see if the coverage goal was met. Find the total length from D.I. 1 to the new contour 19 crossing point:

$$17 + 20.5 = 37.5$$

Once again using the difference in elevation formula, substitute in the new length and the grade:

$$G = .02 \quad L = 37.5 \text{ feet}$$

$$D = G\,L = (.02)\,(37.5) = .75 \text{ difference in elevation}$$

Subtract .75 from the invert elevation out at D.I. 1 to determine the new invert elevation:

$$16.75 - .75 = 16.00$$

Now, add 3-feet (the cover plus the pipe size) to 16.00 to determine if the cover is sufficient:

$$16.00 + 3 = 19.00$$

The cover is sufficient.

The next step will be to determine whether the elevation at contour 18 has sufficient cover. To determine this, scale once again from D.I. 1. The length to contour 18 is 17-feet + 50-feet as shown on the solution sketch, for a total of 67-feet. Substitute in the slope of the pipe and the length:

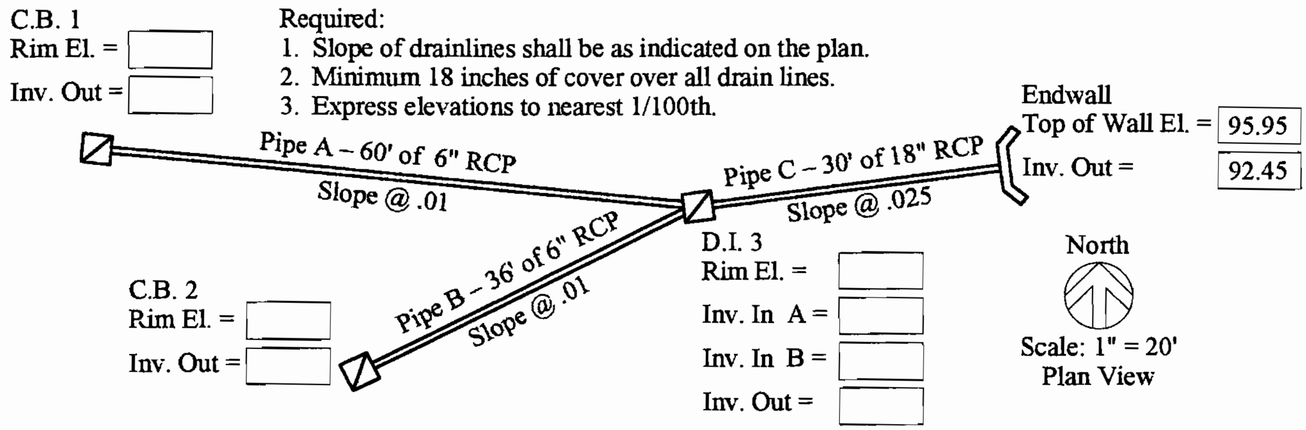
$$D = G \times L \qquad D = .02 \times 67 \qquad D = 1.34$$

Since contour 18 is down stream from D.I. 1, the difference in elevation will be subtracted to find the invert elevation where contour 18 crosses the drainline:

$$16.75 - 1.34 = 15.41$$

4. Set the invert elevations and rim elevations of drain inlet and catch basins and invert elevation at endwall and top of endwall.

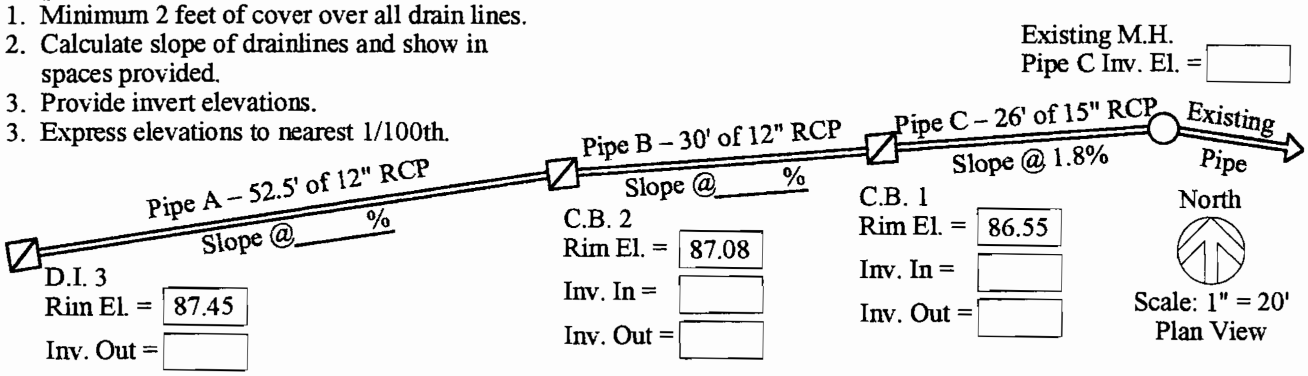
Required:
1. Slope of drainlines shall be as indicated on the plan.
2. Minimum 18 inches of cover over all drain lines.
3. Express elevations to nearest 1/100th.



Problem 4

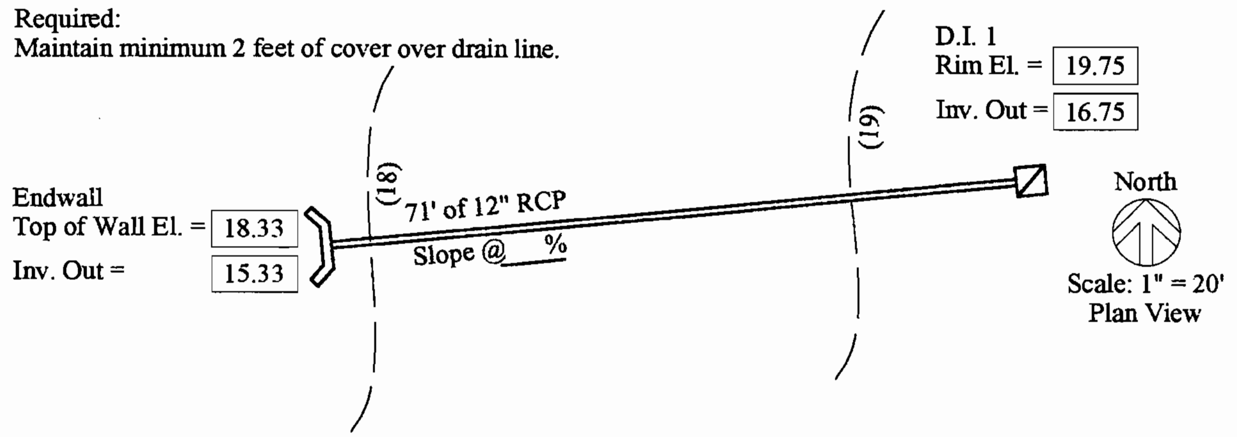
5. Set invert elevations of drain inlet, catch basins and manhole; determine slopes of pipes A and B.

Required:
1. Minimum 2 feet of cover over all drain lines.
2. Calculate slope of drainlines and show in spaces provided.
3. Provide invert elevations.
3. Express elevations to nearest 1/100th.



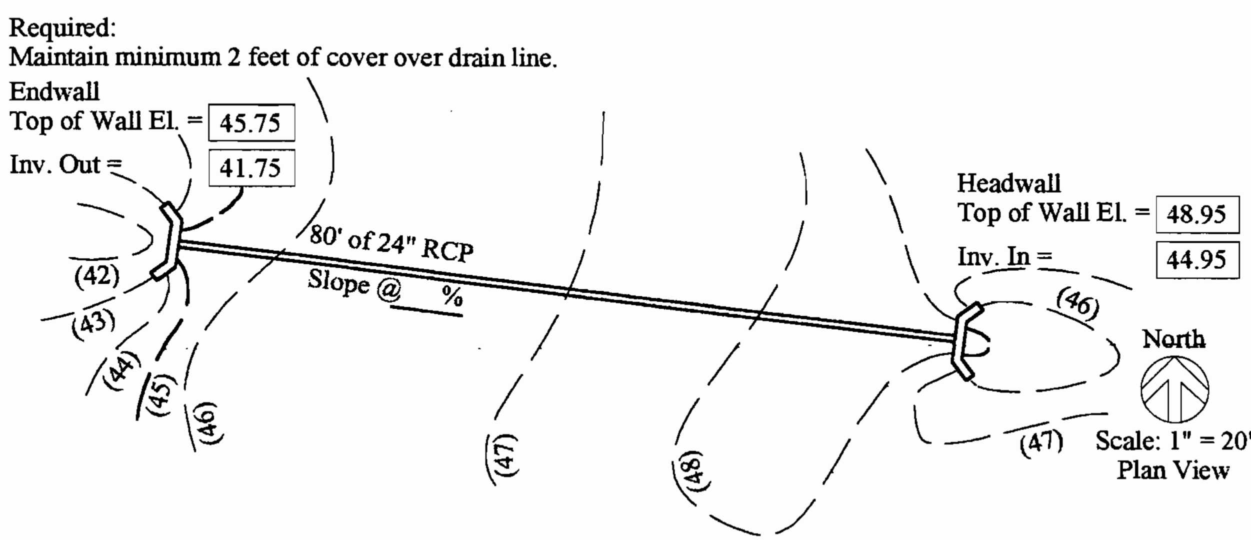
Problem 5

6. Manipulate contours as necessary to ensure required cover over 12-inch RCP drainline; determine slope of pipe.



Problem 6

7. Manipulate contours as necessary to ensure required cover over 24-inch RCP drainline; determine slope of pipe.



Problem 7

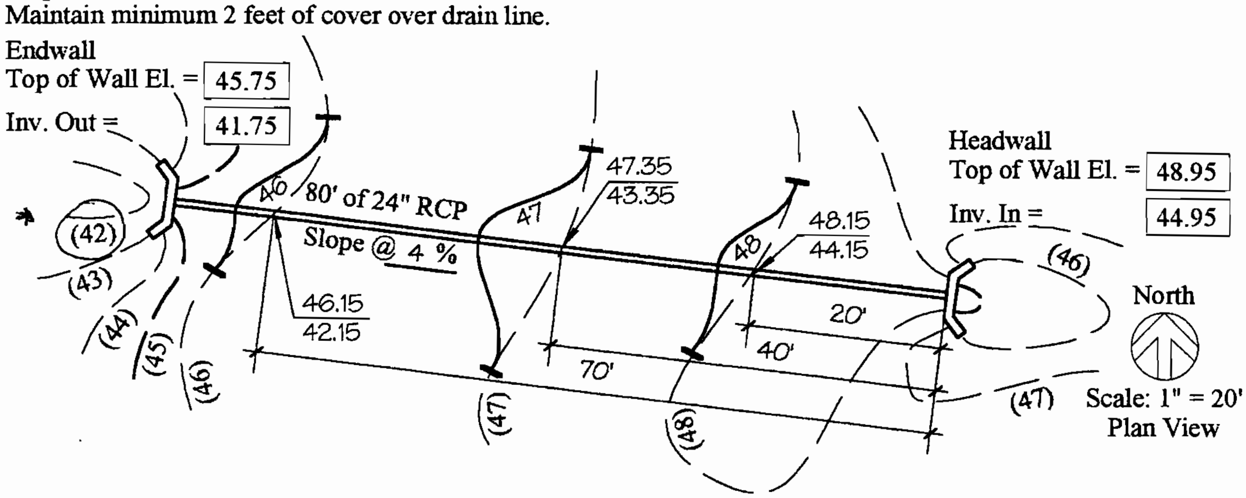
Now, add 3-feet (the cover plus the pipe size) to 15.41 to determine if the cover is sufficient:

$$15.41 + 3 = 18.41$$

The answer reveals that once again the cover is not sufficient. The shortfall is .41-feet (the difference between 18 and 18.41). Therefore, it will be necessary to manipulate contour 18. The easiest solution — one that requires no calculation — is to simply manipulate contour 18 to meet the back of the endwall, as shown on the solution sketch. This completes the solution.

7. Solution — Manipulate contours as necessary to ensure required cover over 24-inch RCP drainline; determine slope of pipe.

Required:
Maintain minimum 2 feet of cover over drain line.

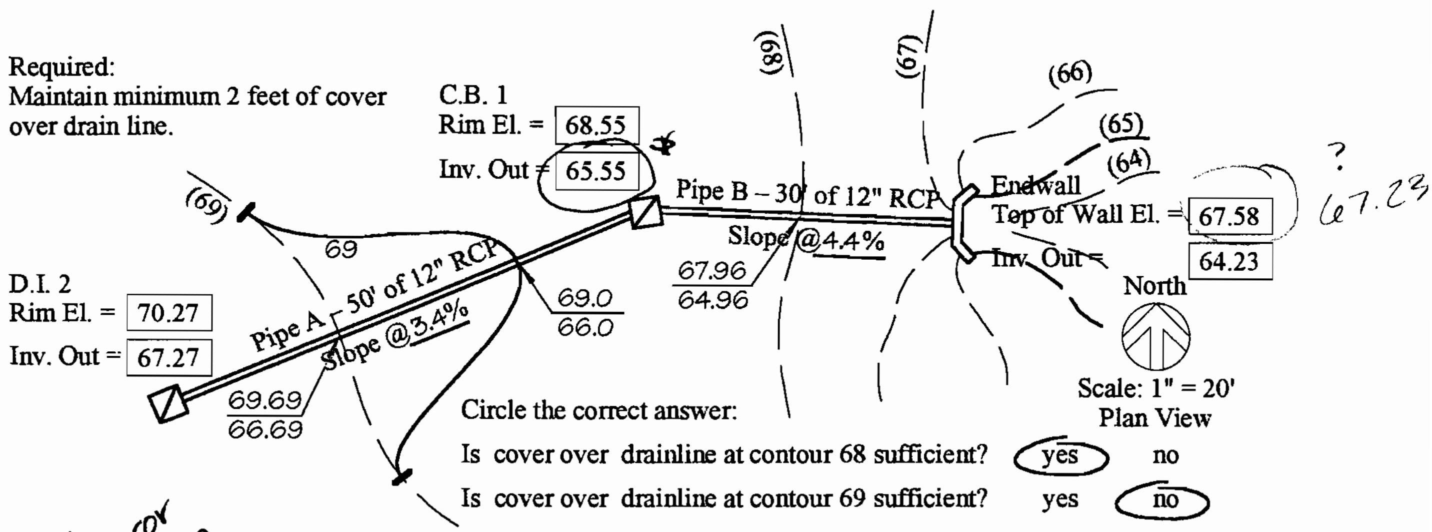


Problem 7 Solution

The solution to exercise 7 follows a pattern similar to the previous problem. The numbers that appear at each contour crossing point are, from *bottom to top*, the calculated invert elevation of the pipe, and the invert elevation plus the sum of the required cover and pipe size added. (This convention will be used typically on the remaining exercises.) At contour 48 for example, the top number, 48.15, reveals that there is a coverage shortfall of .15, therefore contour ~~15~~ 48 must be manipulated to increase cover, as shown in the solution sketch.

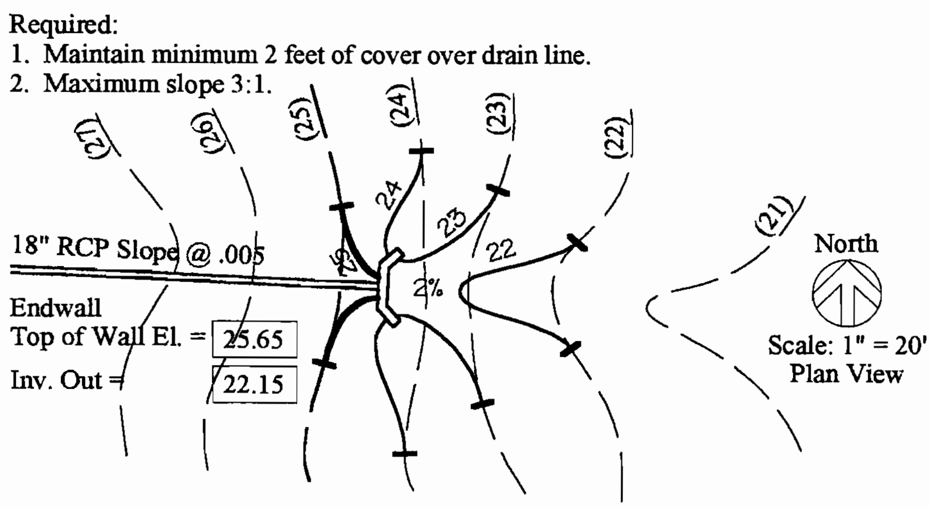
CONTOUR 42 HAS TO GO INTO THE WALL & ANOTHER HAS TO GO ... BE ADDED

8. Solution — Answer the questions concerning cover over contours 68 and 69. If either or both contours have insufficient cover, revise the existing contours to correct.



Problem 8 Solution

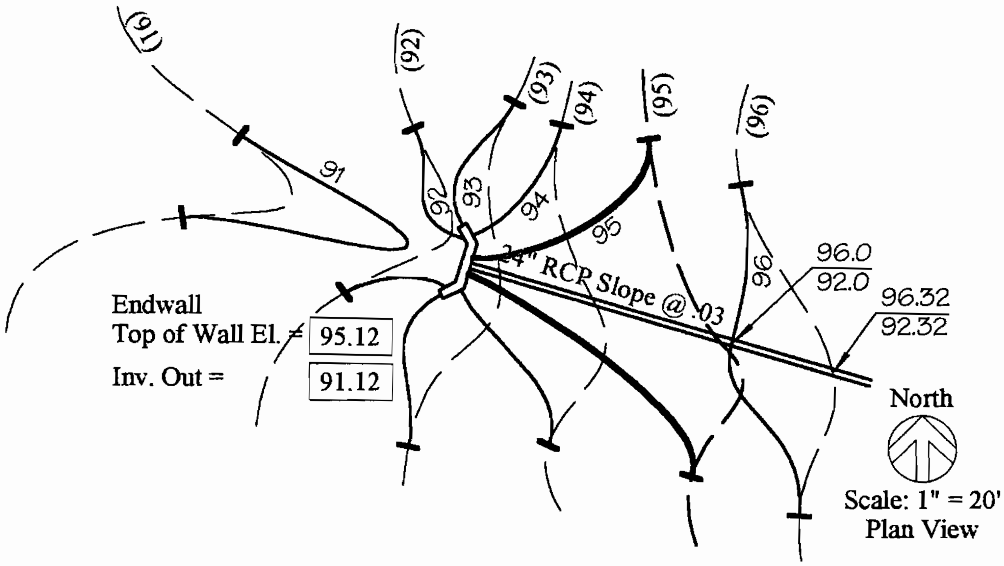
9. Solution — Manipulate existing contour lines as necessary to site new endwall and ensure that there is sufficient cover over 18" RCP drainline.



Problem 9 Solution

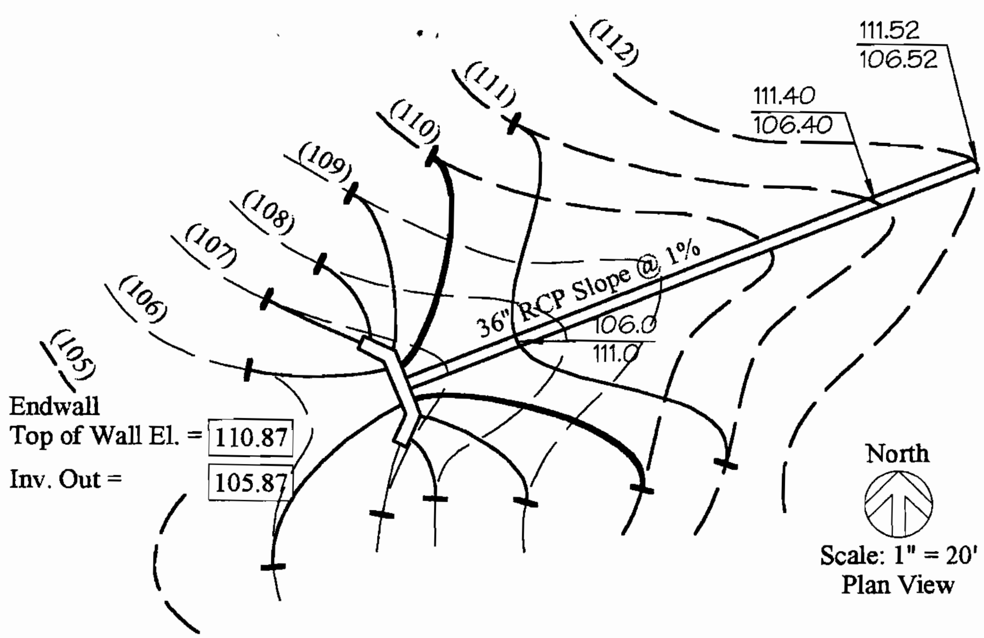
The key to solving headwall and endwall problems is to look carefully at the invert elevation out and top of wall elevations, and then determine which contours must be manipulated to grade the wall. For exercise 9, the top of the wall is higher than contour 25, but lower than contour 26, therefore contour 25 must meet the wall. The invert elevation is just above contour 22, therefore contour 22 will not meet the wall. In this case, the flowline was calculated at 2%, which should be considered the minimum grade.

10. Solution — Manipulate existing contour lines as necessary to site new endwall and ensure that there is sufficient cover over 24" RCP drainline.



Problem 10 Solution

11. Solution — Manipulate existing contour lines as necessary to site new endwall and ensure that there is sufficient cover over 36" RCP drainline.



Problem 11 Solution

Chapter 6
Breadth Subjects

The June 2006 administration of the exam began a new exam cycle, which brings with it some unanswered questions regarding content. This Chapter is provided to prepare you for several possible content additions to a future exam administration.

Review the information on the new exam provided by CLARB in the document entitled *Introduction to the LARE Section E Workshop,* which was included in pre-review mailing. Review in particular *The Landscape Architect Registration Examination Content Guide*

http://www.clarb.org/documents/2006content.pdf

and *The Landscape Architect Registration Examination Specifications*

http://www.clarb.org/documents/2006specs.pdf

CUT AND FILL CALCULATIONS — TWO METHODS

Task number 14 states: "Prepare earthwork calculations," which translated means cut and fill calculations. Cut and Fill calculation problems could take several possible forms. The most likely being where you're provided with areas of either sections, where you would be required to use the Average End Area method for determining the volume of cut or fill, or areas in plan view between existing and revised contour lines where you would be required to use the planimeter method for determining the volume of cut or fill.

Average End Area Method

The *average end area method* is used to find the volume of cut or fill, in cubic yards for linear areas, such as roads, etc. It is based on the assumption that volumes are prismoidal masses, meaning masses that have depth, height and length. In the context of the *average end area method,* a prismoid is a volume with parallel ends that have different areas. Figure 6-1 shows areas of cut. Notice that the areas in this case are measured in square inches, and that the sections are 50-feet apart. If you were to convert the square inches to square feet, and multiply those square feet by 50-feet, you would know the approximate volume of earth in that one area of cut. That is the premise of the Average End Area Method.

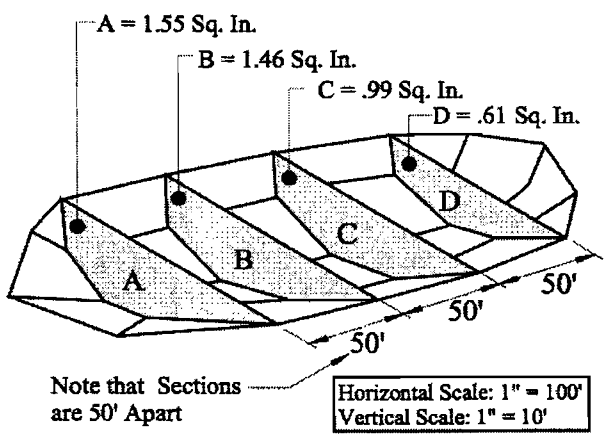
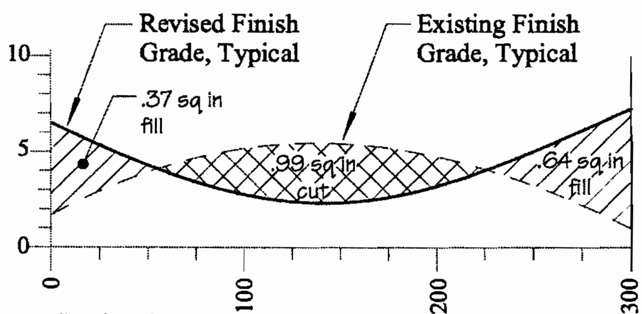


Figure 6-1. Cut Excavation, Average End Area Method

Procedure: For the LARE, since the examinee cannot be expected to have the means for measuring areas, these would have to be provided. Note that the area to be calculated is made up of cross-sectional profiles at equal intervals — in this example at 50 feet on center — as shown in Figure 6-1. This is important to note, because it is taken into account in calculating the volume. Also note that in the section shown in Figure 6-2, this particular section is identified as 1+00 (the C corresponds to Section C shown in Figure 6-1) The 1+00 follows the standard engineering convention for expressing lineal lengths. 0+00 is always the starting point. 0+50 equals 50-feet, 1+00 equals 100-feet, 1+62 equals 162-feet, 5+23.75 equals 523.75-feet, and so on. In other words, simply removing the plus sign yields the lineal measurement. The sections typically consist of both the existing finish grade and the proposed finish grade. In the average end area method, because the measurements are shown as sections, it's easy to differentiate between areas of cut and fill. Figure 6-2 shows a typical section, and the calculation used to convert square inches into square feet. Note that sections of cut, and sections of fill, are calculated separately.



Section C, 1+00

Vertical Scale: 1" = 10'
Horizontal Scale: 1" = 100'

Multiplier:
(100) (10) = 1000

Fill:
.37 + .64 = 1.01
(1.01) (1000) = 1010 sq ft of fill

Cut:
(.99) (1000) = 990 sq ft of cut

Figure 6-2. Typical Average End Area
Section With Sq In to Sq Ft Calculation

An important first step is to note the units. If the section areas are given in square inches, as they are in this example, it will be necessary to convert them to square feet by multiplying them by a conversion factor. To determine the conversion factor, *multiply the horizontal scale times the vertical scale* (note that the vertical scale is customarily exaggerated to enable measurement). The resulting product is the factor you will multiply by to convert the area to square feet. Substitute these square footages into the formula shown below in Figure 6-3. The procedure is identical for both cut and for fill.

Average End Area Method Example

Note that there is a so-called textbook Average End Area Method formula that most of us were exposed to in school. I was. Being lazy, I began pondering this cumbersome formula, wondering if all this adding and dividing was really necessary. You already know the answer. The shortcut formula shown below yields exactly the same result as does the traditional method but with 1/3 the steps and in less than 1/3 the time. For the record, here's the traditional textbook version:

$$V = i\left(\frac{A}{2} + \frac{A+B}{2} + \frac{B+C}{2} + \frac{C+D}{2} + \frac{D}{2}\right)$$

And here's the corresponding shortcut version:

$V = i(A + B + C + D)$ Really! That's all there is to it; both yield exactly identical answers.

Here's what the terms of the formula represent.

V = volume of soil in cubic yards

i = interval between sections

a, b, c and d. These letters represent arbitrary labels used here to identify the sections, which correspond to those shown in Figure 6-1. These could also be numerical labels, such as the stations described above, and the number of sections that are to be calculated can certainly vary.

In the first step noted above, we observe that the units in this case are in square inches. Therefore, they will need to be converted to square feet. Had they already been expressed in square feet, this step would be omitted. Multiplying the horizontal scale by the vertical scale:

$$(100)(10) = 1000$$

Therefore, the multiplication factor is 1000. Multiplying each of the square inch areas by the factor yields the following areas in square feet respectively:

Section A: (1.55) (1000) = 1550 Sq. Ft.
Section B: (1.46) (1000) = 1460 Sq. Ft.
Section C: (.99) (1000) = 990 Sq. Ft.
Section D: (.61) (1000) = 610 Sq. Ft.

Example solution using the shortcut formula based on the numbers shown above:

$$V = i(A + B + C + D) = 50(1550 + 1460 + 990 + 610) = (50)(4610) = 230{,}500 \text{ cubic feet of cut}$$

Note that the sum of the square footages was multiplied by 50 — that's the *i* in the formula. Don't neglect this crucial step (it's a common omission).

Next, be aware that volumes of earth are always expressed in cubic yards. Therefore, since the volume so far is in cubic feet, it will be necessary to divide 230,500 by 27 to convert to cubic yards (27 is based on three raised to the third power, or 3^3).

$$230500 \div 27 = 8{,}537 \text{ cubic yards of cut}$$

The Planimeter Method

Of the two methods for determining the volume of cut and fill described in this Section, the Planimeter Method is by far the faster, at least in the 'real world' because sections don't have to be drawn as a first step. However, on the exam, it's probably a moot point since the measurements will have to be provided anyway. In the Planimeter Method, notice that the contour interval is accounted for rather than the horizontal length between sections. The volume is based on areas that are the thickness of the contour interval — usually one-foot — measured directly off a topographic site plan. See Figure 6-3. On the exam, a similar graphic could be used as a means of providing the area measurements. Again, just as with the Average End Area Method, the measurements could be in either square inches or in square feet, so be sure to check carefully.

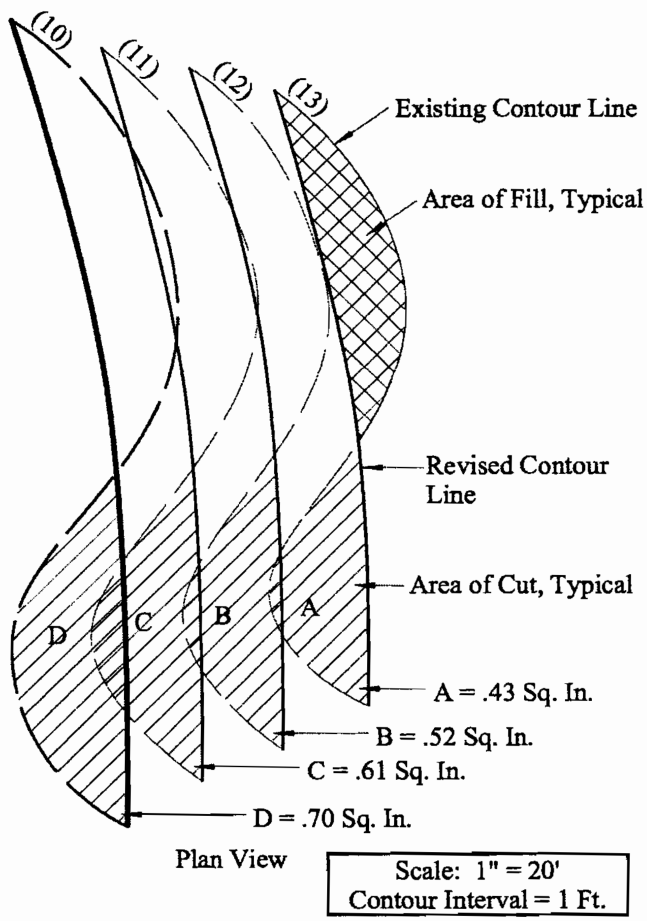


Figure 6-3. Planimeter Method Example

Procedure: In this method, as with the Average End Area Method, both areas of cut and areas of fill are calculated separately. The first step will be to identify the areas of cut and fill. Because the areas of cut and fill are viewed in plan view, differentiating between them is not as easy as it is in the average end area method where you're viewing them as sections. Here's a quick, sure way, to determine which is cut, and which is fill: Look at any *revised contour* and its relationship with its existing contour counterpart. If the revised contour moves into, or toward the high side of the existing contour, it is an area of cut; if it moves away from, or toward a lower contour, it is an area of fill. Use care in doing this so you don't confuse cut with fill. Once you're certain of which is which, note areas of cut with a "C" and areas of fill with a "F" to avoid later confusion.

The formula used for the Planimeter Method is functionally identical to that used for the Average End Area Method. The only difference is that the rather that using *i* to account for the interval between sections, *ci* is used to account for contour interval. Here's the traditional formula:

$$V = ci\left(\frac{A}{2} + \frac{A+B}{2} + \frac{B+C}{2} + \frac{C+D}{2} + \frac{D}{2}\right)$$

And here's the corresponding shortcut version:

$$V = ci\left(A + B + C + D\right)$$

In the Planimeter Method, the first step will be to convert square inches into square feet. Had they already been expressed in square feet, this step would be omitted. Since in this example areas have been given in square inches, they'll need to be multiplied by a conversion factor that is conceptually similar to that used for the Average End Area Method. In this case, since the scale and contour interval are at a 1:1 ratio, simply square the scale. The scale is one inch = 20-feet, therefore, the factor will be twenty squared:

$$20^2 = 400$$

Multiplying each of the areas given in square inch of cut shown in Figure 6-3 by 400 yields the following areas in square feet respectively:

Section A: $(.43)(400) = 172$ Sq. Ft.
Section B: $(.52)(400) = 208$ Sq. Ft.
Section C: $(.61)(400) = 244$ Sq. Ft.
Section D: $(.70)(400) = 280$ Sq. Ft.

Example solution using the shortcut formula based on the numbers shown above:

$$V = ci\left(A + B + C + D\right) = 1\left(172 + 208 + 244 + 280\right) = (1)(904) = 904 \text{ cubic feet of cut}$$

Note that in this case, since the contour interval is one foot, the total number of square feet is multiplied by one, so the number of square feet remains unchanged. Always verify the contour interval. If it is other than one, multiply the sum of the square feet by whatever it is.

Next, the volume must be expressed in cubic yards. Therefore, since the volume so far is in cubic feet, it will be necessary to divide 230500 by 27 to convert to cubic yards (27 is based on three raised to the third power, or 3^3).

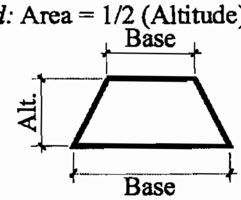
$$904 \div 27 = 33.5 \text{ cubic yards of cut}$$

COMMON FORMULAS FOR FINDING AREA

Figure 6-4 shows formulas for finding the areas of common geometric shapes. The following formulas may be used to find the area of geometric shapes. Figure 7-28b shows formulas for finding the area of a circle, and the circumference of a circle.

Rectangle And Parallelogram: Area = (Base) (Altitude)

Area of Trapezoid: Area = 1/2 (Altitude) (Sum of Bases)



Area of Right Triangle or Any Triangle: Area = 1/2 (Base) (Altitude)

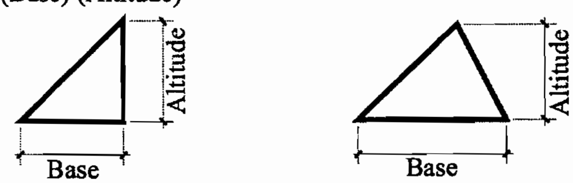


Figure 6-4. Formulas for Finding Areas of Common Geometric Shapes

Figure 6-5 shows the formula for finding the area of a circle, and the formula for the circumference of a circle.

Area of Circle: Area = (π) (Radius ^{2})

Circumference of Circle: Circ. = (2) (π) (R)

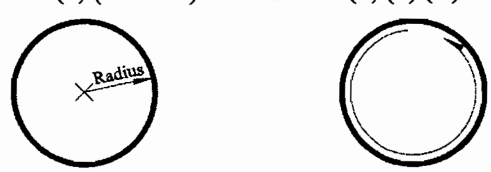


Figure 6-5. Circle Area and Circumference Formulas

Chapter 7
Large-Scale Exercises

CHAPTER SEVEN EXERCISES

Large-scale exercises begin on the following page. Instructions for each exercise are given on the problem pages. To help develop good test-taking habits, treat these exercises as if they were miniature LARE vignettes — that is, read each problem statement with the same care and thoroughness you would if it were the actual exam.

Note regarding those exercises that require manipulation of contour lines: Although your solution will invariably be different from the solutions shown owing to the variability of how contour lines have been drawn, your solution may be just as correct as that shown on the following pages. Look at the solutions given to self-evaluate your solution.

Exercsie 1. Grade the walk.

Required:

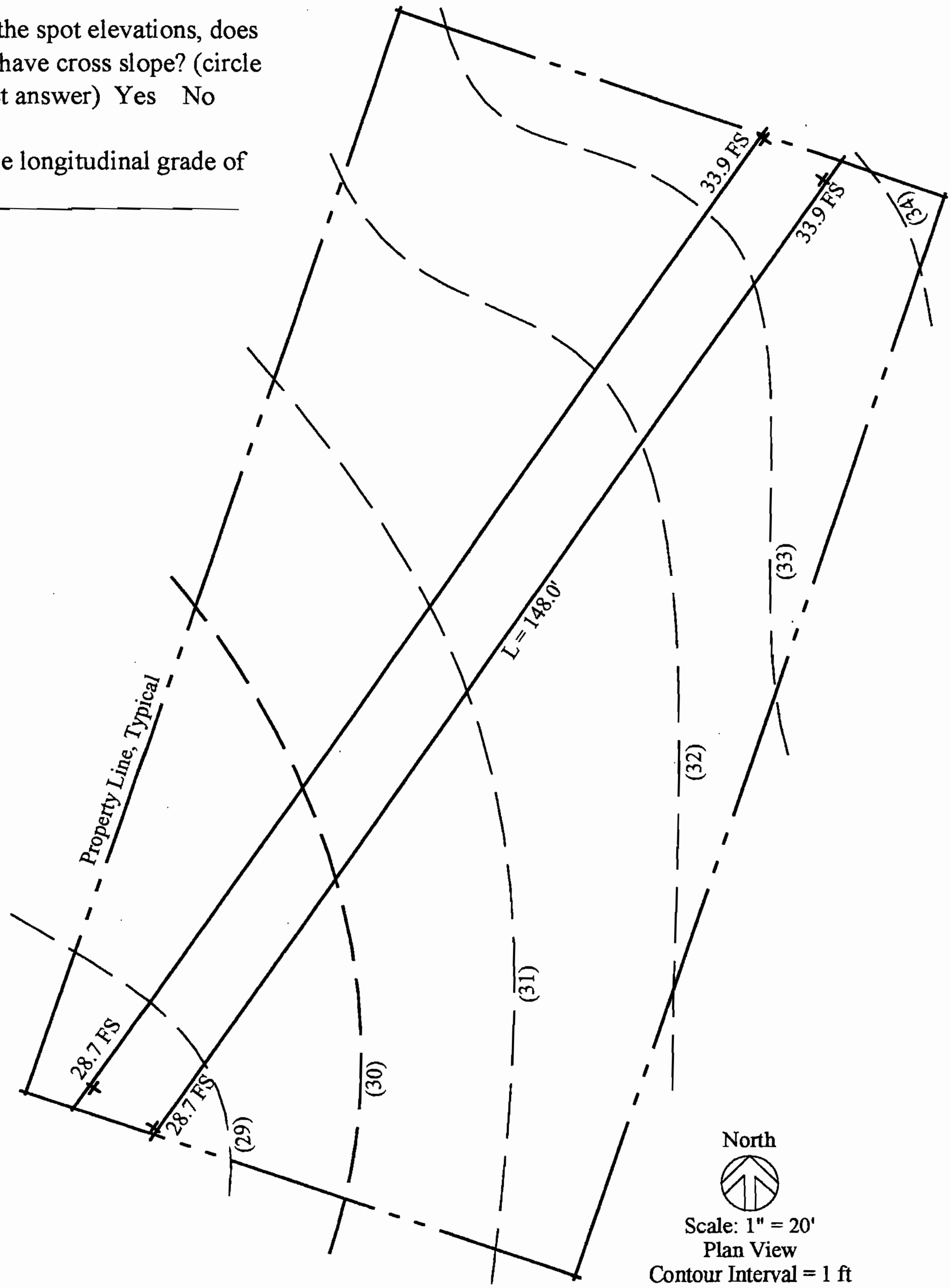
. Show and label all proposed 1 ft contours and meet existing contours within the property lines.

2. Drainage across walk is permitted; a swale is not required.

3. Answer the two questions below:

1. Based on the spot elevations, does this walk have cross slope? (circle the correct answer) Yes No

2. What is the longitudinal grade of the walk?________________



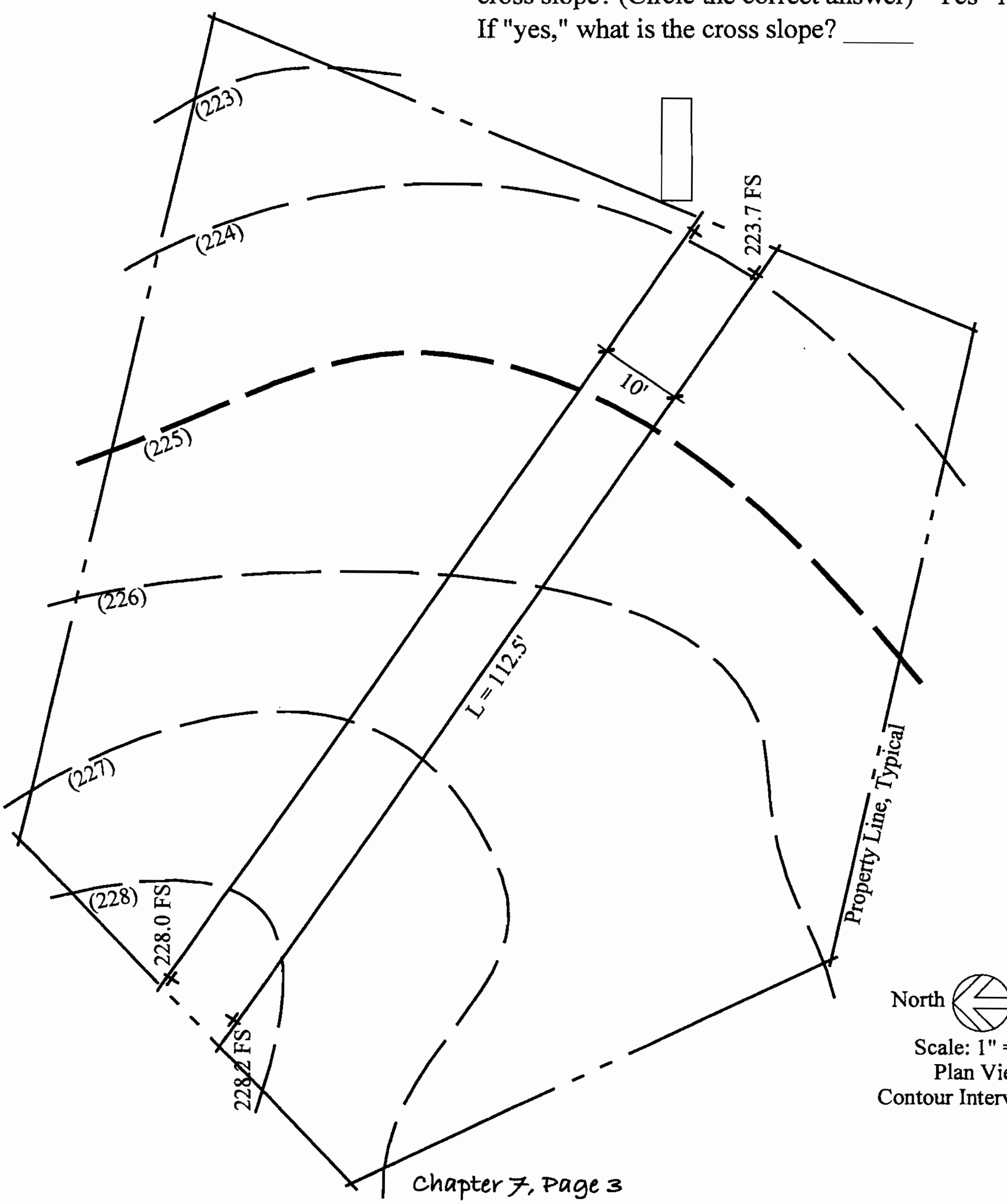
Exercsie 2. Grade the walk shown.

Required:

1. Indicate spot elevation in box provided (to nearest 10th of a foot).
2. Show and label all proposed 1 ft contours and meet existing contours within the property lines.
3. Drainage across walk is permitted; a swale is not required.
4. Answer these questions:

What is the longitudinal grade of the walk? _____

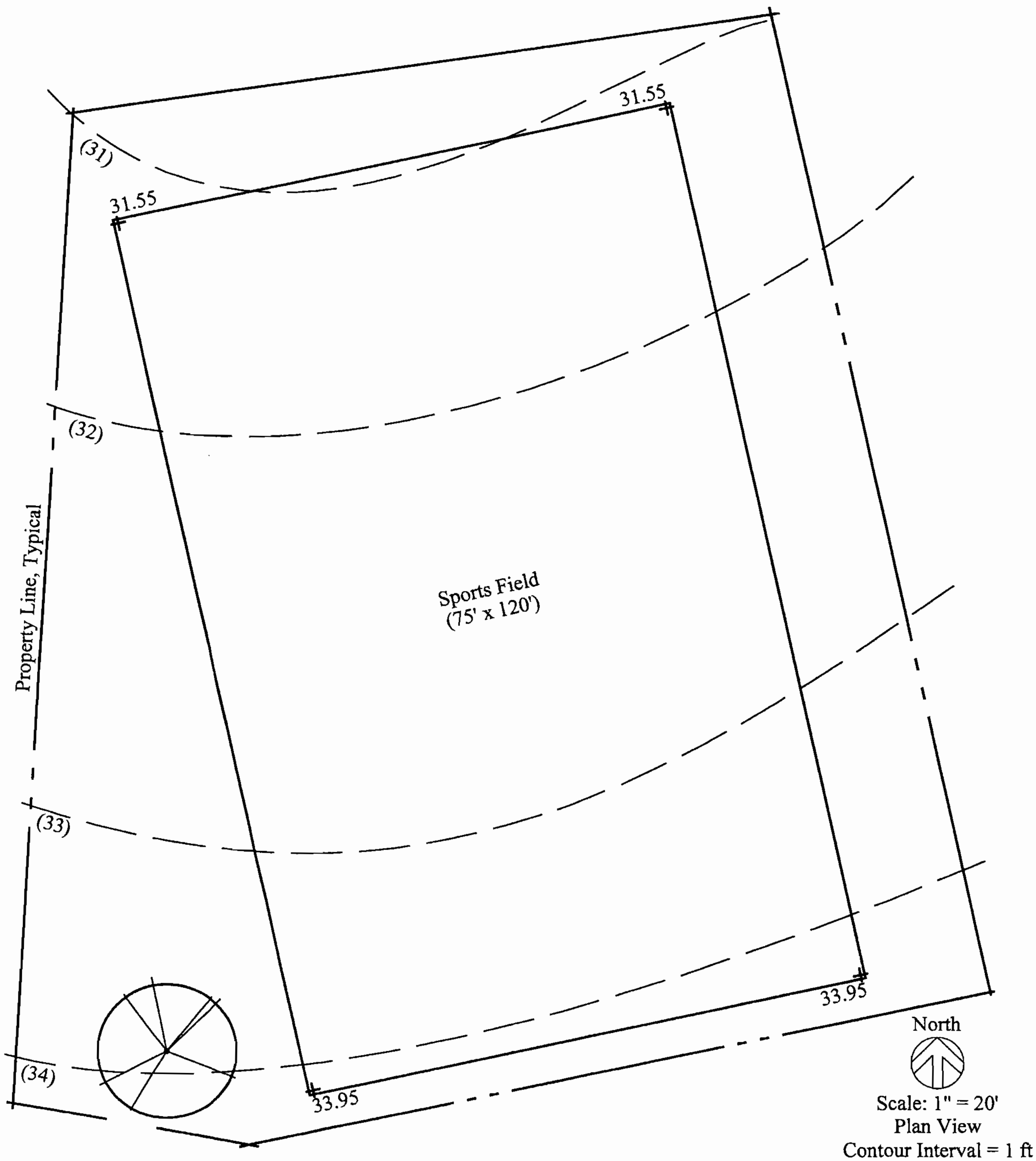
Based on the sopt elevations, does this walk have cross slope? (Circle the correct answer) Yes No
If "yes," what is the cross slope? _____



Scale: 1" = 20'
Plan View
Contour Interval = 1 ft

Exercsie 3. Grade the sports field shown with a straight grade.

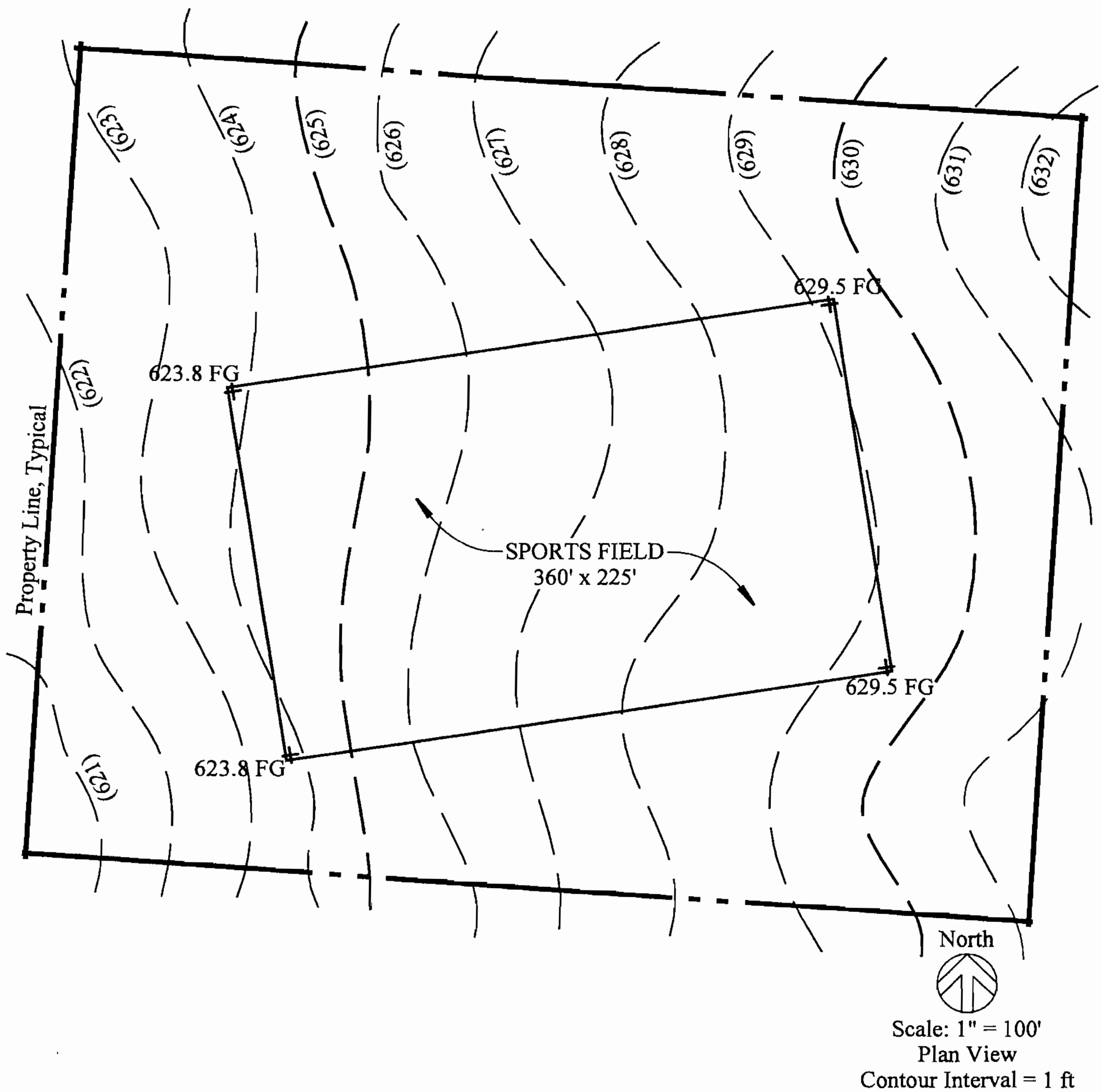
Required:
1. Show and label all proposed 1 ft contours and meet existing contours within the property lines.
2. Drainage onto sportsfield is permitted; a swale is not required.
3. Maximum grade off sportsfield is 10:1.
4. No grading revision permitted within dripline of trees.



Exercsie 4. Grade the sports field shown with a straight grade.

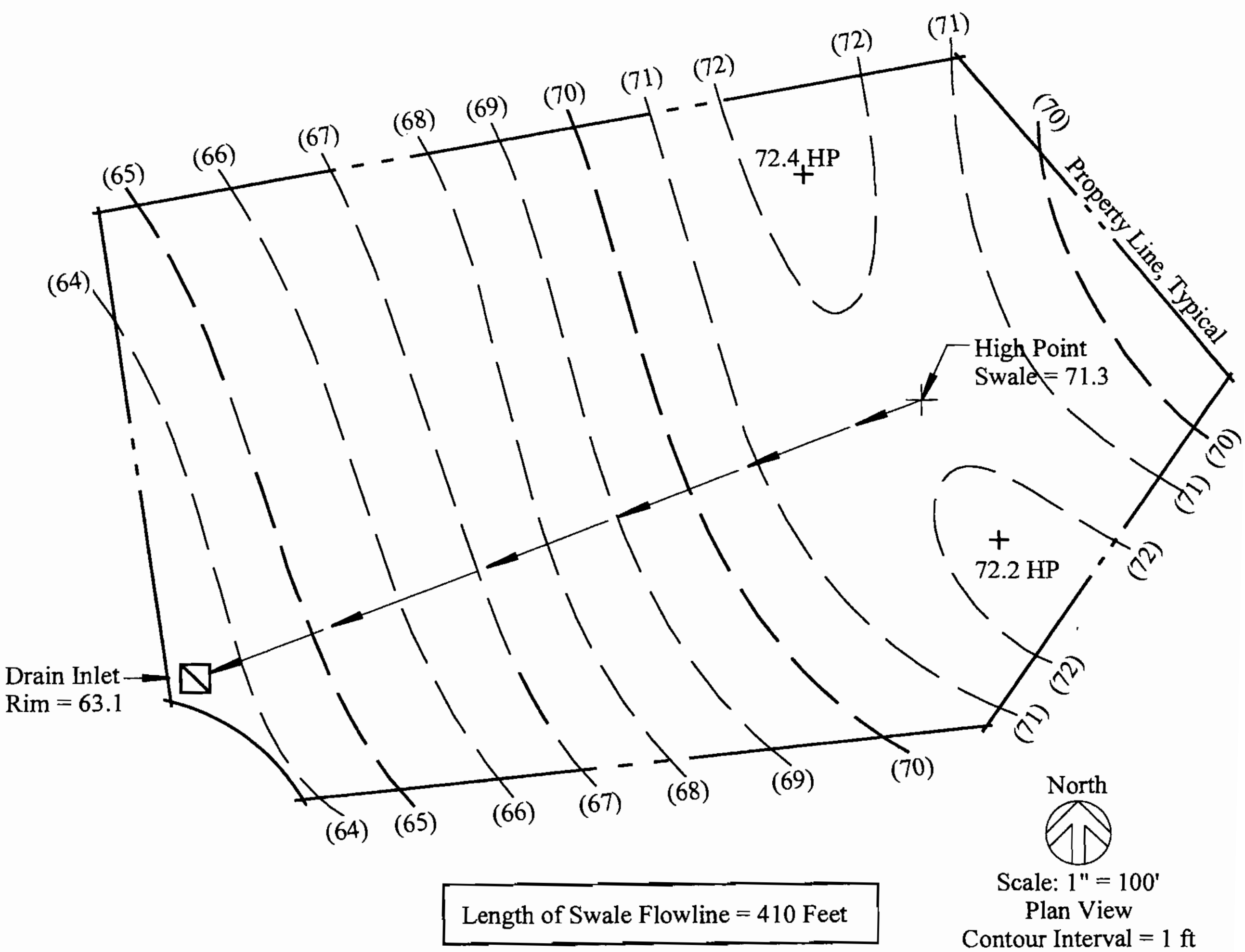
Required:

1. Show and label all proposed 1 ft contours and meet existing contours within the property lines.
2. Drainage onto sportsfield is permitted; a swale is not required.



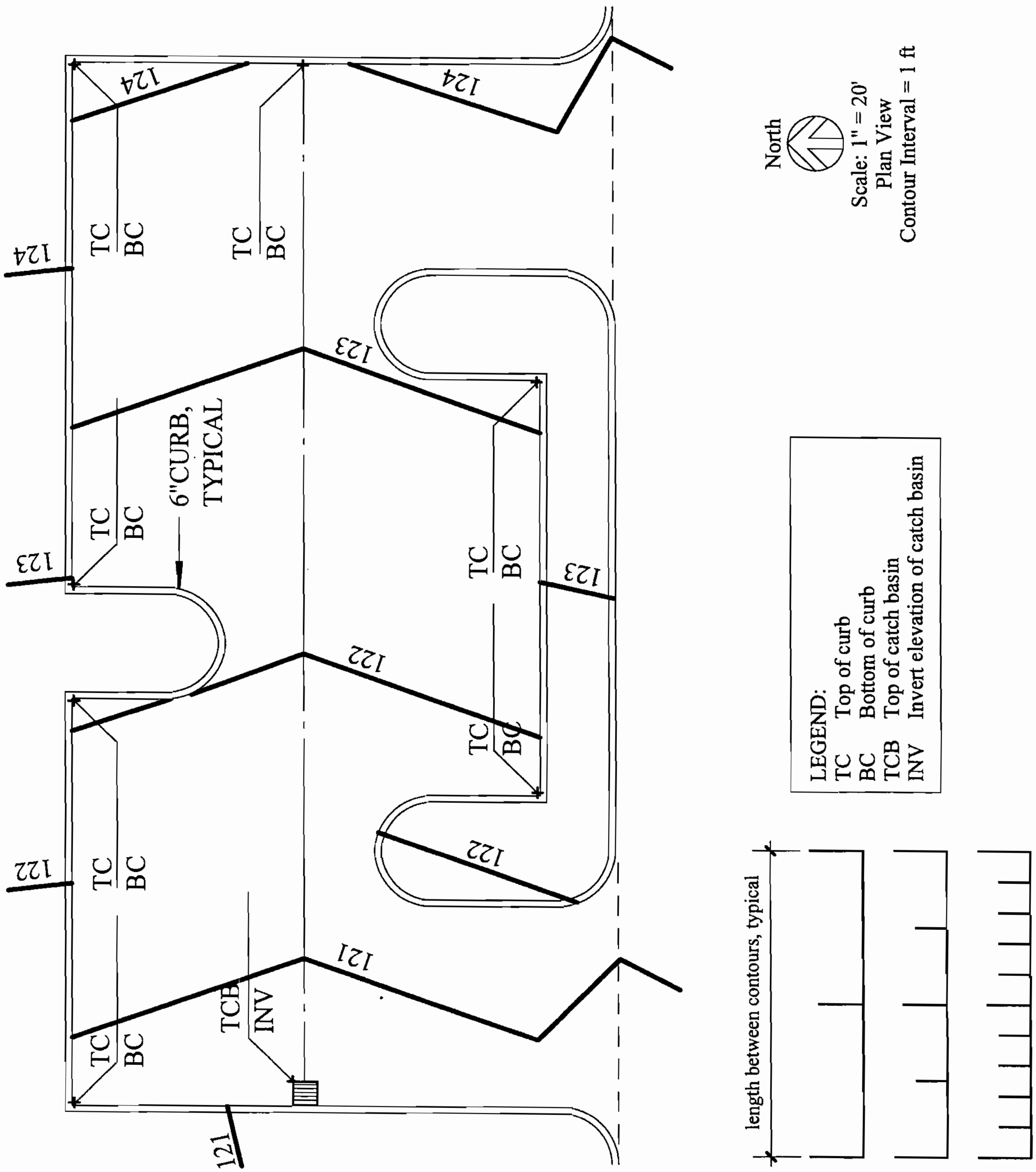
Exercsie 5. Develop a swale on the flowline shown.

Required:
1. Length of the flowline is as shown.
2. All runoff collected by swale is to flow to drain inlet.
3. Swale is to have a minimum flowline slope of 2%, maximum 10%.
4. Show and label all proposed 1 ft contours and meet existing contours within the property lines.



Exercise 6. Using the revised contour lines shown, estimate the elevation of the points shown on the plan.

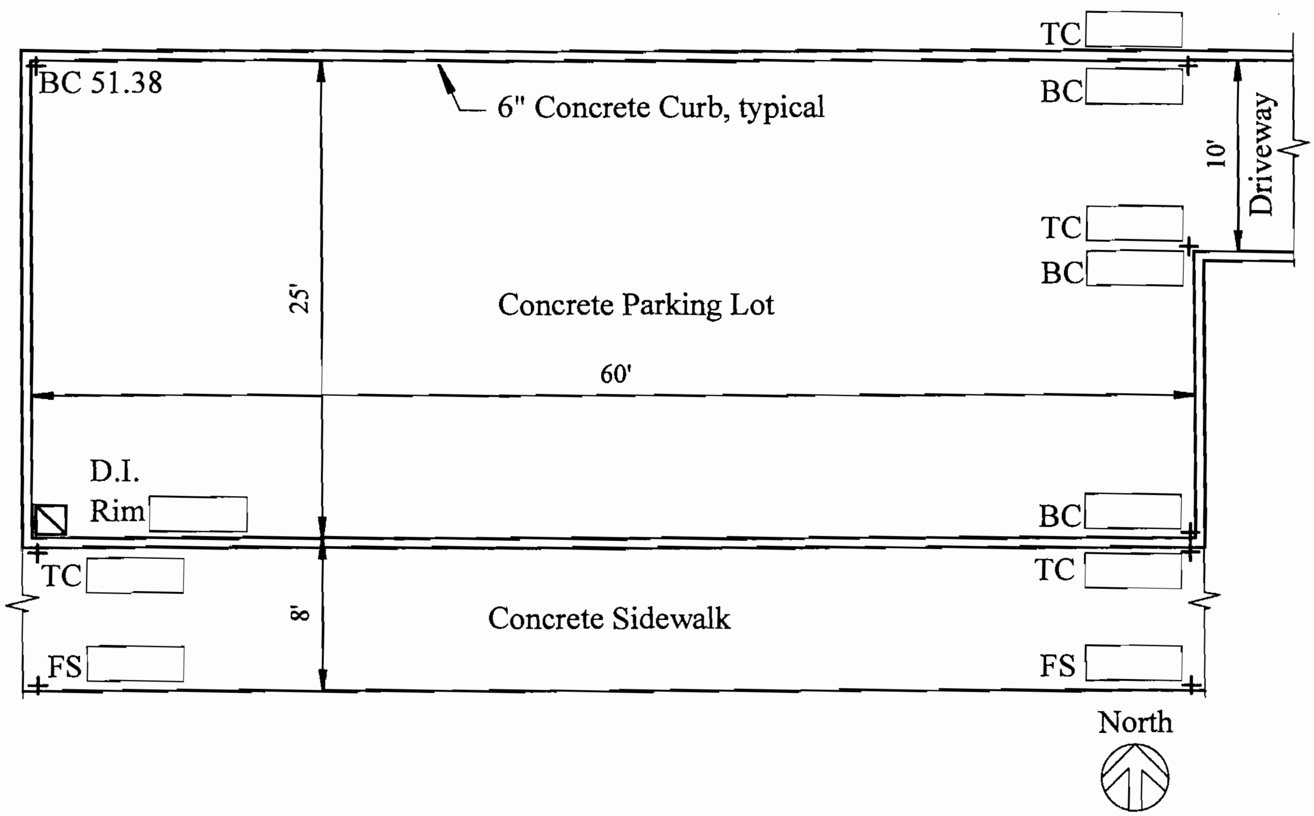
Required:
1. All curbs are concrete, 6 inches high.
2. Required cover over drainline is 2 feet, drainline diameter is 12-inches.



Exercise 7. Grade the parking lot and sidewalk.

Required:

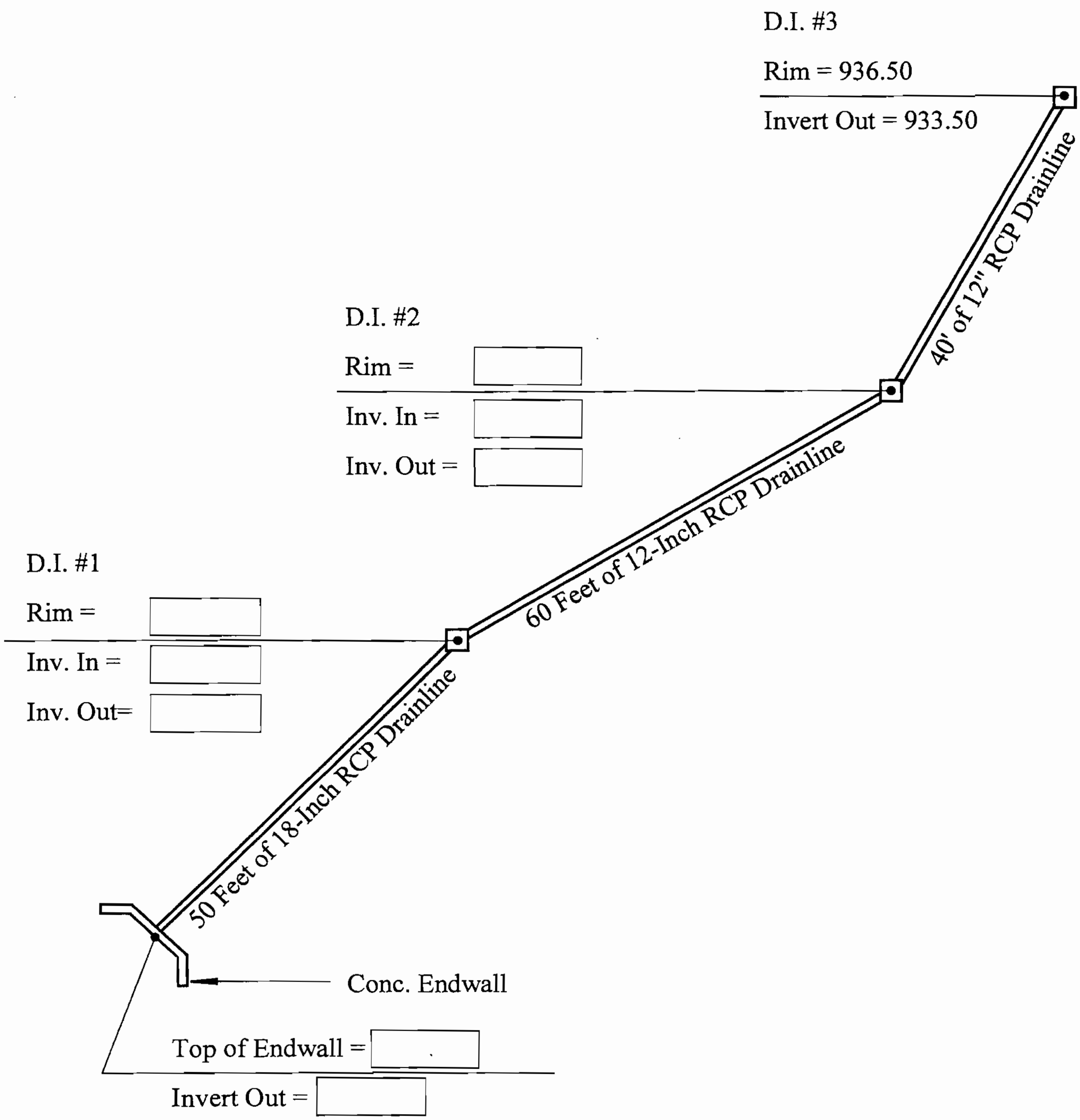
1. Parking lot is to have a longitudinal grade of 4%. Indicate spot elevations in the boxes provided (to the nearest 100th of a ft).
2. Show and label all proposed 1 ft contour lines.
3. Curbs are concrete, 6 in high.
4. Cross slope of parking lot is 2% and cross slope of sidewalk is 1-1/2%.
5. All surfaces shall slope to drain to D.I. in southwest corner of parking lot. Indicate rim elevation of drain inlet.
6. All grades shall be straight grades; plane surfaces shall slope uniformly.



Scale: 1" = 10'
Plan View
Contour Interval = 1 ft

Exercise 8. Design drainage system.

Required:
1. Slope of drainline is to be .01 (1%).
2. Set rim elevations of catch basins to maintain minimum of 2-feet of cover over all drain lines.
3. Adjust inverts at drain inlets to minimize head loss.



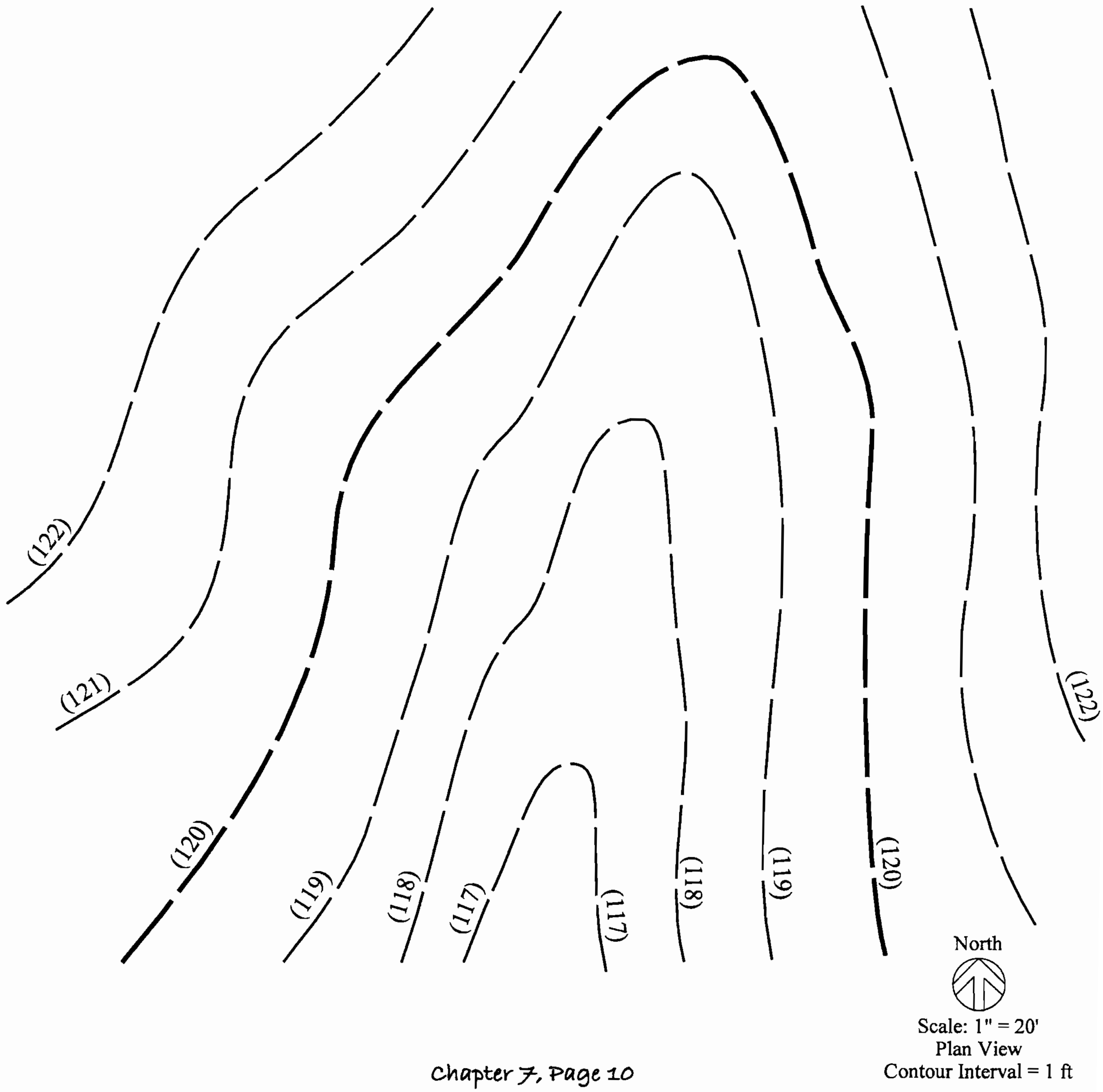
Exercise 9. Grade dam to retain stormwater in retention pond.

Required:

1. Locate a dam to create a retention pond that has an average depth of 2-feet over a surface area of at least 3,500 square feet. (3,500 square feet in the form of a square measures approximately 59-feet by 59-feet, or a circle with a raduis of approximately 34-feet.)

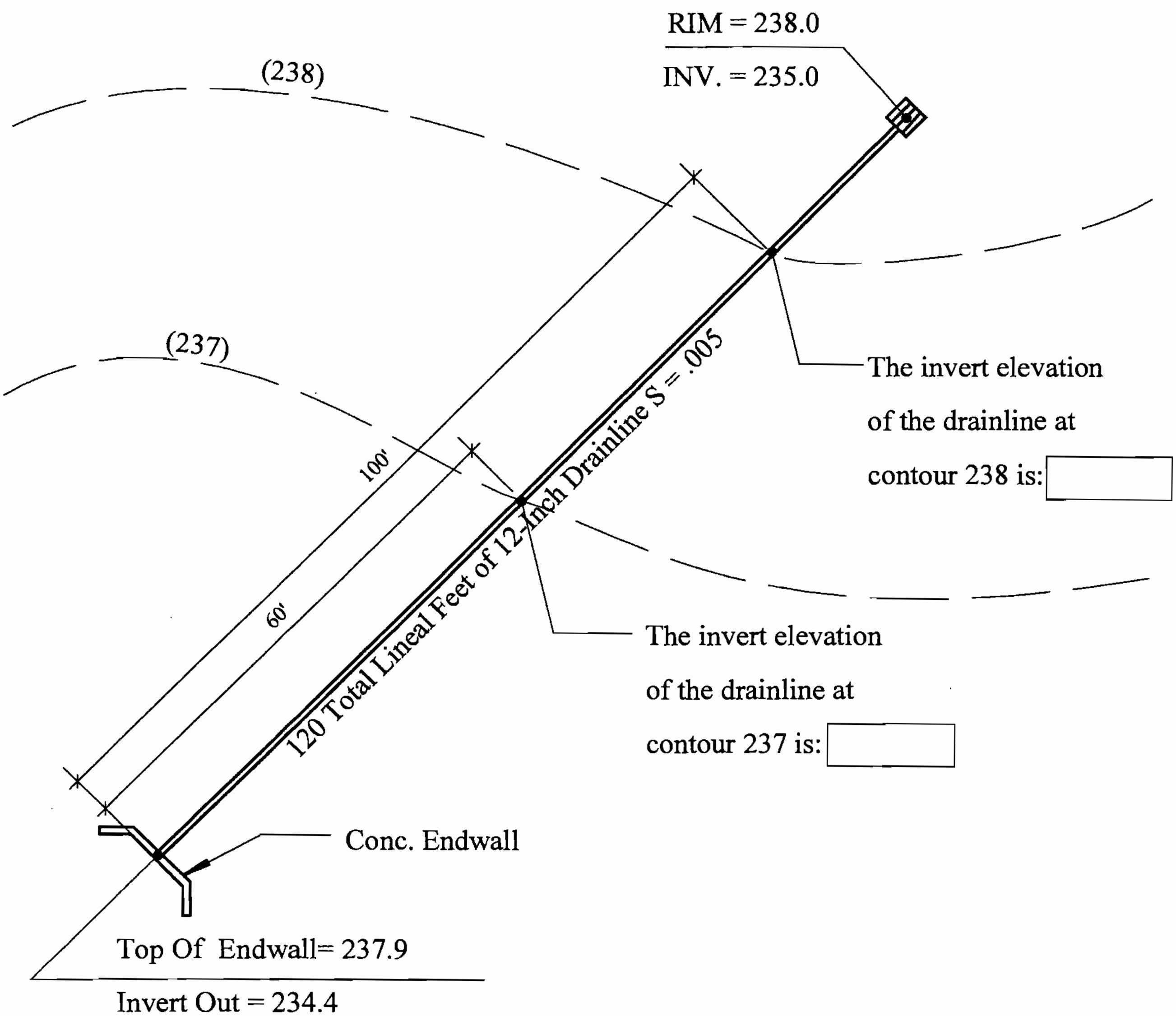
2. Maximum slope on face of dam is 5:1.

3. Delineate retention pond area with cross hatching.



Exercise 10. Verify cover over drainline.

1. Requirement—Maintain 2 feet minimum cover over drainline



Circle the Correct Answer:

Is Cover Over Drainline at Contour 237 Sufficient? Yes No

Is Cover Over Drainline at Contour 238 Sufficient? Yes No

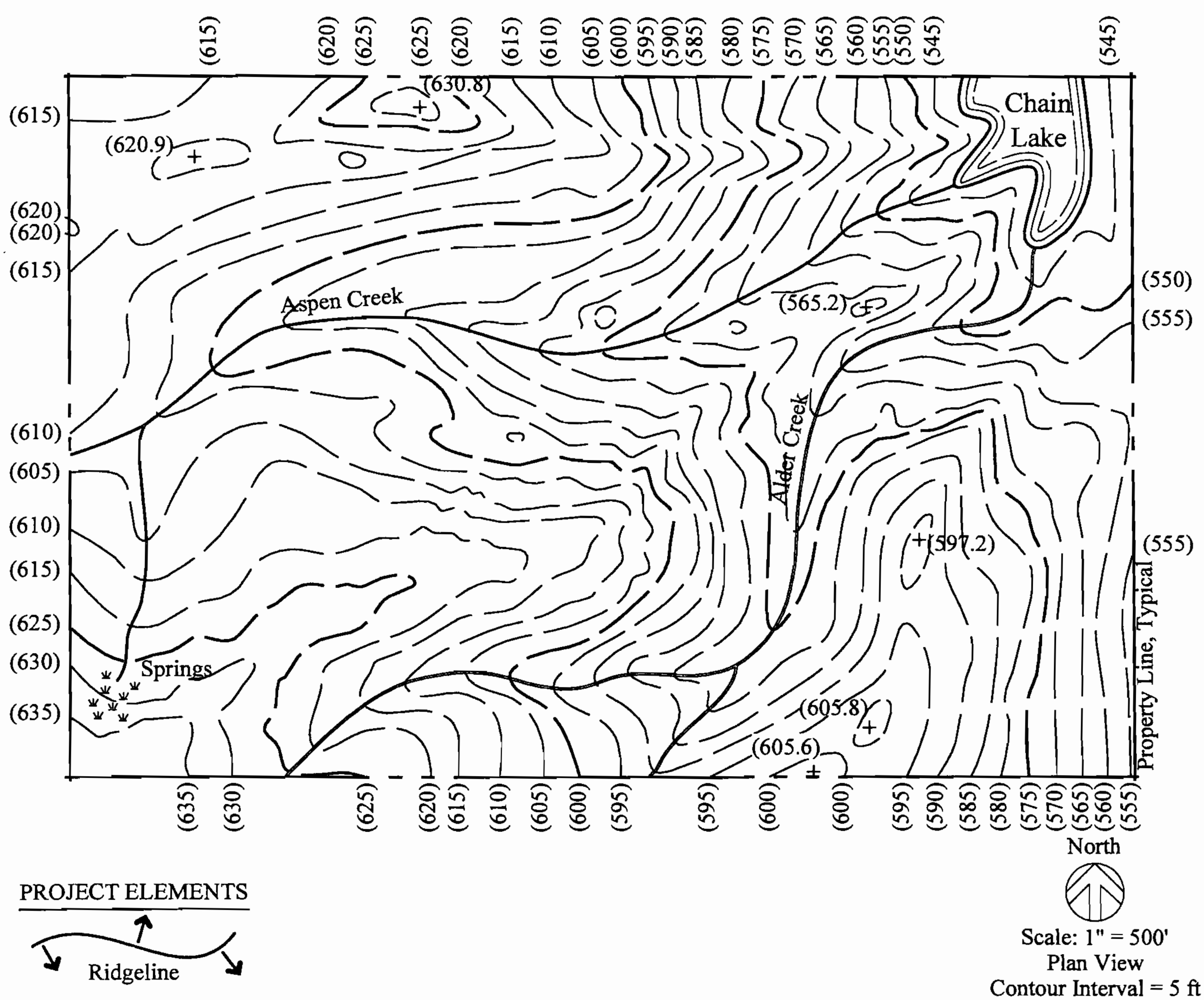
Scale: 1" = 20'
Plan View
Contour Interval = 1 ft

Exercise 11. Delineate ridgelines.

Required

1. Identify the ridgelines that define the Aspen Creek and Alder Creek watersheds with the graphic element shown below.

2. Extend ridgelines to property lines or water bodies.



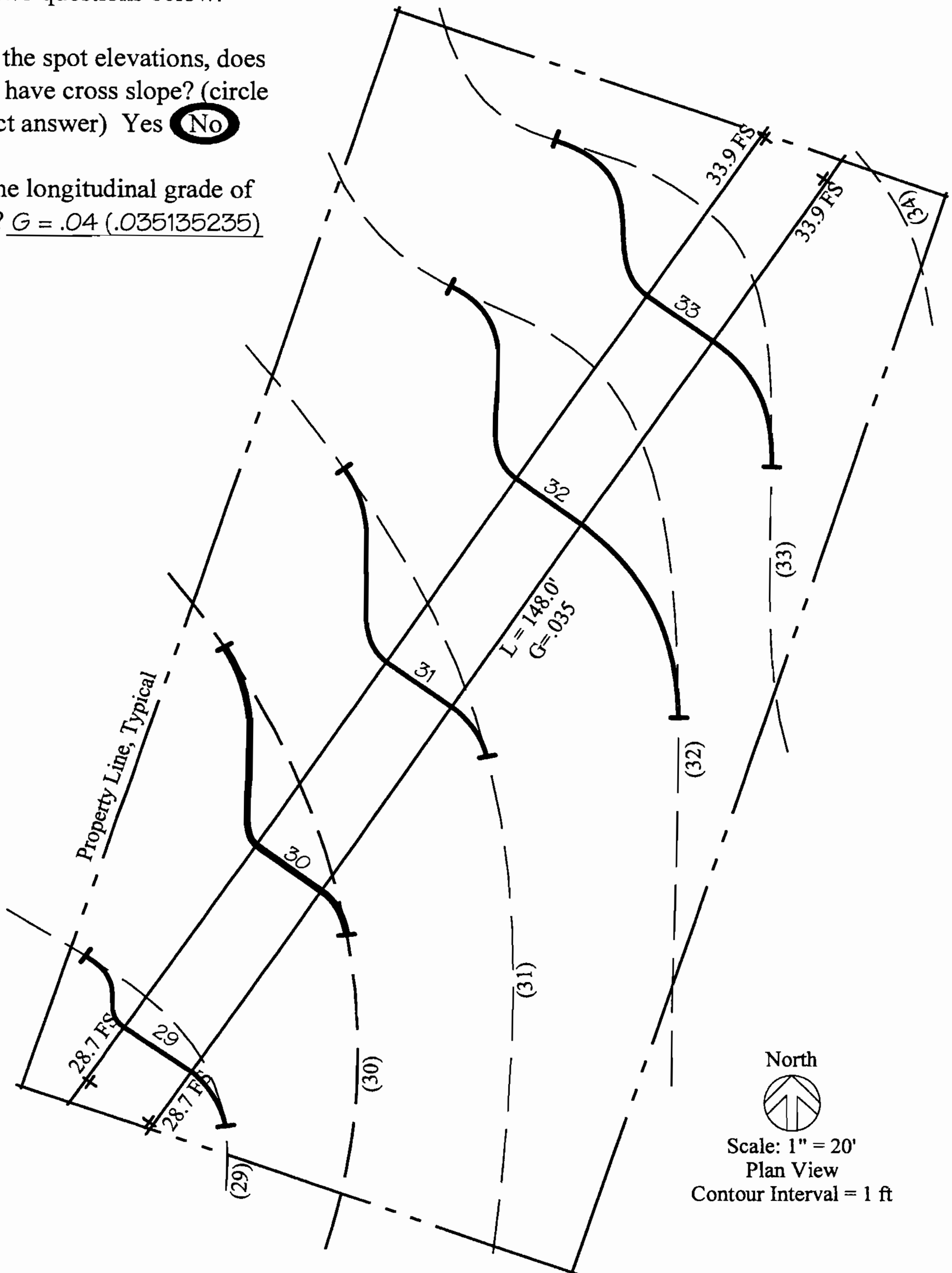
Solutions (Problems 1 through 11); Problem solving approaches begin on page 24)

Exercsie 1. Grade the walk.

Required:

1. Show and label all proposed 1 ft contours and meet existing contours within the property lines.
2. Drainage across walk is permitted; a swale is not required.
3. Answer the two questions below:

   1. Based on the spot elevations, does this walk have cross slope? (circle the correct answer) Yes **(No)**
   2. What is the longitudinal grade of the walk? G = .04 (.035135235)

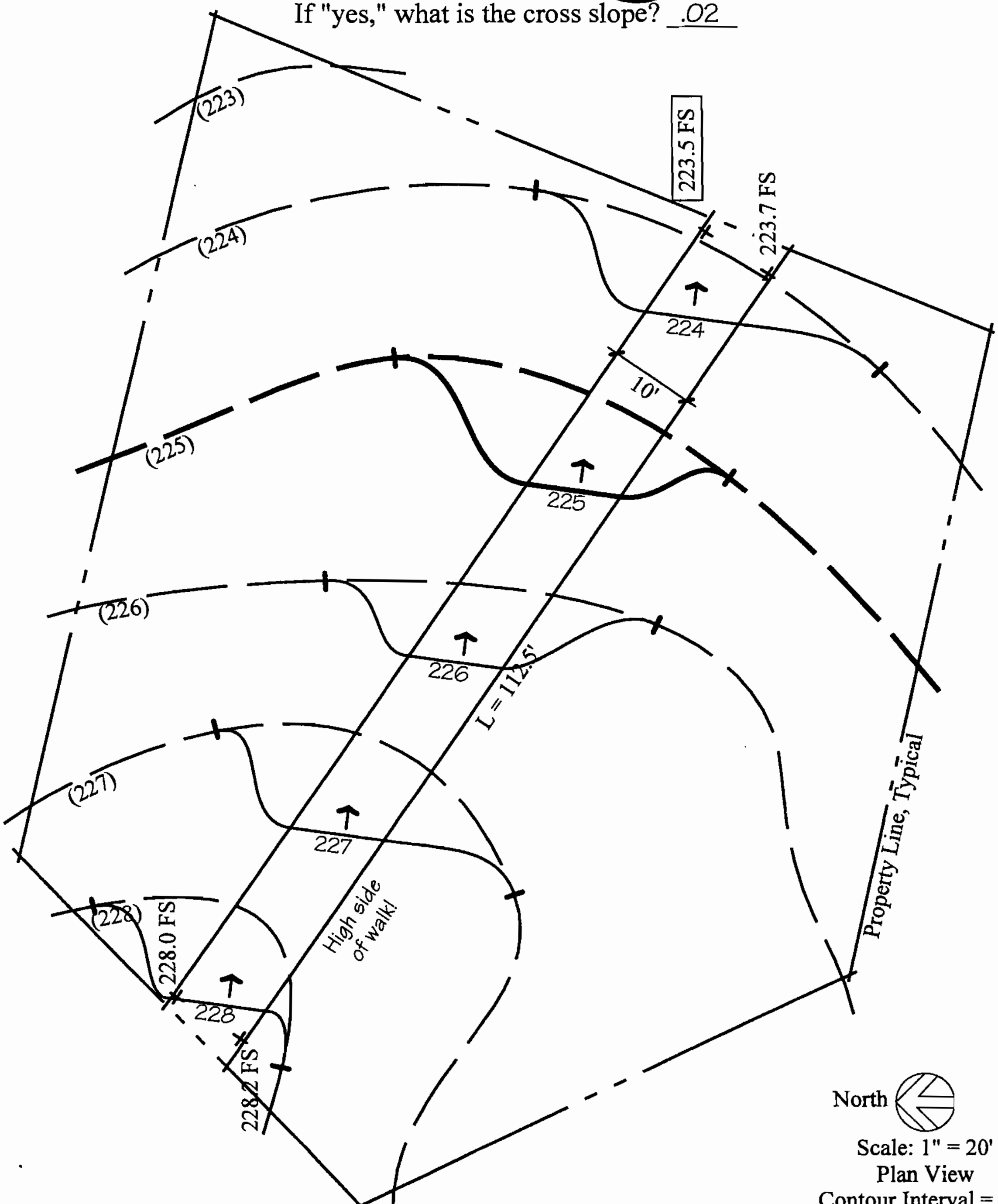


Exercise 2 Solution. Grade the walk shown.

Required:
1. Indicate spot elevation in box provided (to nearest 10th of a foot).
2. Show and label all proposed 1 ft contours and meet existing contours within the property lines.
3. Drainage across walk is permitted; a swale is not required.
4. Answer questions below:

What is the longitudinal grade of the walk? .04

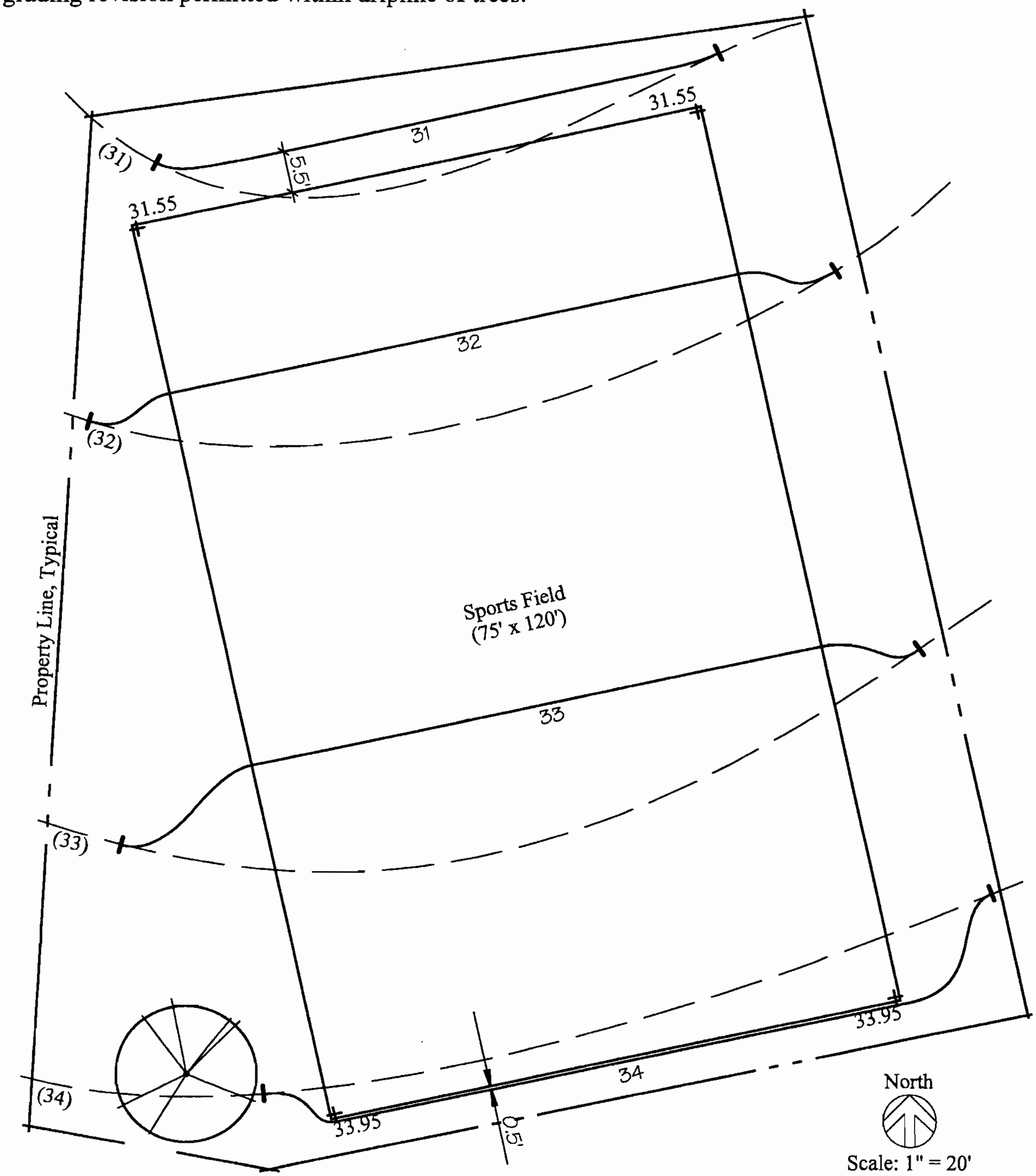
Based on the sopt elevations, does this walk have cross slope?
(Circle the correct answer) Yes No
If "yes," what is the cross slope? .02



Scale: 1" = 20'
Plan View
Contour Interval = 1 ft

Exercsie 3 Solution. Grade the sports field shown with a straight grade.

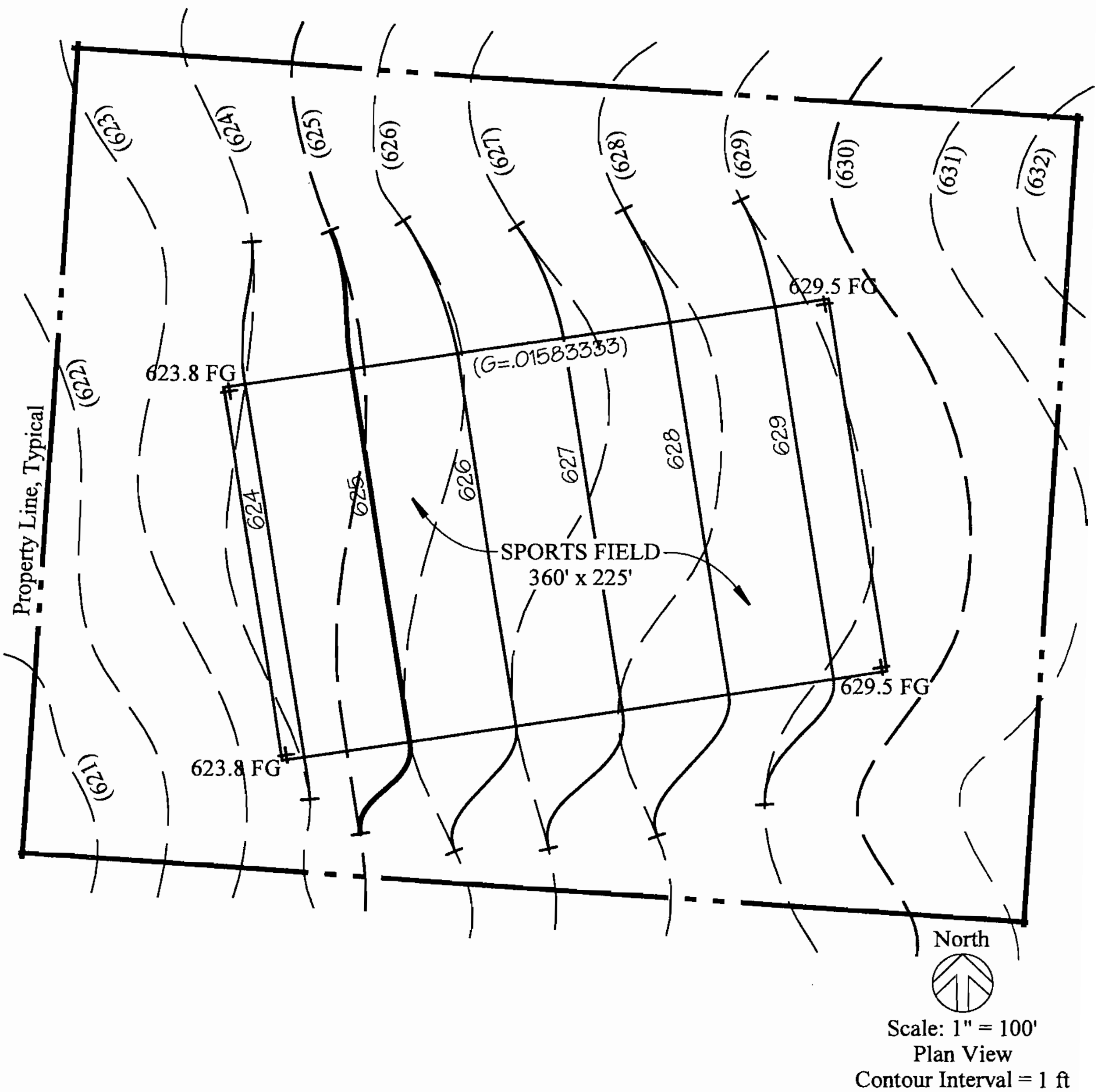
Required:
1. Show and label all proposed 1 ft contours and meet existing contours within the property lines.
2. Drainage onto sportsfield is permitted; a swale is not required.
3. Maximum grade off sportsfield is 10:1.
4. No grading revision permitted within dripline of trees.



Exercsie 4 Solution. Grade the sports field shown with a straight grade.

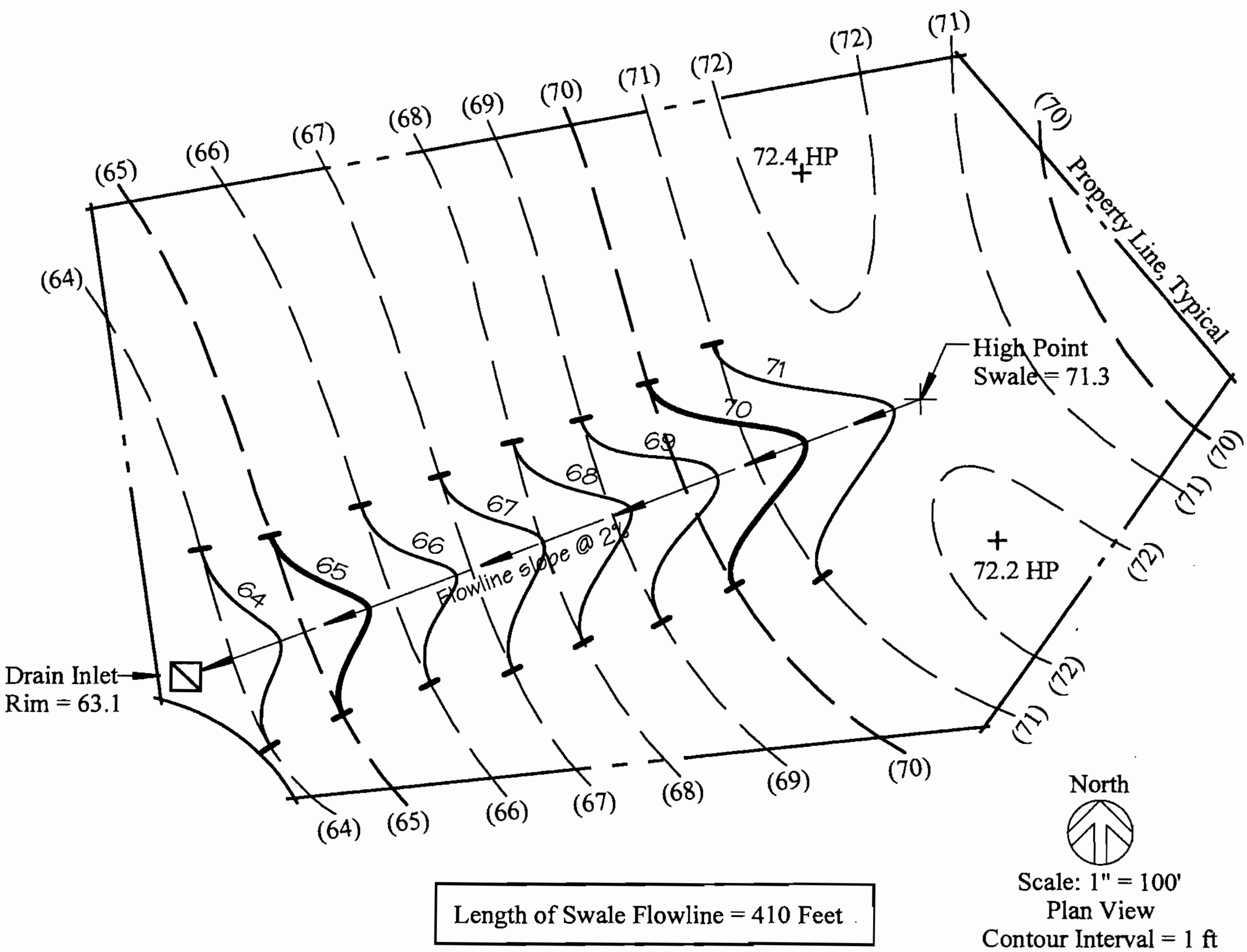
Required:

1. Show and label all proposed 1 ft contours and meet existing contours within the property lines.
2. Drainage onto sportsfield is permitted; a swale is not required.



Exercsie 5 Solution. Develop a swale on the flowline shown.

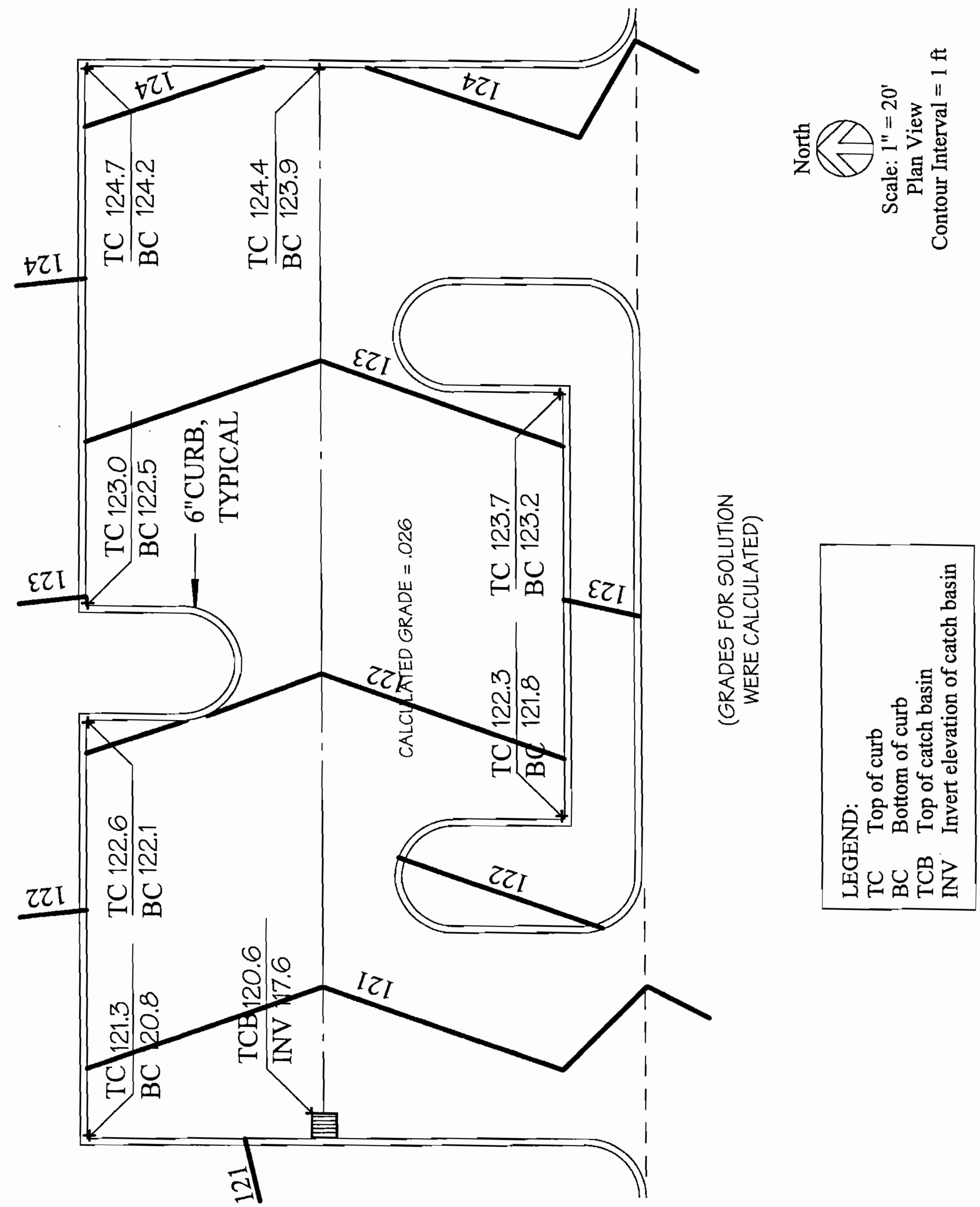
Required:
1. Length of the flowline is as shown.
2. All runoff collected by swale is to flow to drain inlet.
3. Swale is to have a minimum flowline slope of 2%, maximum 10%.
4. Show and label all proposed 1 ft contours and meet existing contours within the property lines.



Exercise 6 Solution. Using the revised contour lines shown, estimate the elevation of the points shown on the plan.

Required:

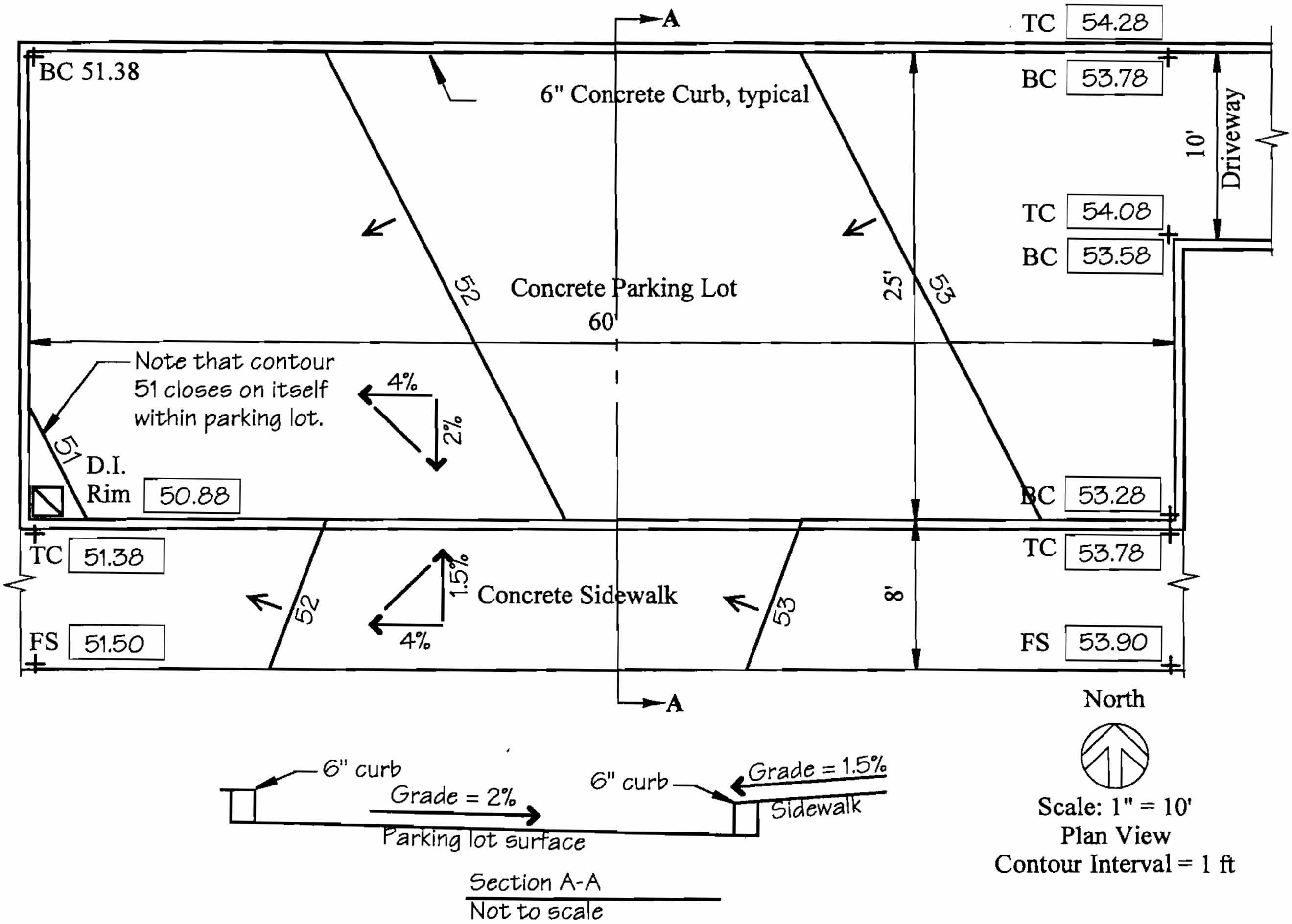
1. All curbs are concrete, 6 inches high.
2. Required cover over drainline is 2 feet, drainline diameter is 12-inches.



Exercise 7 Solution. Grade the parking lot and sidewalk.

Required:

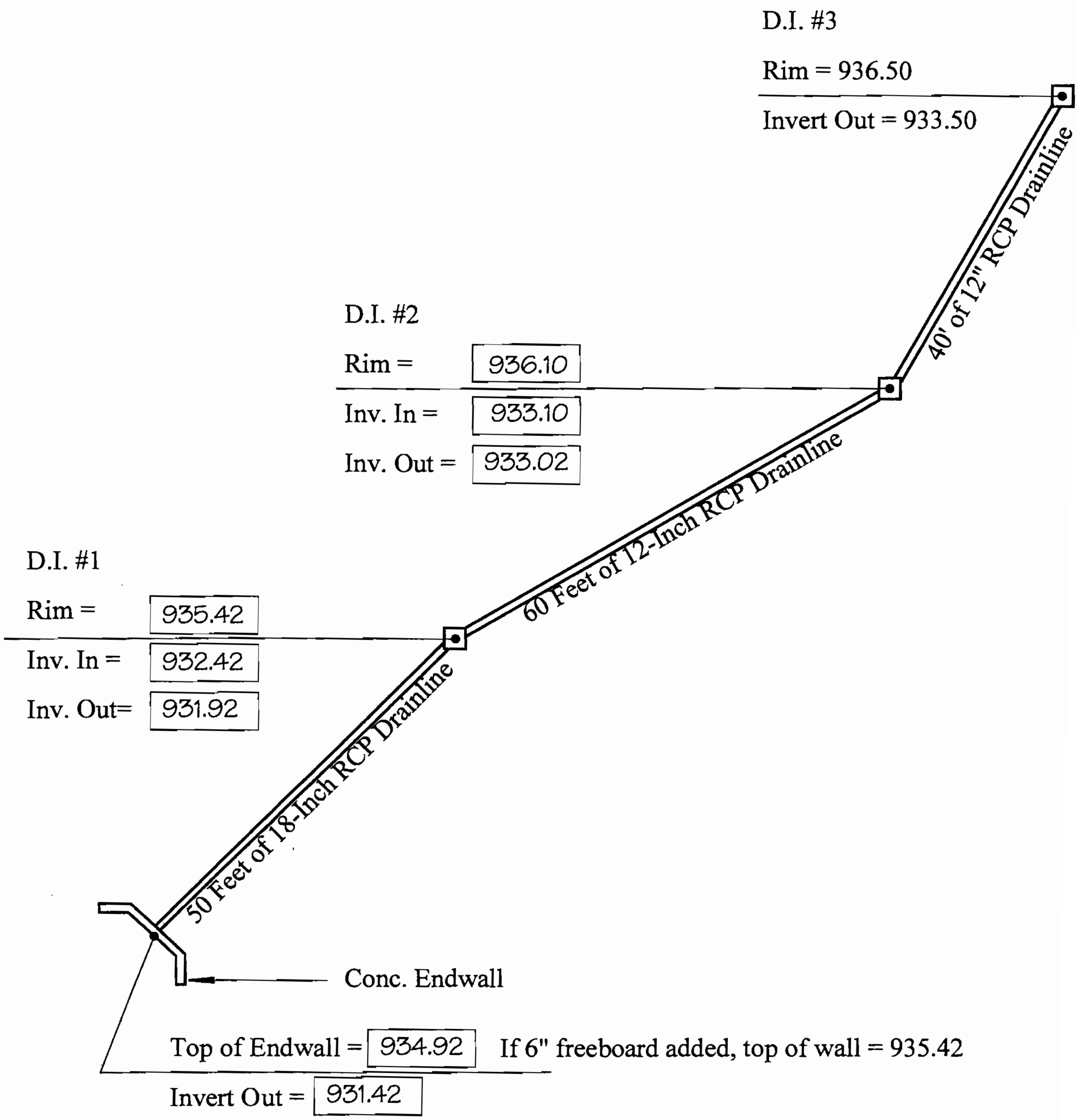
1. Parking lot is to have a longitudinal grade of 4%. Indicate spot elevations in the boxes provided (to the nearest 100th of a ft).
2. Show and label all proposed 1 ft contour lines.
3. Curbs are concrete, 6 in high.
4. Cross slope of parking lot is 2% and cross slope of sidewalk is 1-1/2%.
5. All surfaces shall slope to drain to D.I. in southwest corner of parking lot. Indicate rim elevation of drain inlet.
6. All grades shall be straight grades; plane surfaces shall slope uniformly.



Scale: 1" = 10'
Plan View
Contour Interval = 1 ft

Exercise 8 Solution. Design drainage system.

Required:
1. Slope of drainline is to be .01 (1%).
2. Set rim elevations of catch basins to maintain minimum of 2-feet of cover over all drain lines.
3. Adjust inverts at drain inlets to minimize head loss.



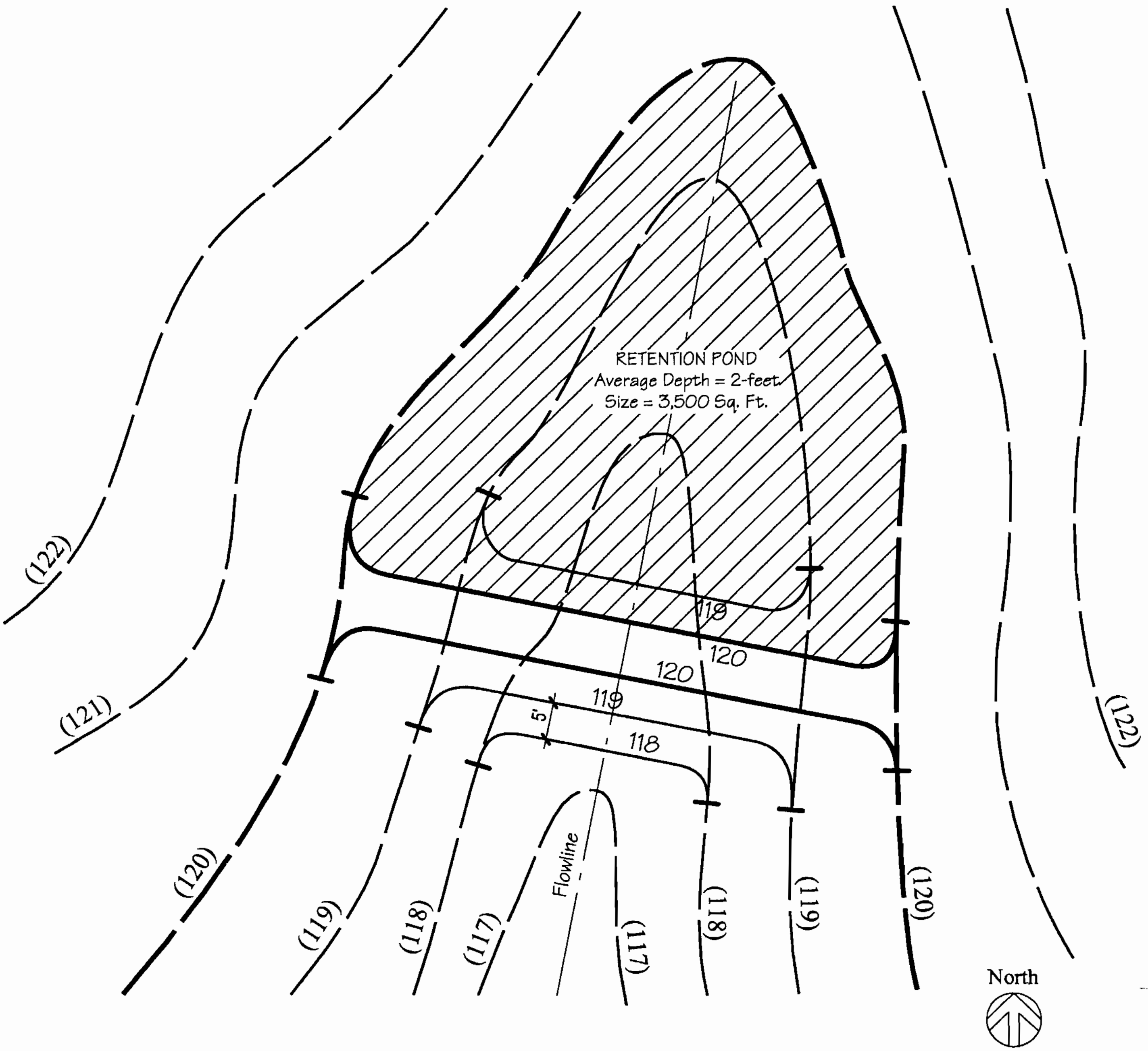
Exercise 9 Solution. Grade dam to retain stormwater in retention pond.

Required:

1. Locate a dam to create a retention pond that has an average depth of 2-feet over a surface area of at least 3,500 square feet. (3,500 square feet in the form of a square measures approximately 59-feet by 59-feet, or a circle with a raduis of approximately 34-feet.)

2. Maximum slope on face of dam is 5:1.

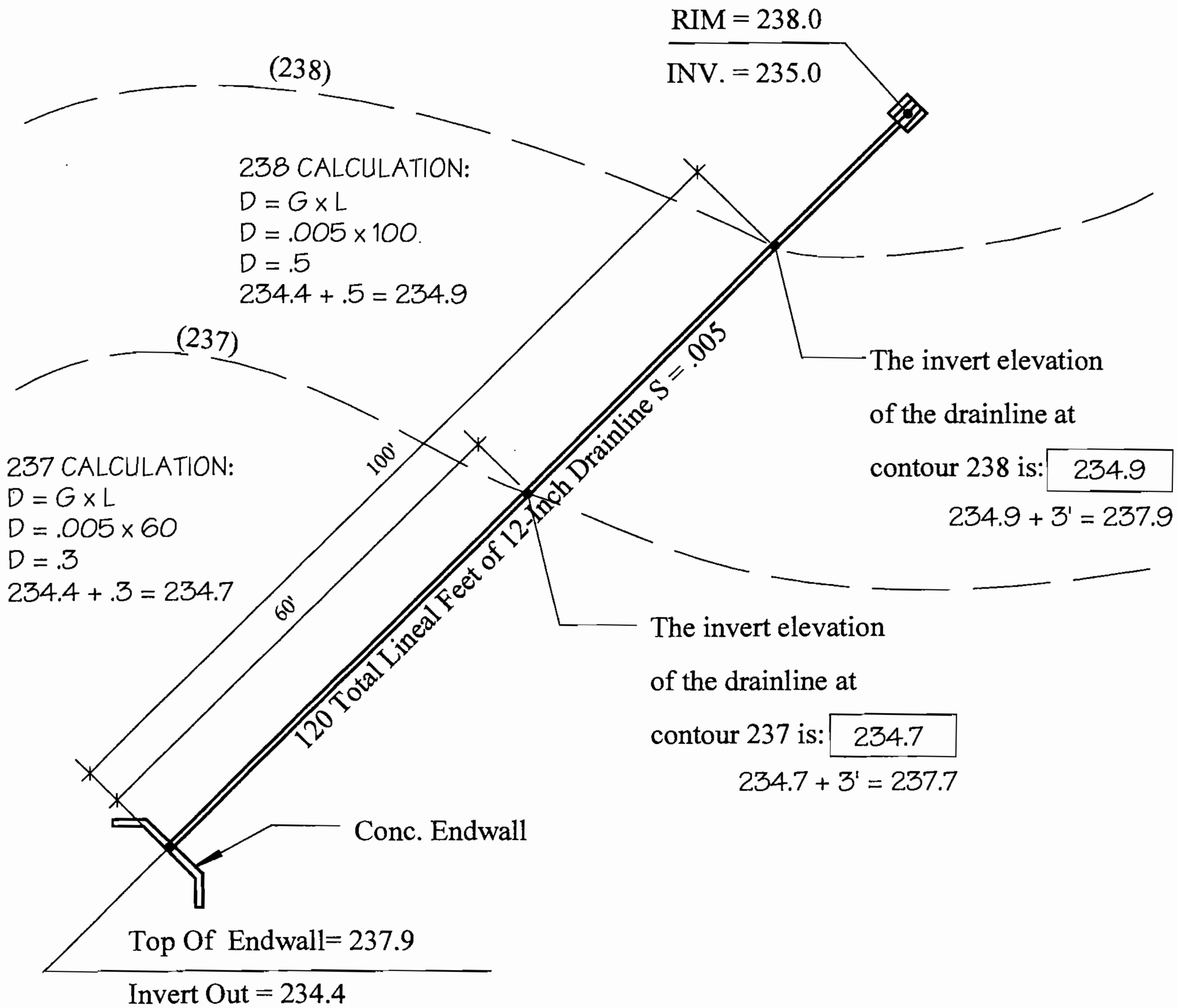
3. Delineate retention pond area with cross hatching.



Scale: 1" = 20'
Plan View
Contour Interval = 1 ft

Exercise 10 Solution. Verify cover over drainline.

1. Requirement—Maintain 2 feet minimum cover over drainline



Circle the Correct Answer:

Is Cover Over Drainline at Contour 237 Sufficient? Yes **(No)**

Is Cover Over Drainline at Contour 238 Sufficient? **(Yes)** No

North

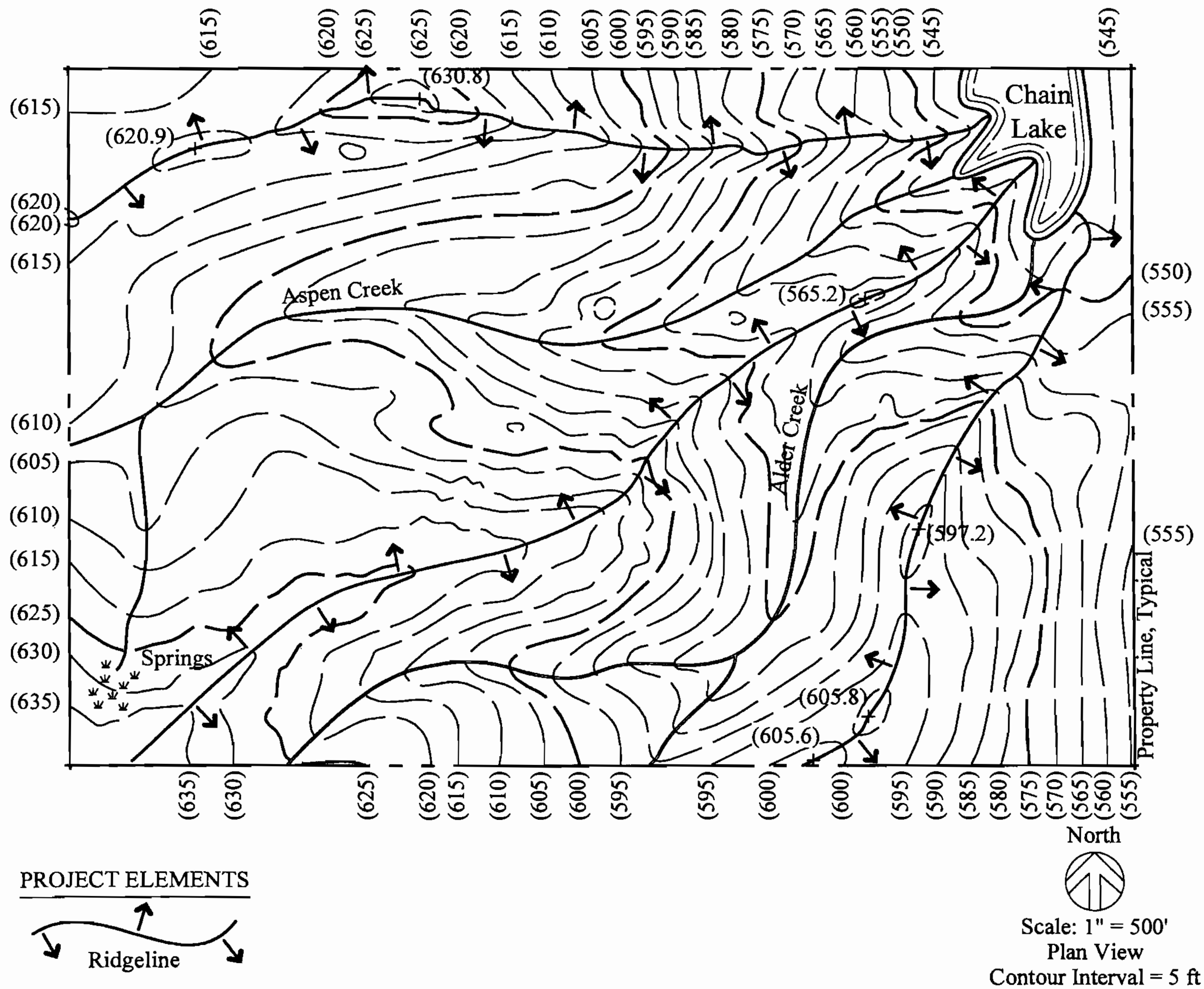
Scale: 1" = 20'
Plan View
Contour Interval = 1 ft

Exercise 11 Solution. Delineate ridgelines.

Required

1. Identify the ridgelines that define the Aspen Creek and Alder Creek watersheds with the graphic element shown below.

2. Extend ridgelines to property lines or water bodies.



Problem Solving Approaches for Exercises 1 Through 11

Exercise 1 Problem-solving Approach: The first step is to take note of all information provided on the plan. In this case, spot elevations are provided on the walk, as well as the length between the spot elevations. Study these existing spot elevations, and then compare them side-to-side and end-to-end. Note that the spot elevations side-to-side are identical, indicating that this walk has no cross slope. But note that there is a difference in elevation end-to-end, meaning that the walk does have longitudinal slope. Therefore, the second step will be to determine the longitudinal grade of the walk, which is also asked for in the problem statement. The length of the walk is given as 148 lineal feet between the spot elevations. As shown on the solution, the calculated grade is .035 or 3.5%. As pointed out previously, plane surfaces must be graded before non-plane surfaces. So, the third step will be to find the points where the whole number contours cross the walk. Once the points have been plotted, the contour lines are drawn on the plane surface and numbered, and then manipulated to meet the existing contour lines. Check to make sure that the elevations of the revised and existing contours match (e.g., 31 revised meets 31 existing, and so on).

As in all problems where contour lines are to be manipulated, there are an infinite number of possible correct solutions. For example, it would have been possible to shorten or lengthen the path the revised contours took to meet the existing contours. A middle-ground solution is usually best — if the transition is too abrupt, there could be a public safety issue, or, in some cases, the contour moving away from the walk at a sharp angle will cause runoff to undercut the edge of the walk. Going to the other extreme, if the contour revisions extend out to the property lines, the solution could be looked upon as being excessive in that it disturbs more of the site than it needs to. In some cases, depending on the natural signature of the existing contours, and how the revised contours meet them, care must be exercised to not inadvertently design a swale where one is not intended, especially at the edge of a paved surface, such as a walk —always keep in mind that it is undesirable to concentrate the flow of water across property lines.

Exercise 2 Problem-solving Approach: The strategy is identical to the previous problem. The biggest difference between the two problems is that the walk on exercise 2 does have cross slope. The cross slope formula can be use to expedite the solution. Alternately, the contour crossing points can be established on both sides of the walk with the contours being drawn between the two points. Other than cross slope, the issues that must be dealt with are the same.

Exercise 3 Problem-solving Approach: Like the first exercise, the sports field is straight graded and does not have cross slope. Since it is a plane surface, it must be graded prior to grading the non-plane surfaces. This exercise features an existing tree in the southwest corner of the site to be considered. Because the grade within the drip line of the tree must not be disturbed, revised contour 34 will need to meet existing contour 34 short of the tree. Also, existing contour 31 at the north end of the field crosses the end of the sports field that has an elevation of 31.55. Consequently, contour 31 must be revised to clear the end of the field. Also note that because the south end of the sports field has an existing elevation of 33.95, revised contour 34 comes to within a half a foot of it.

Exercise 4 Problem-solving Approach: The approach is identical to Exercise 3.

Exercise 5 Problem-solving Approach: The first four exercises required that whole number contour lines be plotted on plane surfaces. This problem is similar, except that the revised contours are to form a swale to conduct runoff to the drain inlet at the west end of the site. As always, the exact configuration of the swale will vary from solution to solution. As pointed out above, the extent of the contour revisions should not be excessive, but the swale signature must be defined sufficiently to indicate that it is a swale.

Exercise 6 Problem-solving Approach: Chapter 1 describes the steps to take if running short of time. One of the suggestions is to "guesstimate" elevations *without* calculating them. This exercise is intended to build confidence in your ability to do exactly that. It is assumed in this case that the contours have already been plotted, and all that is left to do is fill in the boxes with the correct spot elevations. The technique is simple: Identify a point where a spot elevation is needed. Look at a pair of revised contour

lines and gage where the point falls between them. If the point is roughly halfway, then the spot elevation must be .5 higher than the contour below it. With a little practice, most examinees are amazed to find how close they can come to consistently coming within a tenth of the actual elevation. On most LARE vignettes, that level of accuracy is close enough.

Exercise 7 Problem-solving Approach: This problem raises the level of rigor several notches. It consists of a parking lot with cross slope and six-inch concrete curbs, and the requirement for preventing runoff from flowing onto the surface of the parking lot. Study the topography to understand where runoff will flow.

As always, the plane surface must be graded before the non-plane surfaces. Notice that both the longitudinal and cross slope grades are given in the problem statement, and that a sole bottom of curb spot elevation (79.3) is given in the northwest corner of the lot. This is the starting point for grading the parking lot. Note that in grading a parking lot that has six-inch curbs, as this one does, the spot elevations at the surface of the lot must be used to establish the location of the contours. If the elevation had been a top of curb elevation, six-inches would need to be subtracted from the top of curb elevation to establish the elevation at the surface of the lot.

Although it is possible to plot the parking lot whole number contour lines first, it is usually preferable to calculate the spot elevations first—there is less chance of accidentally omitting them later as more information and clutter is added to the plan. And, when plotting whole number contour lines, having the spot elevations available provides a high point to start from (that is not an issue in this particular problem because the bottom of curb elevation of 79.3 happens to be the high point).

Once the spot elevations have been calculated and the contours plotted and numbered, the points at the top of the curb where the contours mount the curb are established. At this point, always recheck the drawing carefully to make sure all boxes that are to have spot elevations have been filled in.

The next step is to establish the flowline for the swale. In this problem, the two drain inlets essentially dictate the orientation of the flowline. The next step is to ascertain the high point swale. The point of attack on this problem is the northwest corner of the parking lot, therefore, that is where the high point swale will be located. The high point elevation, as always, must be set lower than the site feature that is to be protected. Use the methodology described in Chapter 3 to design the swale. Double check to make sure that the slope ratio requirement—10:1 in this case— has been met. That means that there must be at least ten-feet between the last revised contour drawn on the backslope and the next higher existing contour. Number all revised contours and place tick marks at the points where they meet the existing contours. Add plan notes that are appropriate, such as the flowline grades.

Exercise 8 Problem-solving Approach: This problem is very simple to do correctly if you work in an orderly, methodical way. Start at the top of the drainage system and work down toward the endwall. Pay attention to the pipe sizes and apply the rules pertaining to negating head loss through drain inlets.

Exercise 9 Problem-solving Approach: As in the previous problem, this one also requires a step-by-step approach. Begin with the known rim elevation at drain inlet 1. Note that the pipe is 8 inches in diameter. 8 inches expressed in decimal feet is .67. Since the required cover is two feet, the two numbers are added together to equal 2.67. Now, subtract this from the rim elevation to determine the invert elevation. Continue to work down the pipe in this manner. Lastly, grade the endwall by revising the contour lines as shown in the solution.

Exercise 10 Problem-solving Approach: Use the formula $D = G L$ to find out what the invert elevation is at the points where contours 237 and 238 cross the drainline. Once you know the inverts, add three feet (pipe size plus required cover) to determine if the cover is sufficient. If the sum of the pipe size and cover produces a number higher than the contour, the cover is insufficient, and vice-versa.

Exercise 11 Problem-solving Approach: This exercise is intended to give you some practice in identifying ridgelines. In this problem, major ridgelines are the sole focus. Defining watersheds are not. The most direct way to approach this type of problem is to look for a high point, then a ridgeline coming off that point. Notice highpoint of 605.6 in the southeast corner of the site. Begin here by drawing a line along the ridge signature to the next highpoint at 605.8, then to 597.2. Continue to follow the obvious ridgeline all the way to the property line. Next, look for any other similar ridgelines. There will be three altogether. Identify all ridgelines with the required graphic symbol.

This concludes the solutions to the exercises and the approach notes.

The Appendices follow on the next page.

Appendices

Optional Warm-up Homework Assignment

LARE Section E: An Intensive Review

The purpose of this Optional Warm-up Assignment is to give you a head start on reacquainting yourself with the basic grading skills you'll need to pass Section E. Begin by reviewing *Grading Basics — A Grading Primer.* Work through any of the examples that you're uncertain about. This will lead you through all of the basic grading formulas and their uses. As you do the exercises, refer to the solutions that begin on page 12 to verify that you've done them correctly. Bring this completed assignment along with any questions you have to the first meeting on Friday.

PERCENTAGE FORM VERSUS DECIMAL FORM

When it is required that a grade be shown on a problem as part of the solution, it may be expressed in either percentage form (e.g., 2%) or decimal form (e.g., .02). However, when using grades for calculations, they must be in decimal form. The provided solutions give all answers in decimal form, but they would be equally correct expressed in percentage form.

ACCURACY AND ROUNDING-OFF GUIDELINES

Rules for Accuracy: Express grades of *greater than* 1% to the nearest 100th (2 places to right of decimal point); express grades of *less than* 1% to the nearest 1000th (3 places to right of decimal point). Express lengths and differences in elevation to at least the nearest 10th. On the LARE, the required accuracy for grades is usually given in the problem statement; it may be to the nearest 10th, or the nearest 100th. For spot elevations, required accuracy is usually to the nearest 10th of a foot. (Always comply with the stated accuracy requirements.)

INSTRUCTIONS

Show your calculations on page with problems or on back of facing page for later reference. Approximate time goals are given with each set of problems. Your time will vary depending on your level of experience. Practice will increase your speed. Stress speed while emphasizing accuracy.

ROUNDING OFF EXERCISE

Purpose of exercise — to make certain that you know how to express grades, lengths, and differences in elevation at a specified level of accuracy. *Rational* — a specific level of accuracy is required on the LARE *Time goal for problems 1 and 2:* several seconds per problem.

1. Round off the following decimal numbers to the nearest 1/100: .051 = ____; .075 = ____; .014 = ____; .316 = ____; .029 = ____; .095 = ____; .6 = ____

EXPRESSING GRADES IN DECIMAL FORM EXERCISE

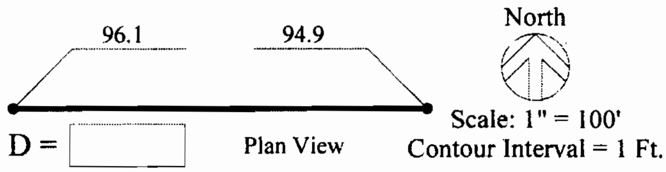
Purpose of exercise — to make sure that you know how to convert grades from percentage form (e.g., 2%) to decimal form (e.g., .02). *Rational* — you'll need to be able to convert grades to decimal form in order to do calculations. Apply standard round-off criteria to these problems.

2. Rewrite the following "percentage" grades as "decimal" grades (e.g., 2% = .02): 1% = ____ ; 15% = ____ ; 33% = ____ ; .5% = ____ ; 8% = ____ ; 1.5% = ____ ; .7% = ____

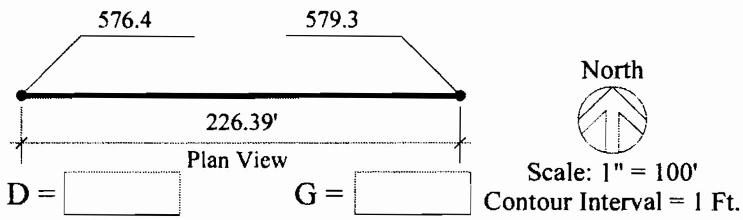
CALCULATING GRADES EXERCISE

Purpose of exercise — to review the process for finding the grade between two points of known elevation. *Time goal* — less than 25 seconds per problem. *Rational* — expect to be tested on this most basic of all grading skills. During the workshop, the curious phrase *"Always Be Curious About the Grade"* will be introduced and discussed. Being curious about the grade requires you to be proficient in quickly and accurately determining grades. During the workshop, a helpful shortcut involving use of the reciprocal key for finding grade will be explained and demonstrated.

3.



4.



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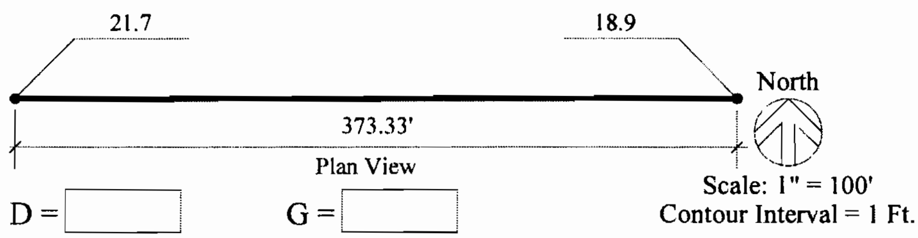

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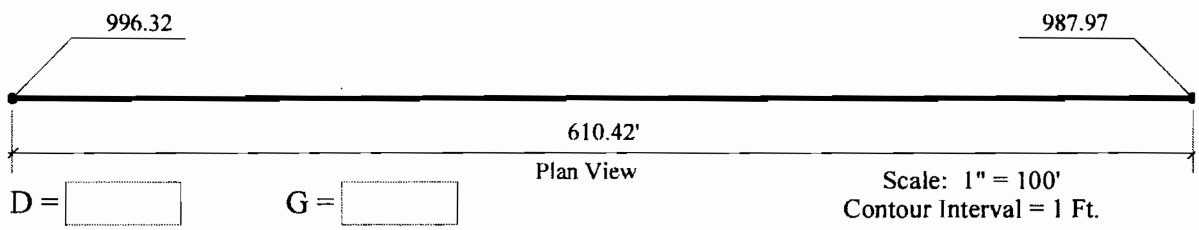

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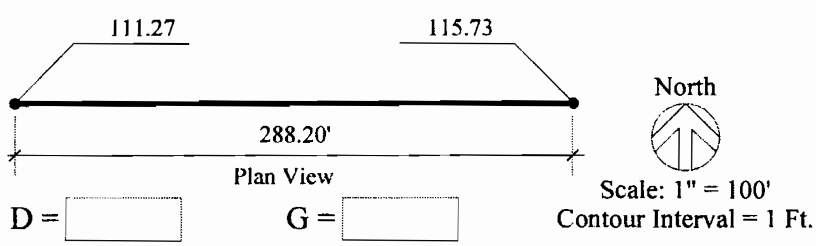
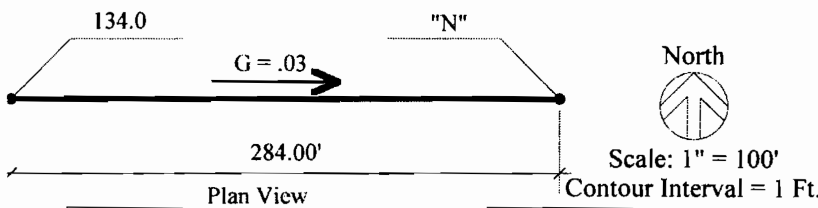


FINDING AN UNKNOWN ELEVATION

Purpose of exercise — to find an unknown elevation quickly and accurately when a second elevation, the grade, and the length are known (remember, when length is not given, you must scale it). *Time goal* — under 20 seconds per problem. *Rational* — many types of problems on the LARE require this basic skill. The following problems address the process required. Note flow arrows point **DOWN HILL.**

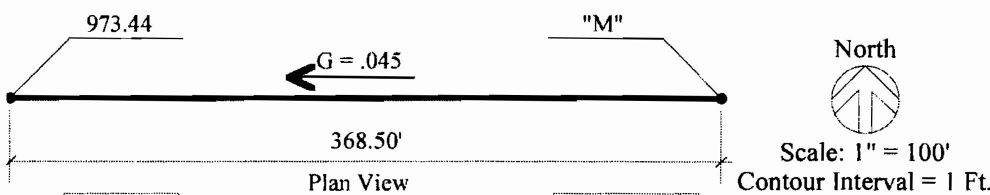
Note: Grade arrows, where shown, always point *down hill.*

8.



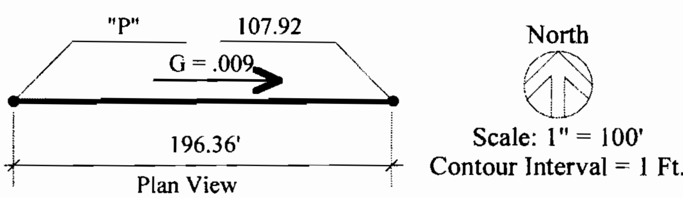
D = [ ] Elevation At "N" = [ ]

9.



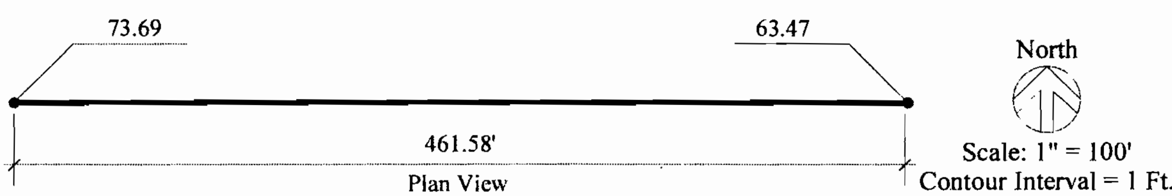
D = [ ] Elevation At "M" = [ ]

10.



D = [ ] Elevation At "P" = [ ]

11.

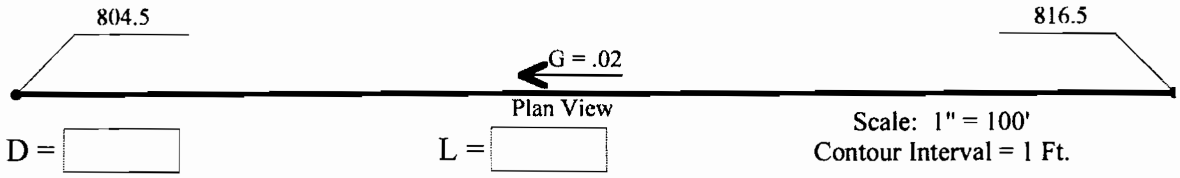


D = [ ] G = [ ]

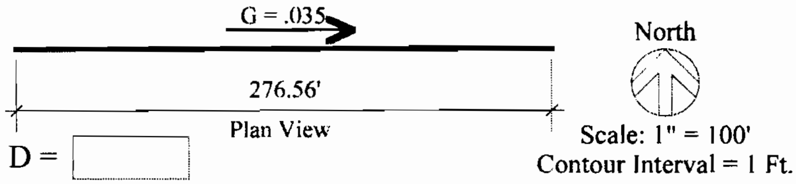
MISCELLANEOUS GRADING EXERCISES

Purpose of exercise — to gain experience in solving various kinds of basic, simple, grading problems. *Time goal* — less than 40 seconds per problem. *Rational* — to gain experience in finding and using the correct formula to solve a variety of simple grading problems.

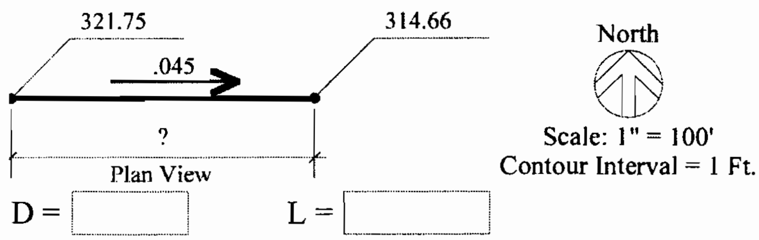
12.



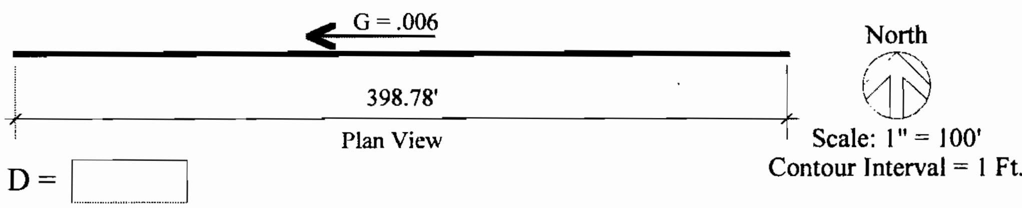
13.



14.



15.

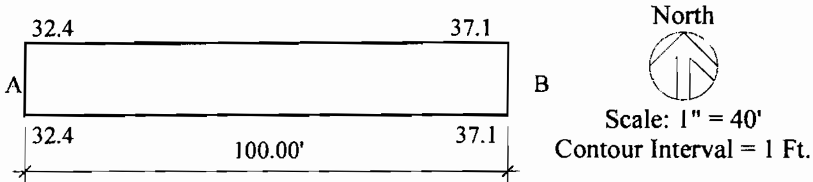


PLOTTING WHOLE NUMBER CONTOUR LINES EXERCISE

Purpose of exercise — to be able to quickly and accurately plot contour lines on a plane surface, or along a line, such as the centerline of a road, or the flow line of a swale. *Time goal* — under 30 seconds to complete all calculations, and approximately one additional minute to plot and number all whole number contours (time will vary depending on the number of contours to be plotted and the complexity of the contour signature). *Rational* — **be aware that your ability to accurately plot whole number contour lines, possibly in several different ways, will be tested on the LARE.** It is essential that you be facile at doing this on a variety of problem types.

Although the following problems feature simple plane surfaces, the procedure used to plot contours on any surface or along any line is exactly the same. It may be a walk, a parking lot, a sports field, the centerline of a road or the flowline of a swale. Don't let the form of the problem confuse you. Note that plotting contour lines produces a *straight graded* surface (contour lines regularly spaced). In the case of swale design, it usually isn't necessary to straight grade the flow line.

16.

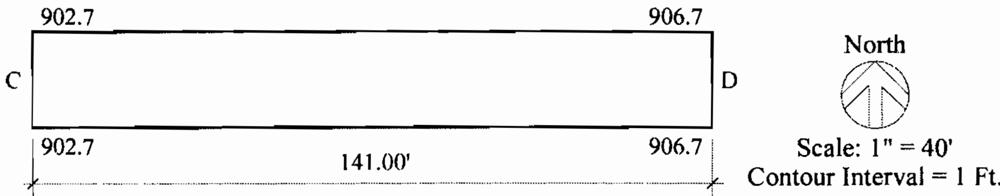


G = Grade in non-rounded off form =

Length to the first whole number contour line from high end (end B) =

Length between remaining whole number contour lines =

17.

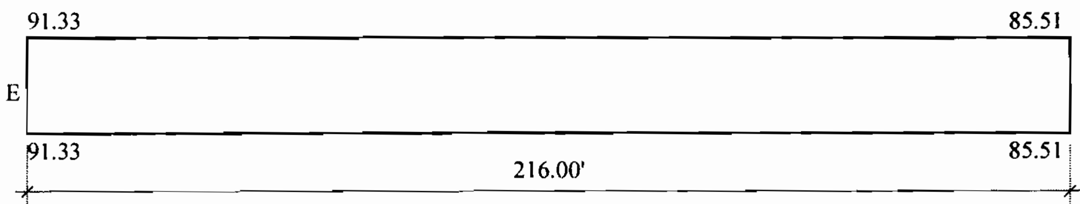


G = Grade in non-rounded off form =

Length to the first whole number contour line from high end =

Length between remaining whole number contour lines =

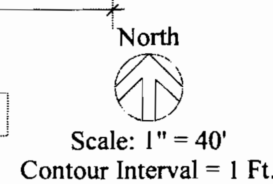
18.



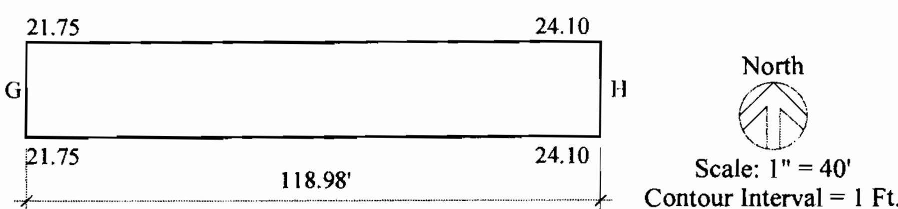
G = Grade in non-rounded off form =

Length to the first whole number contour line from high end =

Length between remaining whole number contour lines =



19.

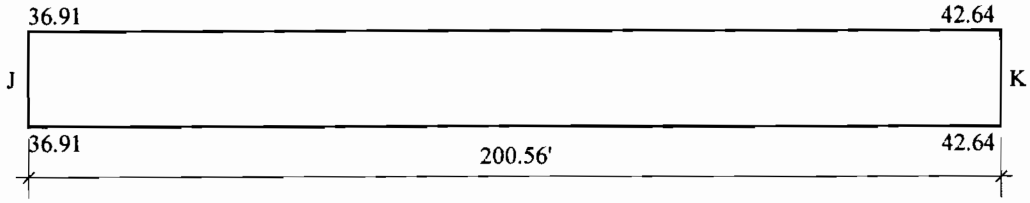


G =

Length to the first whole number contour line from high end =

Length between remaining whole number contour lines =

20.



North

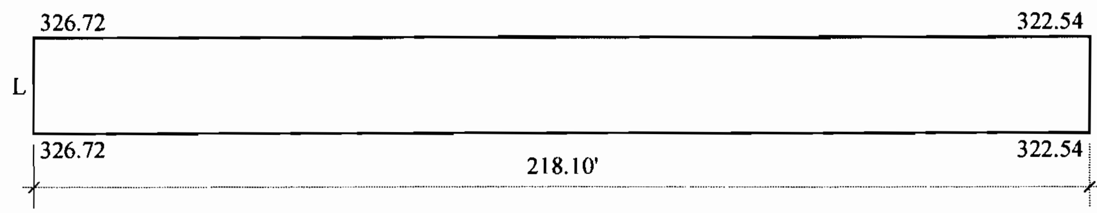
Scale: 1" = 40'
Contour Interval = 1 Ft.

G =

Length to the first whole number contour line from high end =

Length between remaining whole number contour lines =

21.



North

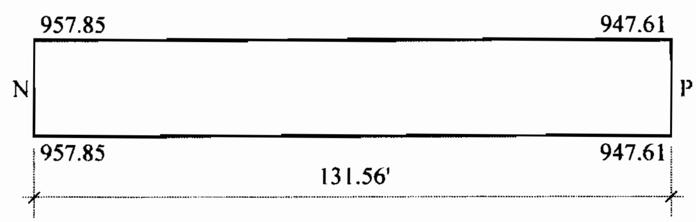
Scale: 1" = 40'
Contour Interval = 1 Ft.

G =

Length to the first whole number contour line from high end =

Length between remaining whole number contour lines =

22.



North

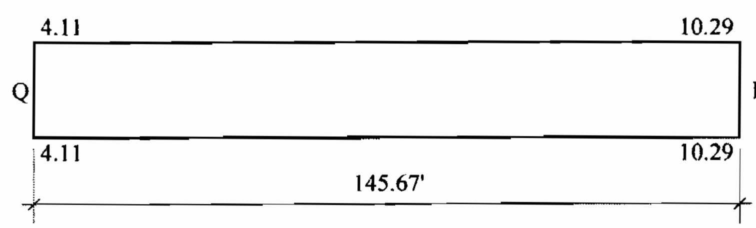
Scale: 1" = 40'
Contour Interval = 1 Ft.

G =

Length to the first whole number contour line from high end =

Length between remaining whole number contour lines =

23.



North

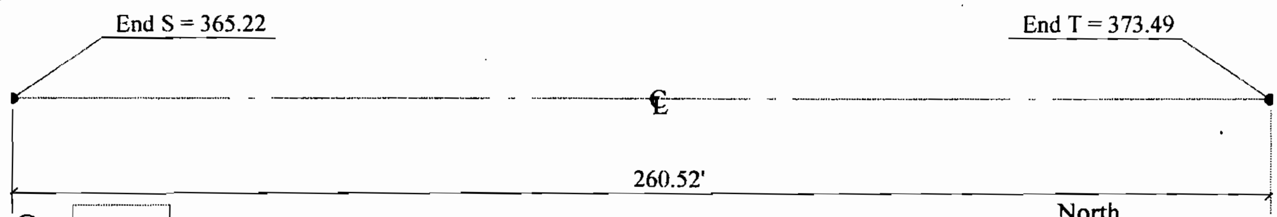
Scale: 1" = 40'
Contour Interval = 1 Ft.

G =

Length to the first whole number contour line from high end =

Length between remaining whole number contour lines =

24.



G = [ ]

North

Length to the first whole number contour line from high end = [ ]

Scale: 1" = 40'

Length between remaining whole number contour lines = [ ]

Contour Interval = 1 Ft.

WORD PROBLEMS

In doing word problems, making a quick sketch often helps you visualize the solution. Determine which information is needed, discarding that which is not.

25. A terrace is 125 feet long by 20 feet wide, and has a longitudinal slope of .017 (1.7%). You are required to draw contour lines at a contour interval of 1 foot to depict the longitudinal grade. How far apart would the contour lines be drawn? [ ]

26. The longitudinal grade of a walk is .025 (2.5%), and its cross slope is .015 (1.5%). The change in elevation between points N and P is 3.9 feet. What is the longitudinal *length* between points N and P? [ ]

27. A grade of .02 (2%) in 190 feet results in a change in elevation of

28. A .12 (12%) slope represents a 7 foot change in elevation in a length of how many feet? [ ]

29. An elevation gain of 4.5 feet in 160 feet indicates a slope of [ ]

30. The length between points A and B is 260 feet. Point A has an elevation of 126.7, and point B an elevation 122.4. The grade between points A and B is [ ]

REFERENCE MANUAL EXERCISE

The following questions have been culled from those portions of the *LARE Reference Manual* relevant to the areas of knowledge required to pass Section E, Grading, Drainage and Stormwater Management. Much of what you will be tested on the exam focuses on the information contained in the *Reference Manual*. Knowledge of the *Reference Manual* is what is referred to as implicit knowledge (as opposed to explicit knowledge, which is what is found in the requirements on the exam materials). **To successfully do this exercise, you'll need a current copy of the *LARE Reference Manual*.** If you do not have a copy at this time, you can access the current version on CLARB's Web site. The URL is http://www.clarb.org/. On the Home Page, find the red text in the upper left corner. Click on Exam Preparation, then LARE Reference Manual. Find the "Click here to download..." text in the last paragraph. This will open a pdf version of the manual.

Answer the following questions by circling the correct answer. If you don't know the answer, look it up in the *Reference Manual*.

RAMPS

1. Any part of an accessible route having a slope greater than what percent grade is considered a ramp?
   a. 2%
   b. 3%
   c. 5%
   d. 8.3%

2. The minimum clear width of a ramp is?
   a. 2 feet
   b. 3 feet
   c. 4 feet
   d. 5 feet

3. True or False: The least possible slope shall be used for any ramp.

4. The maximum permissible slope of a ramp is?
   a. 5%
   b. 8.3%
   c. 10%
   d. 12%

5. The maximum *vertical change in elevatio*n (rise) for any ramp run — that is the rise before a landing is required — is?
   a. 1 foot
   b. 2 feet
   c. 2.5 feet
   d. 3 feet

6. The maximum *horizontal length* (run) for any ramp run — that is the run before a landing is required — is?
   a. 10 feet
   b. 15 feet
   c. 25 feet
   d. 30 feet

7. A landing shall have a slope for drainage of?
   a. none
   b. 5.%
   c. 1%
   d. 2%

8. True or False: Ramps shall have landings at the bottom and top of each ramp and each ramp run.

9. True or False: A landing shall be at least as wide as the ramp run leading to it.

10. The minimum horizontal clear length of a landing shall be?
    a. 3 feet
    b. 5 feet
    c. 6 feet
    d. equal to the width of the ramp

11. If ramps change direction at landings, the minimum landing size shall be?
    a. 5 feet by 5 feet
    b. 5 feet by the width of the ramp
    c. 6 feet by 6 feet
    d. 5 feet by 6 feet

12. The cross slope requirement on any ramp surface shall be no greater than?
    a. 2%
    b. 1.5%
    c. 1%
    d. cross slope isn't required

RAMP HANDRAILS

13. Beyond what amount of vertical rise is a handrail required on a ramp?
    a. 6 inches
    b. 12 inches
    c. 15 inches
    d. 24 inches

14. Beyond what horizontal length is a handrail required on a ramp?
    a. 2 feet
    b. 5 feet
    c. 6 feet
    d. 10 feet

15. True or False: Where handrails are required on a ramp, they are required on only one side.

16. Handrails shall extend at least how far beyond the top and bottom of any ramp segment?
    a. 6 inches
    b. 12 inches
    c. 18 inches
    d. 12 inches at the top of the segment, 24 inches at the bottom

17. True or False: Handrail extensions may extend into adjacent walks?

18. The clear space between a handrail and a wall shall be?
    a. 1 inch
    b. 1-1/2 inches
    c. 1-3/4 inches
    d. 2 inches

19. The cross-section of a handrail shall be round and shall have an outside diameter of at least?
    a. 1-1/4 inches
    b. 1-1/2 inches
    c. 1-3/4 inches
    d. 2-1/4 inches

20. The maximum permissible diameter of a handrail is?
    a. 1-3/4 inches
    b. 2 inches
    c. 2-1/4 inches
    d. there is no stipulated maximum

STEPS

21. Maximum riser height shall be?
    a. 5 inches
    b. 6 inches
    c. 7 inches
    d. 8 inches

22. Minimum tread depth (horizontally) shall be?
    a. 9 inches
    b. 10 inches
    c. 11 inches
    d. 12 inches

23. Treads shall have a wash back to front of what percent?
    a. none
    b. 1/8 inch
    c. 1%
    d. 2%

STEP HANDRAILS

24. At what width must steps have continuous handrails on both sides?
    a. 24 inches
    b. 36 inches
    c. 42 inches
    d. 60 inches

25. Intermediate handrails are required so that all portions of the required width of stairs are within how far of a handrail?
    a. 2 feet
    b. 2-1/2 feet
    c. 3 feet
    d. 3-1/2 feet

26. Only one handrail is required if a run of steps is less than what width?
    a. 42 inches
    b. 36 inches
    c. 24 inches
    d. one handrail isn't permitted regardless of width

27. Handrails shall extend how far beyond the *top step?*
    a. 9 inches
    b. 12 inches
    c. 12 inches plus one tread width
    d. 15 inches

28. Handrails shall extend how far beyond the *bottom step?*
    a. 9 inches
    b. 12 inches
    c. 12 inches plus one tread width
    d. 15 inches

29. The clear space between a handrail and a wall shall be?
    a. 1 inch
    b. 1-1/4 inches
    c. 1-1/2 inches
    d. 1-3/4 inches

30. The top gripping surfaces of a handrail shall be mounted between what height-range above step nosings?
    a. 28 and 34 inches
    b. 34 and 38 inches
    c. 36 and 42 inches
    d. 40 and 46 inches

31. The cross-section of a handrail shall be round and shall have an outside diameter of at least?
    a. 1-1/4 inches
    b. 1-1/2 inches
    c. 1-3/4 inches
    d. 2-1/4 inches

GUARDRAILS

32. Guardrails are required on retaining wall where the difference in grade level on either side of the wall is in excess of?
    a. 6 inches
    b. 12 inches
    c. 1-1/2 feet
    d. 2-1/2 feet

33. Guardrails are required when the difference in grade level on either side of the wall are in excess of the dimension you gave as an answer for question number 33 and how many feet from a walk, path, parking lot or driveway on the high side?
    a. 4 feet
    b. 3 feet
    c. 2-1/2 feet
    d. 2 feet

34. Guardrails shall be a minimum of how high as measured vertically from the leading edge of a stair tread or adjacent walking surface?
    a. 32 inches
    b. 36 inches
    c. 42 inches
    d. 45 inches

35. Guardrails shall have balusters (pickets) such that a sphere with a diameter of how many inches cannot pass through any opening?
    a. 3 inches
    b. 3-1/2 inches
    c. 4 inches
    d. 4-1/2 inches

TIPS FOR LEARNING THE "LARE REFERENCE MANUAL"

The most effective way to have total familiarity with *LARE Reference Manual* is to memorize it. This doesn't mean memorizing it word-for-word, but the rather the concepts and facts it contains. The desired level of familiarity should be such that every requirement can be recalled instantly without having to look at the manual. For example, you would know that the minimum height of a guardrail is 42 inches.

Memorizing by rote isn't fun. One of the most effective ways to memorize the content that has worked well for many examinees is the flash card method. To use the flash card method, buy a packet of 3-inch by 5-inch cards. On the front of each card write one *Reference Manual* question, and on the back the correct answer. The preceding *Reference Manual* exercise is an excellent resource for making a set of Section E cards. Carry six to 12 cards with you at all times. Be sure to pick different cards each day. Then, make use of "slack" time to review them. For example, go through as many cards as time permits while waiting in line at the bank, or waiting to be seated in a restaurant. Put aside any you answer incorrectly for later review.

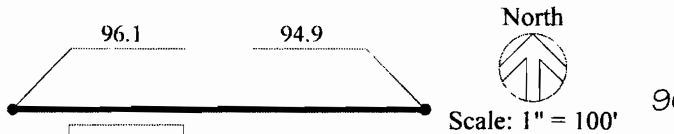
◊◊◊◊◊ END OF WARM-UP ASSIGNMENT ◊◊◊◊◊

SOLUTIONS:

1. .051 = .05; .075 = .08; .014 = .01; .316 = .32; .029 = .03; .095 = .10; .6 = .60

2. 1% = .01; 15% = .15; 33% = .33; .5% = .005; 8% = .08; 1.5% = .02; .7% = .007

3.

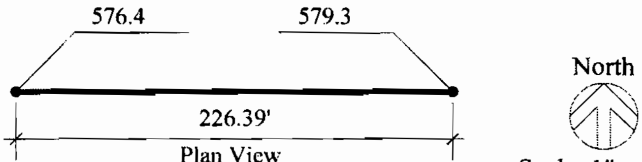


Scale: 1" = 100'
Contour Interval = 1 Ft.

96.1 - 94.9 = 1.2

D = 1.2

4.



Scale: 1" = 100'
Contour Interval = 1 Ft.

579.3 - 576.4 = 2.9

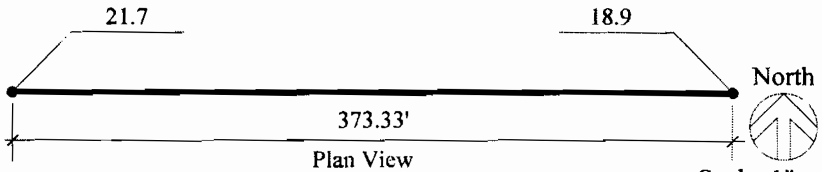
$G = \frac{D}{L}$

$G = \frac{2.9}{226.39}$

G = .012809753

D = 2.9   G = .01

5.



Scale: 1" = 100'
Contour Interval = 1 Ft.

21.7 - 18.9 = 2.8

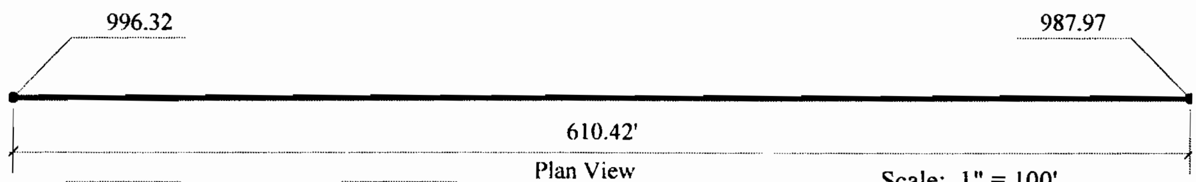
$G = \frac{D}{L}$

$G = \frac{2.8}{373.33}$

G = .007500066

D = 2.8   G = .008

6.

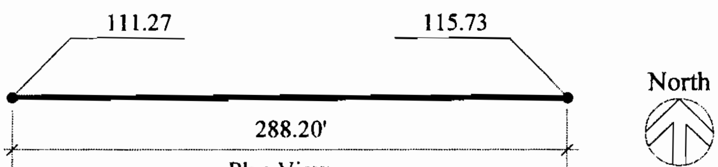


Scale: 1" = 100'
Contour Interval = 1 Ft.

D = 8.35   G = .01

996.32 - 987.97 = 8.35 $G = \frac{D}{L}$ $G = \frac{8.35}{610.42}$ G = .013679106

7.



Scale: 1" = 100'
Contour Interval = 1 Ft.

115.73 - 111.27 = 4.46

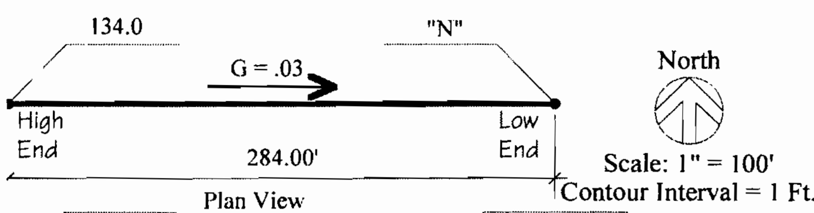
$G = \frac{D}{L}$

$G = \frac{4.46}{288.20}$

G = .015475364

D = 4.46   G = .02

8.

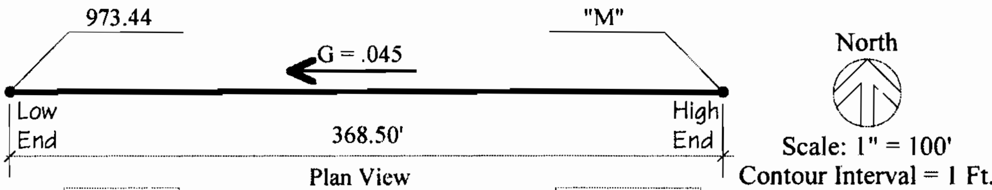


D = 8.52   Elevation At "N" = 125.48

D = G X L   D = .03 x 284   D = 8.52

To Find Elev. at "N"   134 - 8.52 = 125.48

9.

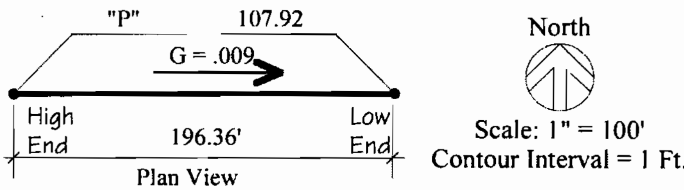


D = 16.58 Elevation At "M" = 990.02

D = G X L D = .045 x 368.50 D = 16.58

To Find Elev. at "M" 16.58 + 973.44 = 990.02

10.



D = 1.77 Elevation At "P" = 109.69

D = G X L

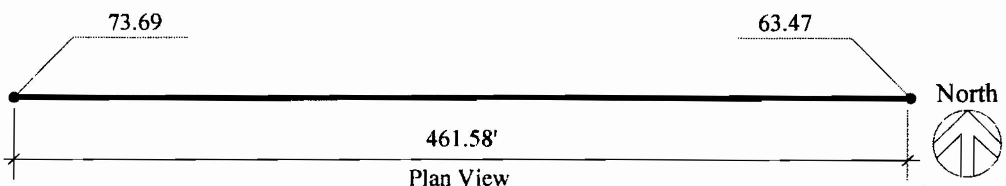
D = .009 X 196.36

D = 1.77

To Find Elev. at "P":

107.92 + 1.77 = 109.69

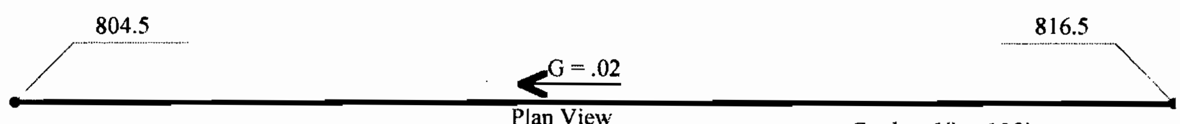
11.



D = 10.22 G = .02

73.69 - 63.47 = 10.22 $G = \frac{D}{L}$ $G = \frac{10.22}{461.58}$ G = .02214134

12.

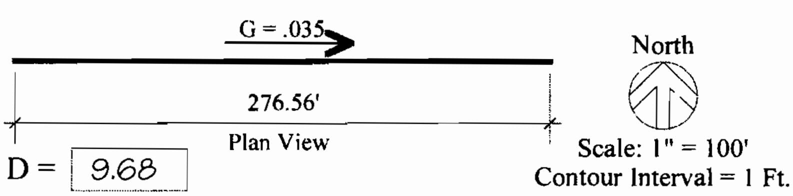


Scale: 1" = 100'
Contour Interval = 1 Ft.

D = 12.0 L = 600'

816.5 - 804.5 = 12.0 $L = \frac{D}{G}$ $L = \frac{12.0}{.02}$ L = 600 FT.

13.



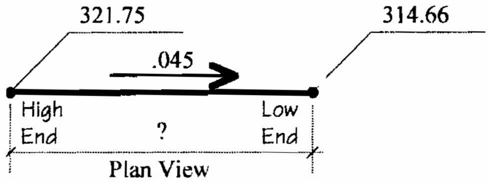
D = 9.68

D = G x L

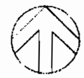
D = .035 x 276.56

D = 9.6796

14.



North



Scale: 1" = 100'
Contour Interval = 1 Ft.

321.75 - 314.66= 7.09

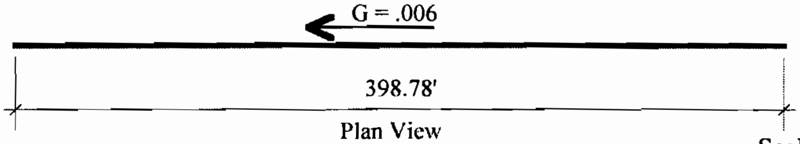
$L = \frac{D}{G}$

$L = \frac{7.09}{.045}$

L = 157.56'

D = 7.09 L = 157.56'

15.



North

Scale: 1" = 100'
Contour Interval = 1 Ft.

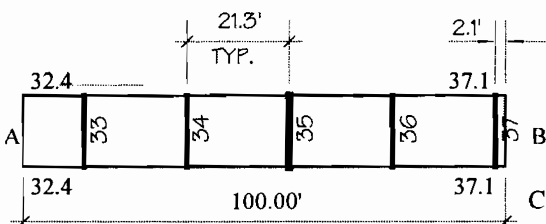
D = G x L

D = .006 x 398.78

D = 2.39268

D = 2.39

16.



North

Scale: 1" = 40'
Contour Interval = 1 Ft.

Grade calculation: 4.7 ÷ 100 = .047

To First Contour: .1 ÷ .047 = 2.1'

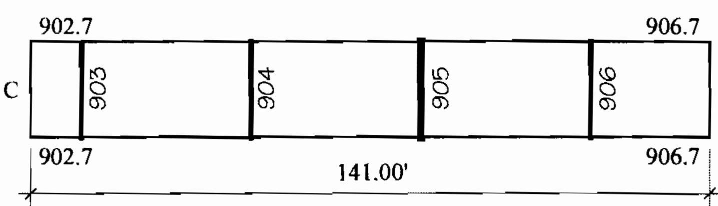
To Remaining Contours: 1 ÷ .047 = 21.3

G = .05 Grade in non-rounded off form = .047

Length to the first whole number contour line from high end (end B) = 2.13'

Length between remaining whole number contour lines = 21.28'

17.



North

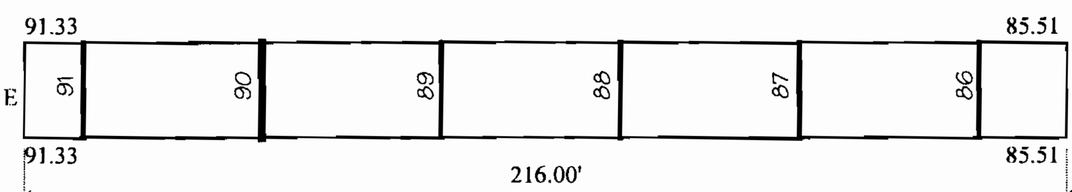
Scale: 1" = 40'
Contour Interval = 1 Ft.

G = .03 Grade in non-rounded off form = .028368794

Length to the first whole number contour line from high end = 24.68

Length between remaining whole number contour lines = 35.25'

18.



G = .03 Grade in non-rounded off form = .0269444444

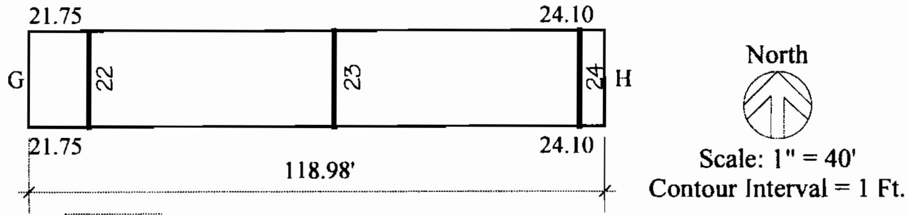
Length to the first whole number contour line from high end = 12.25'

Length between remaining whole number contour lines = 37.11'

North

Scale: 1" = 40'
Contour Interval = 1 Ft.

19.



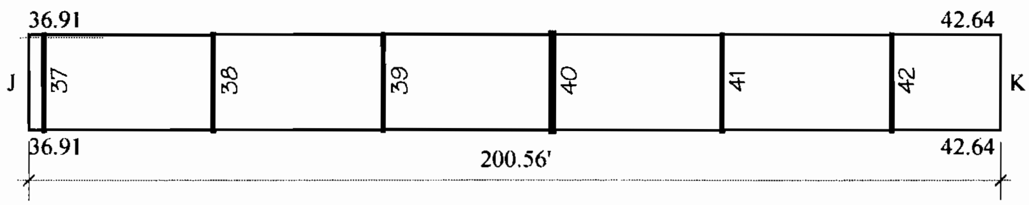
G = .02 (.019751218)

Length to the first whole number contour line from high end = 5.06'

Length between remaining whole number contour lines = 50.63'

(Answers given in parenthesis are informational.)

20.



North

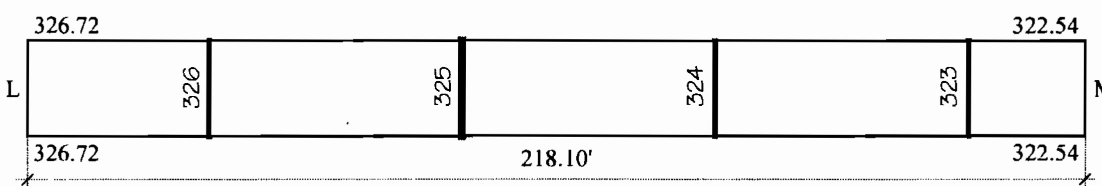
Scale: 1" = 40'
Contour Interval = 1 Ft.

G = .03 (.028570003)

Length to the first whole number contour line from high end = 22.40'

Length between remaining whole number contour lines = 35.00'

21.



North

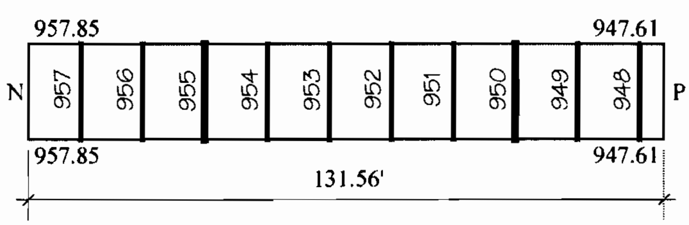
Scale: 1" = 40'
Contour Interval = 1 Ft.

G = .02 (.01916552)

Length to the first whole number contour line from high end = 37.57'

Length between remaining whole number contour lines = 52.18'

22.



North

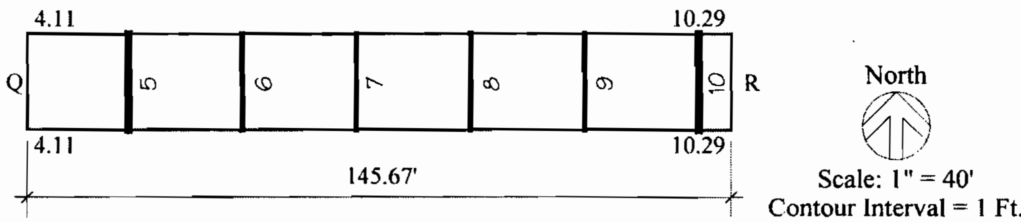
Scale: 1" = 40'
Contour Interval = 1 Ft.

G = .08 (.077835208)

Length to the first whole number contour line from high end = 10.92'

Length between remaining whole number contour lines = 12.85'

23.

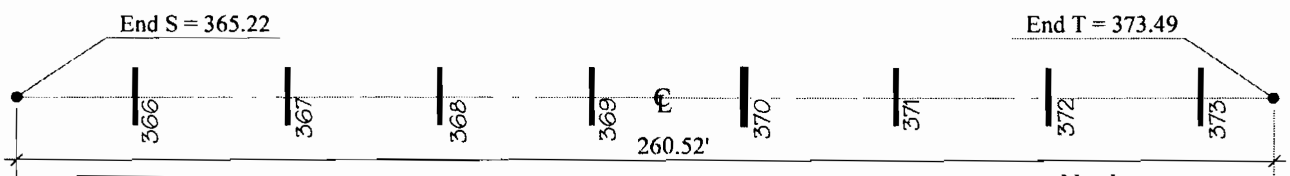


G = .04 (.042424658)

Length to the first whole number contour line from high end = 6.84'

Length between remaining whole number contour lines = 23.57'

24.



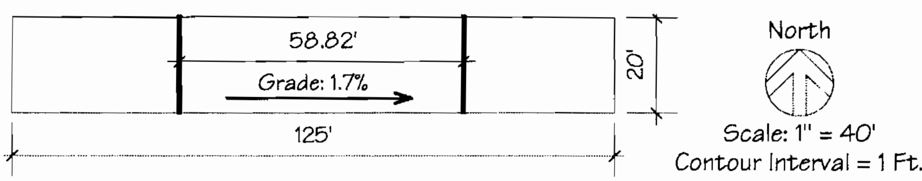
G = .03 (.031744203)

Length to the first whole number contour line from high end = 15.44'

Scale: 1" = 40'
Contour Interval = 1 Ft.

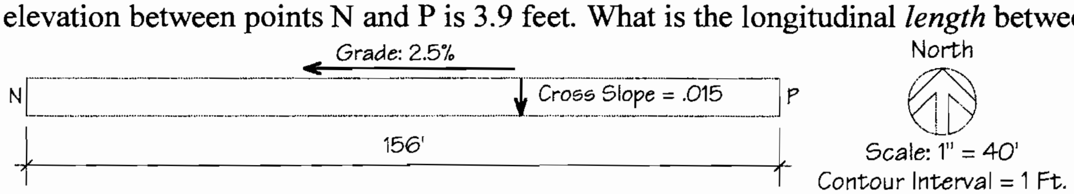
Length between remaining whole number contour lines = 31.50'

25. A terrace is 125 feet long by 20 feet wide, and has a longitudinal slope of .017 (1.7%). You are required to draw contour lines at a contour interval of 1 foot to depict the longitudinal grade. How far apart would the contour lines be drawn?



This problem asks for length between whole number contour lines. A longitudinal slope (grade) of 1.7% is given. Discard the width information—it isn't relevant to this problem. To find length between whole number contours, use formula $L = \frac{D}{G}$ The contour interval is given as 1-foot, therefore, substituting in, $L = \frac{1}{.017}$ L = 58.82 feet

26. The longitudinal grade of a walk is .025 (2.5%), and its cross slope is .015 (1.5%). The change in elevation between points N and P is 3.9 feet. What is the longitudinal *length* between N and P?



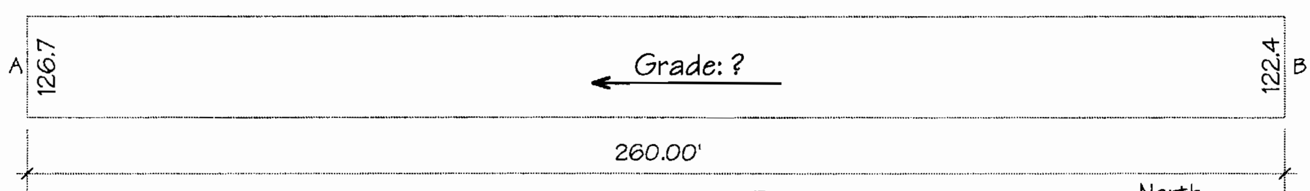
This problem asks for longitudinal length. Difference in elevation and longitudinal grade are given (cross slope isn't relevant). Use formula $L = \frac{D}{G}$ Substituting in, $L = \frac{3.9}{.025}$ L = 156 feet

27. A grade of .02 (2%) in 190 feet results in a change in elevation of?
    Since this problem asks for the difference in elevation, use formula D = G x L. Substituting in, D = .02 x 190 feet   D = 3.8

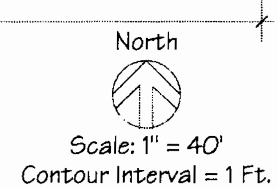
28. A .12 (12%) slope represents a 7 foot change in elevation in a length of how many feet?
    Since this problem asks for length of how many feet, use the formula $L = \frac{D}{G}$
    Substituting in, $L = \frac{7}{.12}$ L = 58.33 feet

29. An elevation gain of 4.5 feet in 160 feet indicates a slope of?
    Since this problem asks for slope (grade), use the formula $G = \frac{D}{L}$
    Substituting in, $G = \frac{4.5}{160}$ G = .03 (.028125)

30. The length between points A and B is 260 feet. Point A has an elevation of 126.7, and point B an elevation 122.4. The grade between points A and B is?



This problem asks for grade, therefore, use formula $G = \frac{D}{L}$
To find difference in elevation: 126.7 - 122.4 = 4.3
Substituting in, $G = \frac{4.3}{260}$ G = .02   (.016538461)



Reference Manual Answer Key

1. c
2. b
3. True
4. b
5. c
6. d
7. d
8. True
9. True
10. b
11. a
12. a
13. a
14. c
15. False
16. b
17. False
18. b
19. a
20. b
21. c
22. c
23. d
24. c
25. b
26. a
27. b
28. c
29. c
30. b
31. a
32. d
33. b
34. c
35. c