GRADE EASY

An Introductory Course in

The Principles and Practices of Grading and Drainage

Developed by
Prof. Richard K. Untermann
Department of Landscape Architecture
University of Washington
Seattle, Washington

Developed and distributed by the
American Society of Landscape Architects Foundation

GRADE EASY

An Introductory Course to
The Principles and Practices of Grading and Drainage

About this course outline — this document covers the basic principles of grading. Grading is simply the manipulation of ground form, and is in a sense the backbone of Landscape Architecture. Grading and drainage and construction courses are usually frightening for most students, as they involve mathematics, technical skills, a special language, etc. This document hopefully changes all that, presenting the easy-to-do, non-technical approach to grading. In fact, 90% of the mathematics normally associated with engineering construction has been eliminated (this is not to slight the development of precise technical skills associated with grading).

The object of this publication is to help the landscape architect become fully versed in the principles of grading and drainage and road alignment so as to be capable of manipulating ground form from a design point of view.

The information contained herein is basic and has been gathered from a variety of sources. I have taken this information, combined it with other data, regrouped, edited, and rewritten it, then turned it upside down, reshuffled it, etc., until it appeared workable.

The material is divided into two categories: a "How to do it" introduction covering basic and easily understood principles, methods and procedures for grading and drainage; and a "How not to do it" series introducing design considerations and constraints to the process.

You will note the words *usually, normally, typically* used throughout the text. This is an indication that there are exceptions, but from a *PRINCIPLE* point of view, the statement is correct.

Prof. Richard K. Untermann
Department of Landscape Architecture
University of Washington

GRADING - SYMBOLS AND ABBREVIATIONS

The use of symbols and abbreviations simplifies your drafting task, and if used carefully and consistently, can clarify and aid understanding of the drawings. There is really no set of accepted symbols; however, these have proved successful - and as long as they are noted in the legend, you will have no trouble in using them.

Contour elevation - number on high side of contour

Existing contour (every fifth contour drawn heavier)

Proposed contour (shown as solid line)

x 59.2	Spot elevation
x T.C. 25.1	Top of curb
x B.C. 24.6	Bottom of curb (include spot elevation)
x T.W. 2.5	Top of wall (include spot elevation)
x B.W. 1.2	Bottom of wall (include spot elevation)

Swale (direction of drainage)

I.E. 98	Invert elevation (include spot elevation)	
H.P.	High point (include spot elevation)	
L.P.	Low point (include spot elevation)	
T.S.	Top of steps (include spot elevation)	
B.S.	Bottom of steps (include spot elevation)	
C.I.	Contour interval	
P/L	Property line	
R.O.W.	Right of way	
D.I.	Drain inlet	Needs R.E. and I.E.
S.D.	Storm drain	Needs R.E. and I.E.
M.H.	Manhole	Needs R.E. and I.E.
R.E.	Rim elevation	
C.B.	Catch basin	Needs R.E. and I.E.
A.D.	Area drain	

CONTOUR LINES

Contour lines are the primary two-dimensional graphic vehicle used to express three dimensional ground form. Contour lines show land form, and the relationships of land form.

Definition of contour line - a line drawn on a plan which connects all points of equal elevation above or below a known or assumed reference point or plane. Therefore, all points on the contour line have the same elevation in reference to a common base. Contour lines express surface modulation and the changing of them indicates a change of ground form. To "move" a contour line half an inch may mean in reality moving a ton of earth 50 feet.

Contour lines were first used by Cruquius, a Dutchman, in about 1730 to represent the bottom configuration of a river. Others, perhaps independently, seized upon the idea of representing dry land surface with a similar type of line symbol; but it wasn't until relatively late in the 19th century that contours became the common method of depicting terrain on survey maps. Hachures - another technique utilizing shading to depict terrain were developed in the late 18th century, but never gained prominence.

USE OF CONTOUR LINES

Contour lines are used:

1. To study proposed changes in land form, and eventually to:
2. Guide and direct the work of earthmoving contractors in executing the grading project.

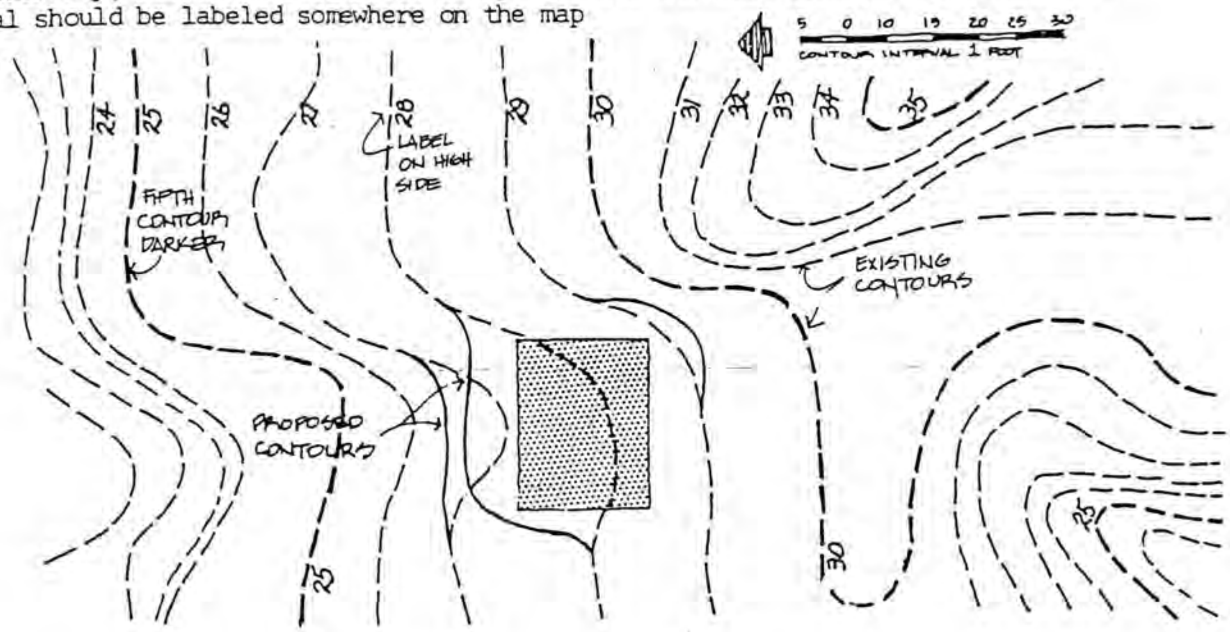
Contours show land forms; i.e., a hill, a valley, ridge, hogback, etc. They show the relationships of land forms - this hill to that valley, to this stream and finally to the ocean, etc. As contours are shown two-dimensionally, the scaled distance between them is exactly the same as in the field.

All grading plans have a vertical contour interval which should remain the same over the entire drawing. This interval stands for the vertical distance between contours, and is always indicated somewhere on the plan.

Proposed and existing contours are both shown on the same drawing. By showing both on the same drawing, it is possible to understand the exact location of work to be performed and the exact amount of work to be done.

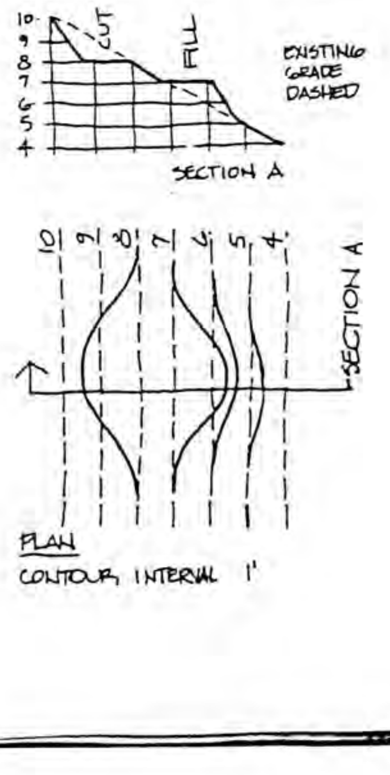
Existing Contours are shown by a light dashed line (usually 1/4" long, spaced about 1/16" apart). Every fifth contour is shown slightly darker for easy legibility. Proposed contours are shown as a solid light line. This solid line begins where you propose to make a grading change, and moves away from the existing (dashed) contour, returning to the existing (dashed) contour at the end of the proposed grading change. It is therefore possible to "read" the change by studying the area between proposed contours and existing contours.

Contour lines are labeled with the number on the high side of the contour. Contour lines correspond to a selected interval which may be 1', 2', 10', etc. Generally, all contour lines on a map indicate the same interval and the interval should be labeled somewhere on the map

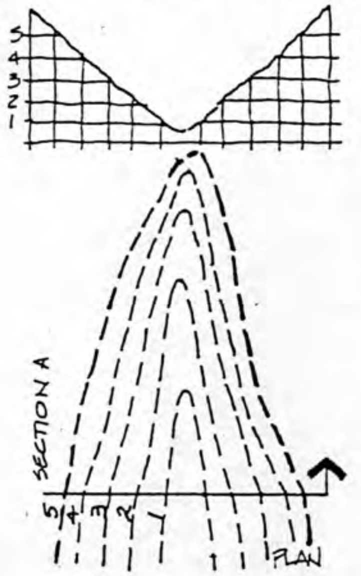


In an area of slight relief or generally flat and level country, the vertical interval may be as low as one foot, whereas in an area of marked relief it may be as large as 500, 250, or 100 feet. It sometimes happens that the relief changes from slight to marked within the limits of a map. When this is the case, intermediate contours are dropped or the vertical interval is changed from a small to a much larger one for the areas of marked relief.

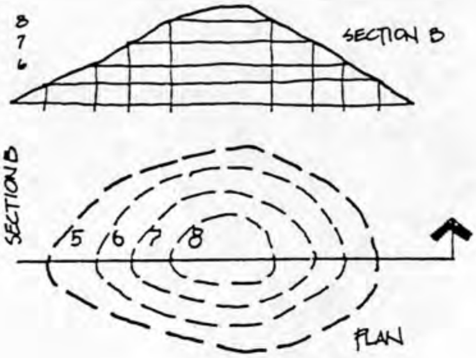
"Reading" changes in contours is tricky, but can be mastered with practice. Basically, proposed grading changes either add earth (called filling) or remove earth (called cutting). A proposed contour which moves in the direction of a lower contour is adding earth (filling). For instance (see diagram), proposed Contour 7 moves in the direction of a lower Contour (6) and indicates filling. Conversely, a proposed contour which moves in the direction of a higher contour is removing earth (cutting). This can be seen where Contour 8 moves in the direction of Contour 9 - and is removing earth (cutting). The amount of earth to be added or removed can be determined by comparing the proposed contour with the existing contours it crosses.



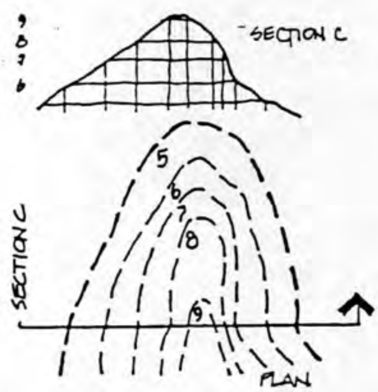
Profiles or sections can be constructed from contours and conversely, contour locations can be determined from profiles. A freehand construction of a cross-section is the best way to understand what the contours are doing. The following are most typical forms found in grading:



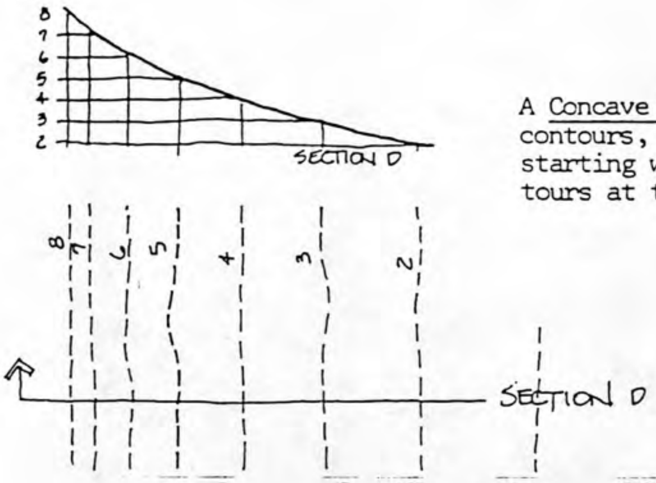
A Valley is represented by contours which point uphill. To construct the section, draw first the place where the section is to be taken (Labeled A), then project up, parallel lines at each place a contour crosses 'A'. Somewhere above, draw lines parallel to 'A' and scaled according to the contour interval. Where the two lines cross becomes the section line, and one has only to connect these points to complete the section.



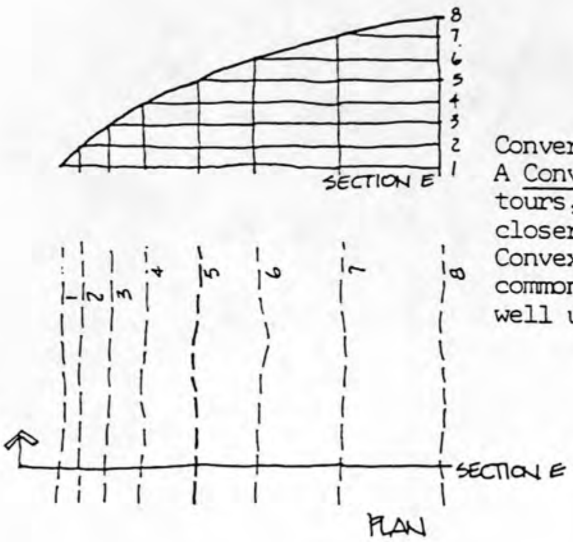
A Summit is indicated by concentric closed contours, and adequate contour labeling to distinguish it from a depression. Depressions are often labeled with hachures and both forms should include spot elevations at the highest or lowest point



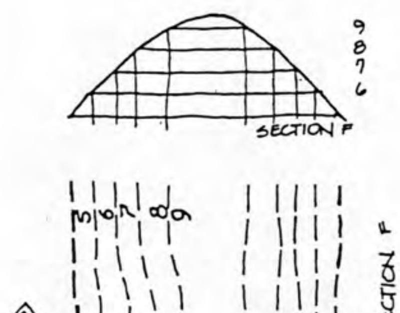
A Ridge is shown similar to a valley, but with the contours pointing downhill (note carefully the contour labeling, for this is the easiest way to determine if it is a ridge or valley). Ridges and valleys often are very wide, and difficult to distinguish on a large scale map.



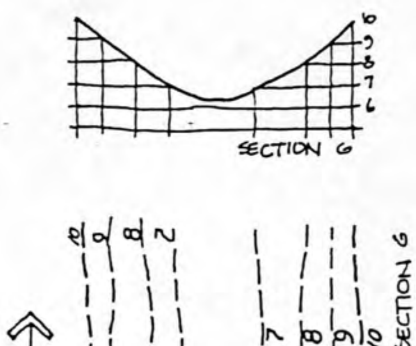
A Concave Slope is shown with parallel contours, each spaced farther apart starting with the closely spaced contours at the top.



Conversely
A Convex Slope is shown with parallel contours, each spaced farther apart with the closer contours at the lower elevations. Convex and concave landforms are the most common forms found in nature and should be well understood by Landscape Architects.



Two Adjacent Contours with the same numbers indicate either the top of a ridge (left) or the bottom of a valley (right). Again, the numbering indicates which it is, so check carefully.



Drainage always occurs perpendicular (at right angles) to the contours. The perpendicular line is the shortest distance between contours, and hence the steepest route (see Diagram 1). Water naturally seeks the easiest (steepest) route as it travels downhill in runoff. Channels, ditches, and valleys are indicated by contours which point uphill, and are sometimes made obvious by drawing an arrow in the direction of drainage, or labeling it a SWALE. (Diagram 2)

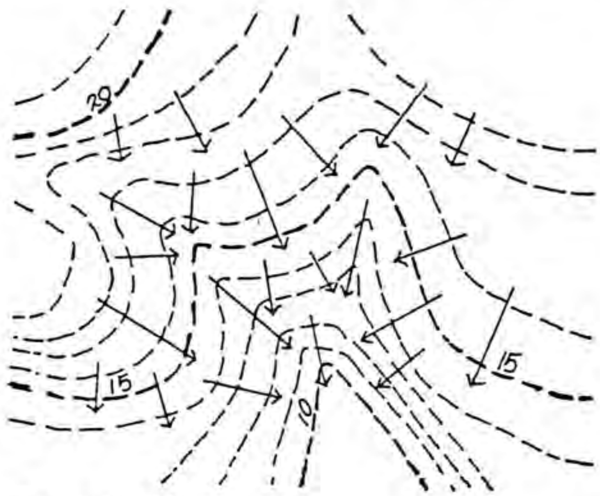


DIAGRAM 1

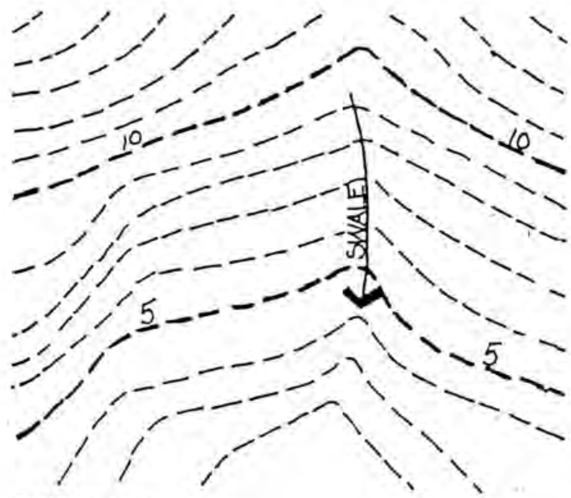
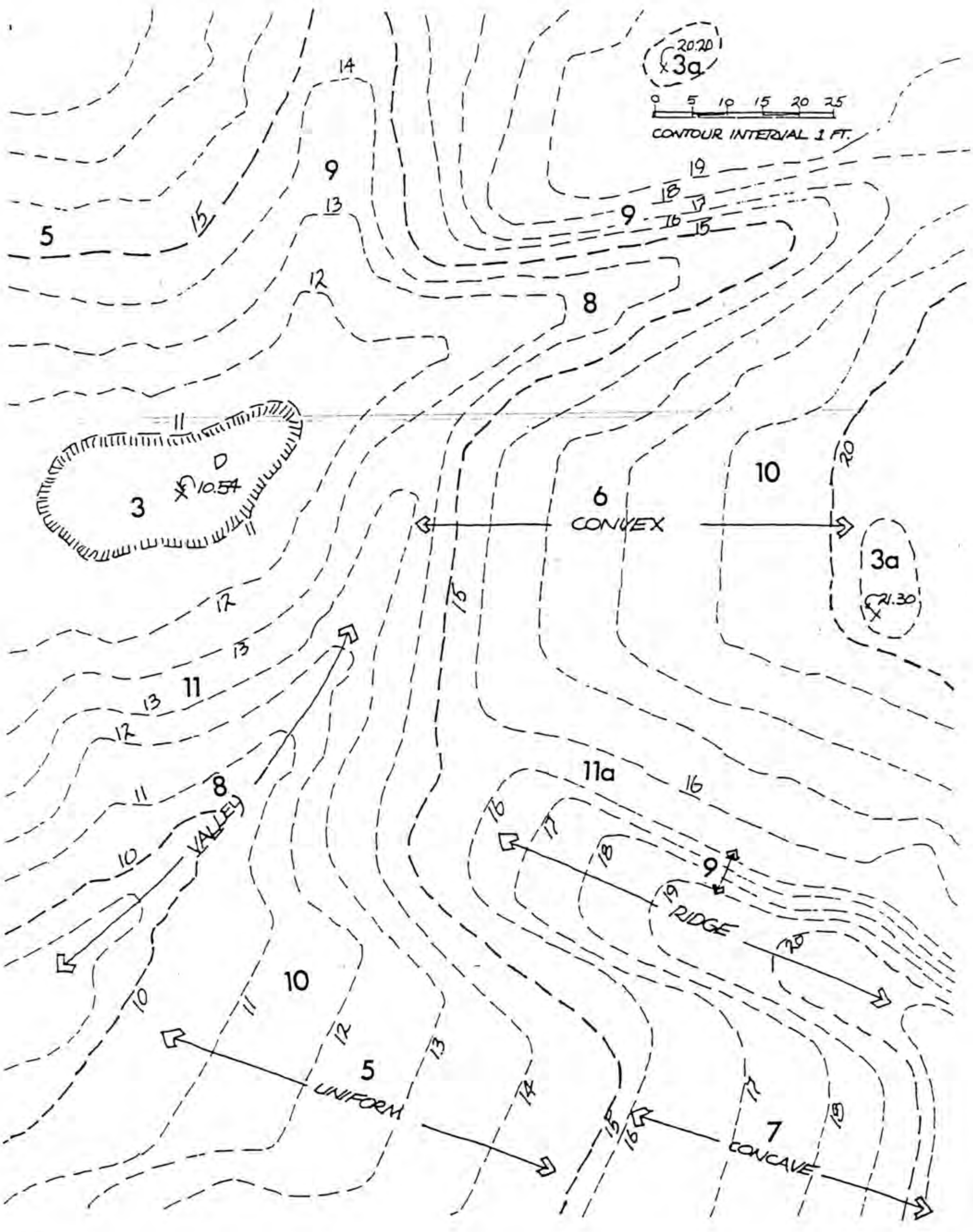


DIAGRAM 2

DRAW SOME FULL SCALE CONTOUR LINES

Contour lines are invisible, which makes visualizing them somewhat difficult. One method to overcome this is to draw imaginary contours on paved land. Find some heavy pieces of chalk, go outside and start drawing contour lines on the land. Start first with a paved parking lot. You can not really draw the exact contours, but begin somewhere at an assumed elevation, say the corner of the lot. By carefully eyeballing level lines, you can begin to see why contours take certain shapes.

This technique is particularly useful for visualizing what happens to contours at a curb, retaining wall, stairs, crowned road or sloping sidewalk. Move from the parking lot into a roadway, or patio, pedestrian walkway or playground. The secret is to always draw the contour lines level.


20.20
3a
0 5 10 15 20 25
CONTOUR INTERVAL 1 FT.
14
9
13
19
18
17
9
16
15
5
15
12
8
11
D
10.54
3
11
6
CONVEX
10
20
3a
21.30
12
13
13
11
12
11a
16
8
11
VALLEY
16
17
18
9
10
19
RIDGE
20
10
10
11
12
13
5
UNIFORM
14
15
16
17
7
18
CONCAVE

CHARACTERISTICS OF CONTOURS (See diagram for clarification)

1. All points on a contour line have the same elevation. A contour line connects points of equal elevation.

2. Every contour closes on itself within or beyond the limits of the map. In the latter case, the contour will not end on the map but will run to the edges.

3. A contour which closes on itself within the limits of a map is either a summit or a depression. A depression is usually indicated by the elevation at the lowest point, a spot elevation, or the letter 'D' placed there. A depression is also indicated by placing short hachure marks on the low side of the contour line (See No. 3 for depression and 3a. for summit).

4. Contour lines never cross other contours except where there is an overhanging cliff, natural bridge, or pierced or arched rock.

5. Contours which are equally spaced indicate a uniform sloping surface (See No. 5).

6. On a convex slope, contours are spaced at increasing intervals going up a hill; the higher contours are spaced farther apart than the lower contour lines (See No. 6).

7. On a concave slope, the contours are spaced at increasing intervals with the lower contour lines spaced farther apart than the higher ones (See No. 7).

8. Valleys are indicated by contours pointing uphill (See No. 8). In crossing a valley, the contour lines run up the valley on one side, turn at the stream and run back the other side.

9. Generally contours which are close together indicate a steep slope (See No. 9).

10. Contours which are spaced far apart indicate a relatively level or slight grade (See No. 10).

11. Contours never split; however, you will occasionally see two contours numbered the same and side by side. This indicates either a high area, or a low area. It will be high (See No. 11) if the numbers for both contours fall in the same interval, and a low area (See No. 11a.) if the numbers don't.

12. The steepest area of a slope runs perpendicular to the contours (water also drains this way).

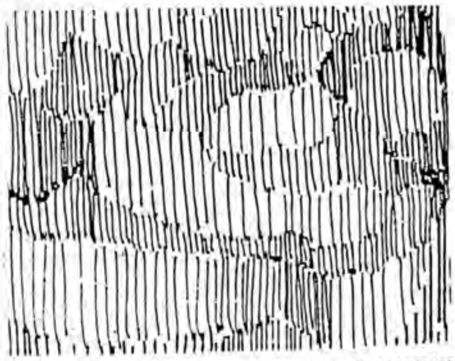
OTHER METHODS OF DEPICTING TOPOGRAPHY AND GRADING

Topographic relief can also be shown:

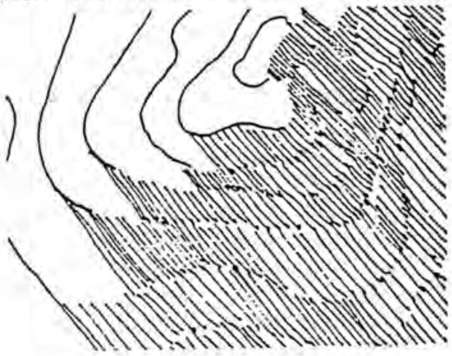
1. By shading
2. With spot elevations
3. With profiles and sections
4. By a scale relief model
5. Using stereo aerial viewers
6. Through symbolic representations.

1. Relief by Shading - showing relief features by shading the slopes in proportion to their degree of slope, steep slopes being darker than slight ones. Three systems: (a.) vertical shading, (b.) oblique shading and (c.) hachures.

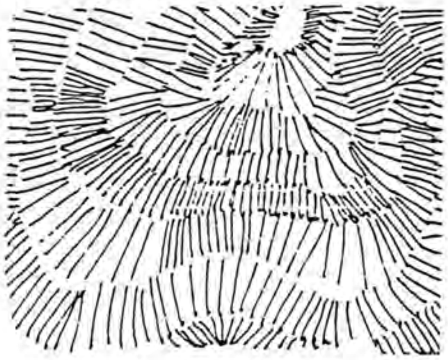
   A. Vertical shading - assumes that the rays of light hitting are parallel and of equal intensity. The more horizontal the surface, the more light will be reflected, and the lighter the surface will appear. Steep slopes will receive less light, will reflect less light, and will be shaded darker.



   B. Oblique shading - term used to designate the method of shading in which the rays of light are assumed as coming from a source in the upper left-hand corner. This lighting causes the relief features to throw shadows to the southeast. A steep slope throws a dark shadow and a slight slope a light one.



   C. Hachures - hachuring is a form of shading to show relief by means of short disconnected lines called hachures drawn in the direction of flow of water, the thickness and spacing of which indicate the degree of slope. To show shading by hachures, make them heavy with closer spacing for steeper slopes and light with wider spacing for slight slopes.



Method of Hachuring - before hachures can be drawn it is first necessary to draw contours. The hachures are then drawn perpendicular to two successive contours usually with a spacing equal to one-quarter of the shortest distance between them and of a thickness depending upon the slope. This rule for spacing contours is called the quarter rule.

Characteristics of Hachures

1. A hachure is the shortest distance between two successive contours.

2. Hachures are always perpendicular to two successive contours.

3. Hachures show the direction of flow of water down a slope.

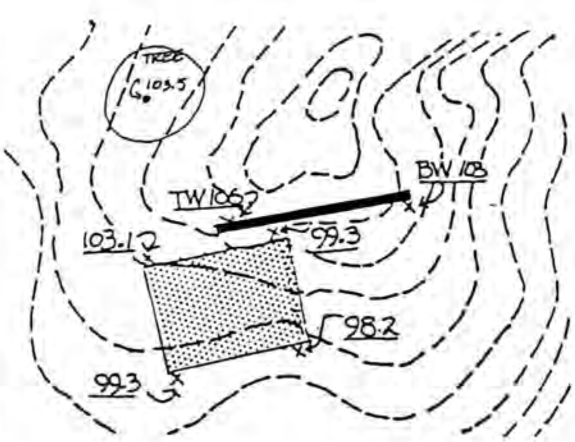
4. When the hachures are heavy and close together, they show a steep slope, and when they are light and far apart, a slight slope.

5. Flat surfaces, such as hill tops, plateaus, and river bottom lands, are shown by white spaces. Hill tops are identified by spot elevations and reference to other terrain features; valleys are identified by the presence of a stream line.

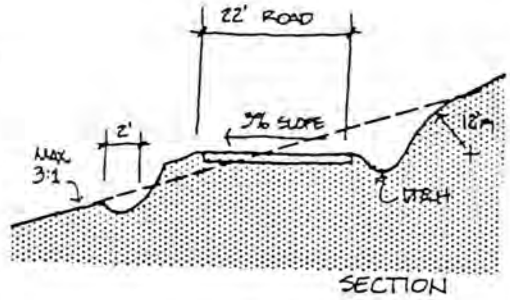
Advantages and Disadvantages of Hachuring and Shading:

Hachured maps also give a good picture of the relief of the ground, but it is extremely difficult to determine elevations, unless they are given by spot heights. The range of hachuring is small. It is impossible to show many different degrees of slope, and determination of such degree of slope as is possible to show is somewhat difficult. It is very hard to show slight folds in the ground, and steep slopes can be shown only at the cost of obscuring other details of the map. Hachures are difficult to draw in the field. A large number of maps have been made using this system of relief, but it is gradually falling into disuse; probably few maps except on a very small scale will be made on this system in the future.

2. Showing grading by Spot Elevations. Spot elevations are used in detail designs where topographic differences are not enough to use contours. A spot elevation is simply a written number corresponding to the proposed elevation. It can be inserted on the drawing in areas where critical grading or drainage must be shown. Spot elevations are normally shown in the whole number plus decimals; for instance, 15.19, and are usually designated by an 'X' mark on the exact spot where the proposed elevation is located. Spot elevations can be used to indicate high points, low points, bottoms of walls, tops of curbs, breaks in direction of drainage, etc. Spot elevations can also be used between contours where specific or critical elevation must be indicated; for instance, the elevation of a tree to be saved may be designated with a spot elevation.



3. Proposing grades using Profiles and Sections. Profiles and sections are often used to indicate grading for circulation routes. Profiles are usually taken at the center line of the route and shown by outlining the existing and proposed topography along the length of the route. Sections show proposed grading through (at right angles to) the roadway including shoulders, road surfaces, etc. Sections typically do not include existing topography but instead show proposed work as well as limits of cut, limits of fill, widths of road, sidewalks, curbs, etc. (for additional information, see Section 4).



4. Depicting Topography and Grading Proposals by Relief Scale Model. A contour plan can be easily transformed into a useful 3-dimensional model by transferring the contours onto a layer whose thickness approximates a contour interval and gluing layers together. More elaborate model making equipment is now used to carve a topographic model from polystyrene, again using the contour at its required interval. These models are normally expensive and not used in student work. It's common for the vertical elevation to be slightly exaggerated in relief models to make grade changes obvious.

5. Using Stereo-Aerial Viewers to Determine Topography. Most topographic maps are made from aerial photographs, utilizing special equipment which, by a means of a focusing device, scans the aerial map and can determine a line of equal elevation. This line is, of course, a contour line.

6. Symbolic Relief. Land forms also can be expressed symbolically with the degree of relationship not stated, or the forms may be expressed in terms of scale with all relationships defined in terms of a given unit.

Examples: Three-dimensional, scaled - the block diagram or the relief model
Three-dimensional, symbolized - South Sea Islander's chart

Two-dimensional, scaled
- Aerial photograph
- Contour map
- Section
- Hachured map
- Fathometer recording
- Layer system (color)
- Conventional sign system
- Nautical chart

Two-dimensional, symbolic
- Aztec map
- Treasure map

GRADING Contour Manipulation

MAKING AN AREA LEVEL TO PUT SOMETHING ON

Buildings, parking areas, play yards - most elements we build require a fairly level pad to sit on. At the same time these level areas must slope enough or be graded properly to assure adequate drainage.

Grading to make an area level is accomplished in one of three ways:

1. By cutting into the bank.

2. By filling out from the bank.

3. By a combination of cut and fill.

To clarify cutting and filling, grading consists of two basic operations:

Removing earth (called cutting)

Adding earth (called filling)

A grading plan tells the contractor where to remove earth (cut) and where to add earth (fill).

GRADING PROCEDURE

The grading procedure in its most basic principles is simple - almost mechanical. Once the proposed level area is located, a finish grade, the slope for new banks and the grading method (cut, fill, combination) should be determined. Contour manipulation can then be laid out as an almost mechanical process.

The level area should be large enough to accommodate your program.

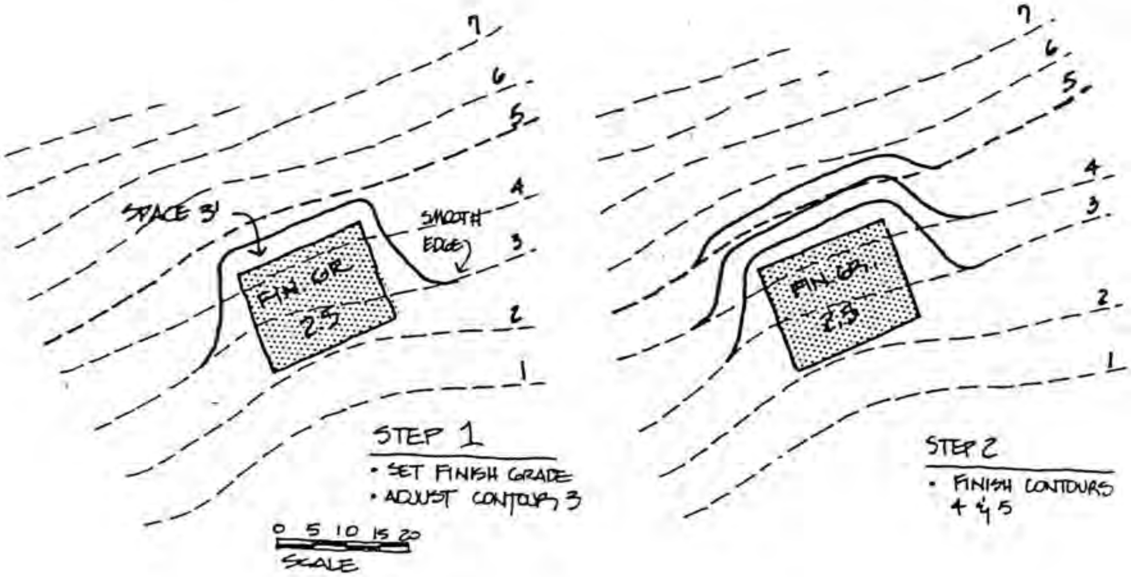
Finish grade can be set at any grade, but it will be clearer and easier if you use a grade .5 (one-half foot) above or below the whole number you select (i.e., 7.5, or 6.5, or 82.5, etc.). This simplifies the location of each contour as you will see.

The slope of new banks can be however steep you want, but for now I suggest using a 3:1 slope (1 foot rise per 3 feet horizontal distance).

1. Grading to make an area level by cutting into the bank.

This method provides a level area surrounded by three sloping walls - the two side walls becoming higher toward the back, with the rear wall being the tallest. First, locate the area to be leveled on the topo map. Determine finish grade by locating the contour just below and outside the level area and raising it .5 (one-half foot). This grade will become the finish grade for the level area. Move up to the next higher contour, and wrap it around behind (above) the level area and back along the other side, connecting to the same contour. As this contour is higher than the established finish grade, it is located behind the level area by enough distance to allow room for the slope up (3 feet when using 3:1 slope ratio). Go to the next higher contour and wrap it around the level area, maintaining the same distance between contours as before, and connecting back to the same existing contour. Continue up the bank until there are no more contours passing through the level area or the adjusted contours.

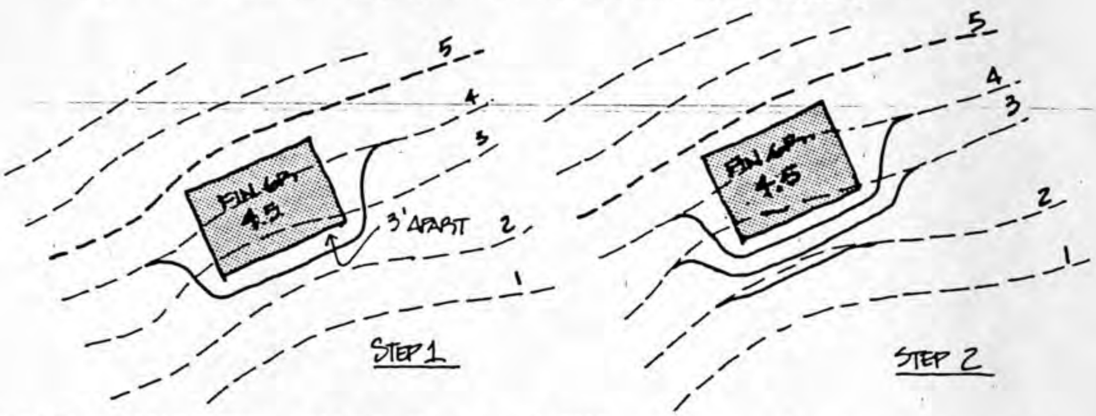
In the example below, the area to be level is shown with diagonal lines. Contour 2 is the lowest contour not passing through the level area and should be raised .5 (one-half foot) to become the finish grade (at 2.5). Contour 3 is wrapped around the level area and returns to join the same contour. (Note the use of solid lines to designate proposed contours.) This contour has been kept a scale 3 feet away from the building to allow a slope between the new finish grade and Contour 3. Now do the same with Contour 4 and 5. Contour 6 passes by without any interference; it does not have to be adjusted.



To explain the "slope up," if the contour interval is one foot, and you want to maintain a 3 to 1 slope (3 foot horizontal to one foot vertical), the contour must be 3 feet behind the level area. Important - you must select a grade for the proposed banks which is steeper than the existing grade, or you will never be able to meet existing grade. A 3:1 slope will usually be steep enough for landscape development. Meeting the grade is jargon which describes the point at which proposed grading ends. One normally attempts to minimize grading by meeting grade as soon as possible.

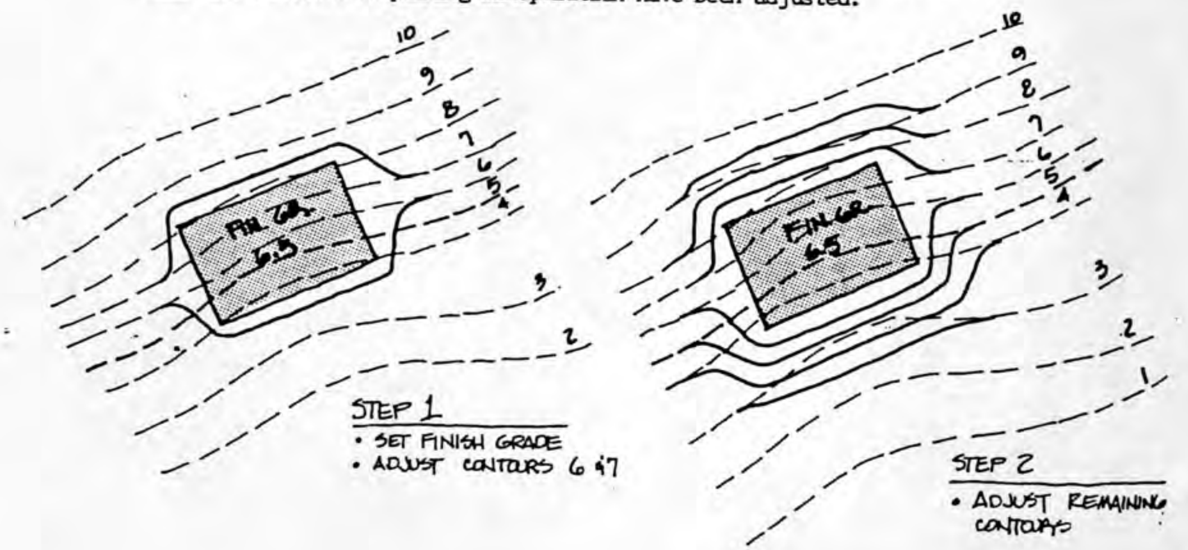
2. Preparing a level area by filling. This is essentially opposite to the method just described. Rather than scooping out a section of the hill, you add fill to the hill, building up a level area over existing contours. To begin, locate the area to be level, set finish grade at .5 (one-half foot) below the highest contour not passing through the level area. Now, move down to the next lower contour, and wrap it around the level area toward the direction of the lower contours. Space this far enough away from the level area to allow for slope between contours, and continue down the slope wrapping contours around until all the contours have been completed.

   Example: As Contour 5 is out of and above the level area, 4.5 becomes the finish grade. Begin next with Contour 4, wrap it around the level area (keep it, in this case, 3 feet from the level area to allow room for the slope) and return to the same contour. Do the same with Contour 2.



3. Grading a level area using both cut and fill. This combination is the usual method of preparing a level area as it balances cut and fill. (Balanced cut and fill means there is approximately an equal amount of cut and fill. This reduces grading costs as you do not have to dispose of or import soil.)

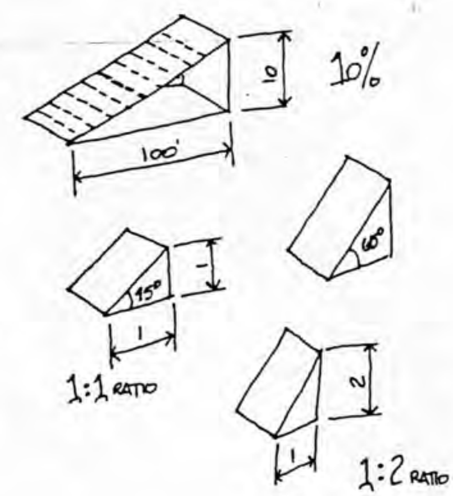
   Begin by locating the area to be leveled on the topo plan. Determine the finish grade by locating the mid-grade running through the level area - that is, there should be an equal number of contours above as below the level you select as finish grade. In this case Contours 6 and 7 are the mid-point, so 6.5 becomes finish grade. Now, wrap the contour below finish grade around the lower side of the level area, and the next higher contour around the high side. Do this with the remaining contours until all the contours requiring manipulation have been adjusted.



GRADES AND GRADIENTS

(short review). The term gradient means the fall or rise of land per horizontal unit and is usually expressed in percentage. A synonym for gradient is slope. Gradients can also be expressed as a ratio; for instance, 3:1 with the 3 being horizontal distance and the 1 being vertical distance. The 3:1 indicates there is a 3' horizontal space for every 1' vertical rise. It is customary to first state the horizontal distance and then the vertical distance, that is 3:1.

Percentages are used to express slopes up to 1:1, with the percentage shown indicating the vertical rise per 100 feet horizontal distance; that is to say, a 10% slope has 10' of rise per 100' horizontal distance and could be expressed in a ration 10:1. Likewise, a 20% slope has 100' horizontal distance and 20' vertical distance, or could be expressed as a 5:1 slope. This carries on until you achieve 100% slope where 100' horizontal distance is required for 100' vertical change in elevation or a 1:1 slope. For slopes steeper than 1:1 it is customary not to use percentages but rather to use ratios. Again, the first number in the ratio indicates horizontal distance; the second number is vertical distance, so a slope with 9' horizontal distance and 10' vertical distance (in excess of 1:1) would be a 9:10 slope ratio.



DETERMINING GRADIENTS MATHEMATICALLY

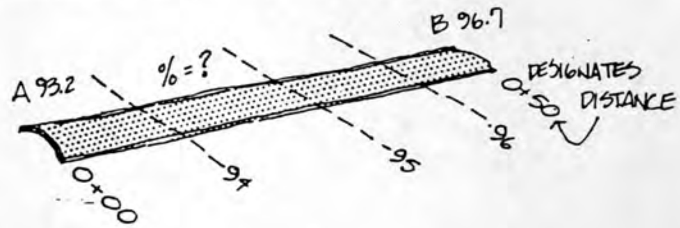
The one essential mathematical formula for most grading problems is used to compute gradients. The formula will allow you to compute:

- The percent of slope between two known points and a given distance.
- The horizontal distance between points when the gradient and vertical elevation are known.
- The vertical elevation between points when the gradient and distance are known.

The formula: $G = \frac{D}{L}$ or $L = \frac{D}{G}$ or $D = GL$

Where: G = the gradient in percent
D = the difference in elevation between two points
L = the horizontal length between two points

Example: <u>Given:</u> A length of roadway with Point A = 93.2 and Point B = 96.7 elevation. The distance between Points A and B = 50'.



<u>Find:</u> 1. The gradient (in percent)
2. The distance from Point A to Contours 94, 95 and 96

<u>Solution:</u> $G = \frac{D}{L}$ Gradient = $\frac{\text{Difference in elevation}}{\text{Horizontal Length}}$

1. The difference in elevation between Points A and B equals 3.5' (96.7 - 93.2)

   $G = \frac{3.5}{50} = .07$ or 7% gradient

2. To find the horizontal distance from Point A to Contour 94, first determine the elevation difference between Contour 94 and Point A: 94 = 93.2 = .8

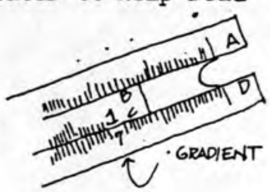
   Then: $L = \frac{D}{G}$ Where $L = \frac{.8}{.7}$ = 11.4 feet from Point A

   Obviously Contours 95 and 96 can be located the same way. All figures are expressed in decimals by converting inches.

This calculation can be carried out easily on the slide rule using the C and D scale.

I. For the Formulas $G = \frac{D}{L}$ or $L = \frac{D}{G}$

   A. The gradient (G) is located on the D scale below the C scale 1.
   B. Length (L) is located on the C scale directly over the drop (D) on the D scale Use the locater to help read the length or drop.



II. For the Formula D = GL

   A. Set C scale 1 over the length (L) on D scale.
   B. Locate the gradient (G) on the C scale, read the Drop (D) directly beneath it on D scale.

As most grading is performed at uniform gradients, it is possible to set the desired gradient (on the D scale below 1). You can then directly read the change in grade for any distance, or vice-versa.

Level areas created by filling are also subject to severe erosion as the soil particles are loose. Slippage and slides can also occur as there is little or no bondage between existing soil and the fill.

3. Making an area level by cuts and fills. This method of grading is most popular. As there is an approximate balance of cut and fill, expensive hauling and disposal fees are eliminated. It is most useful on large sites with minimum topography where it is possible to dispose of fill spoils so they will not cause erosion, or require elaborate foundations. (It is often possible to use fill material in the garden area, for parking, or some other non-structural purpose.)

Regardless of grading method used, the topsoil should be carefully stripped off, stockpiled (stored, so it can be reused) and replaced following grading so planting and erosion control can follow.

> The information here is general, and geared to producing lower grading costs. However, costs must be considered in both short and long term effects. Often a specific design will require an operation which is uneconomic in immediate costs, but may be justified over the long term, and your task is to develop a convincing argument. Justification for specific cases can only be made through a complete understanding of the general condition.

DRAINAGE

Running water is the most important cause of erosion. Water from rainfall causes erosion which probably does more to alter the surface features of the land than all the other agents combined. The average annual rainfall in Seattle is approximately 34 inches of water. Of this, 20 to 30 percent becomes runoff - water flowing from the land. In developed areas this is as high as 90-95% making the problem much more difficult. Additionally, people prefer relatively dry use areas and so we must drain them.

Drainage is a symbiotic adjunct to the grading process. Every grading plan must consider and solve the drainage problem specific to it.

There are four methods by which rainfall is removed from where it falls:

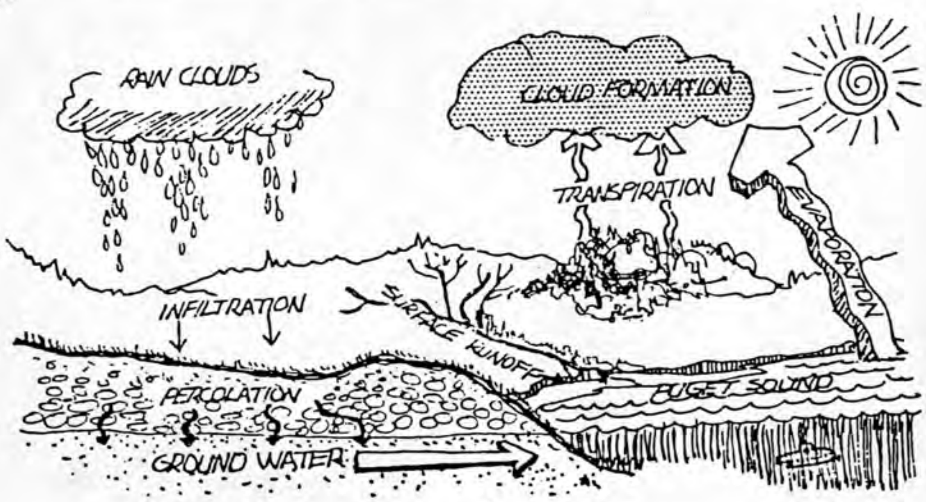
1. By surface runoff - over land and downhill until eventually, in many areas, it reaches the ocean (this method carries off the bulk of our annual runoff.

2. By underground drainage (subsurface)- water infiltrates and moves through most soils both horizontally and vertically under the influence of gravity - though at a much slower rate than surface runoff.

3. By evaporation - from the leaves of plants, from standing water, from many different surfaces, etc., and lastly

4. By transpiration - from trees and plants following photosynthesis.

These four methods of removing rainfall combine and become part of the Hydrologic Cycle.



The cycle is complete when sufficient water evaporates, returns to the air, is transported and dispersed over land, rises with topography and wind currents, cools and returns to the earth as fresh rainfall.

In grading, surface runoff is the primary method to remove excess water. This is usually carried out in some sort of storm drainage system. A storm drainage system collects, conducts and disposes excess surface water caused by runoff from rainfall. Additionally, a storm drainage system can:

1. Safeguard against erosion by reducing the rate of flow and volume of water.

2. Reduce flooding and damage to property as well as increase usability through elimination of excess unwanted water.

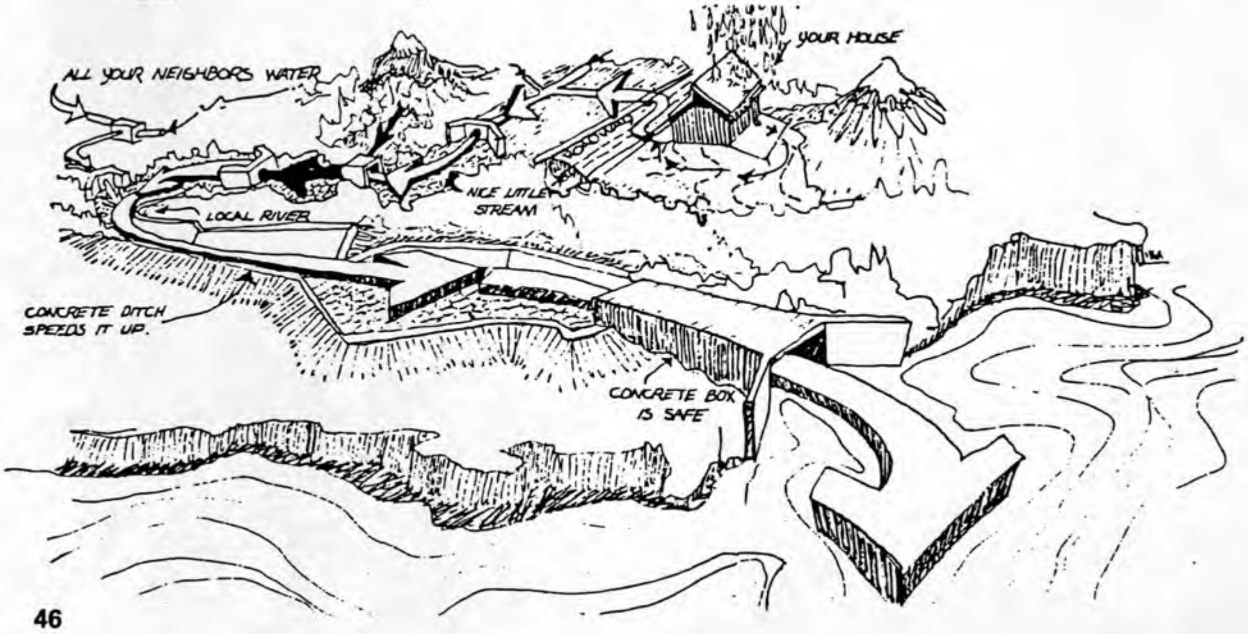
3. Eliminate unnecessary standing water which may lead to pollution and breeding of insects.

4. Provide better growing conditions for trees and plants by reducing soil saturation.

5. Improve load-bearing capacity of soils, thereby increasing the buildability of a site.

Layout and Design of Drainage System. Most runoff is caused by rainfall. Runoff occurs during and for a short time following the rains. This water is collected and conducted away from use areas in a variety of natural drainage patterns, man-made open trenches and closed pipe - called a storm drainage system. A typical storm drainage system might begin in someone's back yard with water draining from the roof, collected in a gutter and through the downspout to the patio. From here it may flow across the patio via gravity (the patio has a slight tilt to assure proper drainage) and onto the lawn. It would then travel across the lawn, along side the house in a wide, gently sloping grass ditch called a swale to the front yard, across this lawn and over the sidewalk (perhaps illegally) to the street. (Some of the water would be lost through sub-surface percolation during this process.) From the street the water would flow in the gutter down hill for some distance until it reached a catch basin.

Once collected in the catch basin, the water would travel in a storm drain line (pipe) until perhaps it crosses a small natural stream where the storm drain line would daylite (surface) and the water would spill into the stream. The water would flow through culverts (large pipes) where roadways crossed the stream, and eventually portions of the stream may have been rip-rapped (lined) with large rocks to prevent erosion. As more and more storm drains feed into the stream, it may be lined with concrete to speed the flow of water, and may eventually be covered for safety and other engineering reasons. Eventually, this water will discharge into a larger river, a lake, or the ocean.



Obviously, there are several other ways it could have been conducted from the house including straight away in a storm drain to the lake or river, or into the sanitary sewer line (combined with household sewerage) where it would be treated prior to disposal into the bay, river, or ocean. (This practice is disappearing as it causes overflow pollution during storms and due to the expense of treating storm water, cities across the nation are installing separate storm drainage systems.)

From this cartoonish description, it is obvious that there are two main categories of storm drainage systems:

1. The private system used to conduct water from your land to the street, and

2. Public storm drainage systems running in streets and other public rights-of-way carrying water eventually to a river, lake, the ocean, etc. We will cover only private drainage in this section.

Storm drainage systems are necessary only where development is dense enough to cause a build-up of runoff following a rain. Higher densities mean more paved areas - patios, driveways, roads, roofs, even lawns, causing a fast runoff immediately following a rainfall. Low density developments (one to two families per acre) have enough open land left in natural plant cover to eliminate the need for an elaborate drainage system to remove water from the property. However, you must still be sure the water drains away from all buildings and flows off all level use areas. This water should be carried away on tilted surfaces and then allowed to disperse slowly over the landscape. In the same manner, roadways built through rural landscapes can be constructed without elaborate drainage systems, allowing the water to run off the road and disperse generally over the landscape.

Your task as a landscape architect will be to devise drainage systems for removing excess rainwater using these and other techniques. Depending on the size and scope of the project, you will usually be designing that portion up to the public right-of-way, and then connecting to an existing public drainage system. However, you may eventually be called upon to develop a storm drainage system for a neighborhood or a larger portion of the public community.

REMEMBER, A STORM DRAINAGE SYSTEM IS DESIGNED TO:

COLLECT CONDUCT DISPOSE

As usual, ECONOMY is the rule, and you will try to design the system producing the best results for the lowest cost. Generally, surface drainage across sloping paved and planted areas is cheaper than installing catch basins and underground pipes.

GOOD DRAINAGE PRACTICES

1. Gravity is the primary vehicle for carrying runoff away. There must, therefore, be a continuous minimum fall in the ground level to assure drainage.

2. Water flows perpendicular to the contours - ALWAYS!

3. It is better (ecologically) to slow runoff water down and let it be absorbed by the soil than to remove all of it through surface runoff.

4. New runoff water must never be directed purposefully from one property onto a lower neighboring property. It is acceptable for water which flows naturally from your property to the neighbors to continue, but you must never increase this flow artificially through grading.

5. Erosion is the biggest problem in drainage - slopes must be carefully calculated to insure continuous flow, yet not steep enough to erode. (Plant all slopes immediately following grading.)

6. Slow-moving water will create a bog, while water moving too fast will erode and form unwanted gullies.

7. Surface drainage is generally preferred to using underground pipes, as this eliminates the danger of pipes clogging, is less expensive, and allows some runoff to percolate into the ground.

8. Duplicate the natural runoff principles where possible (see Hydrologic Cycle).

9. Paved areas look better when graded almost level - avoid wildly sloping paved areas.

10. Large amounts of water (from a parking lot, etc.) should not cross a sidewalk to reach the street drain (install a catch basin or french drain before the sidewalk).

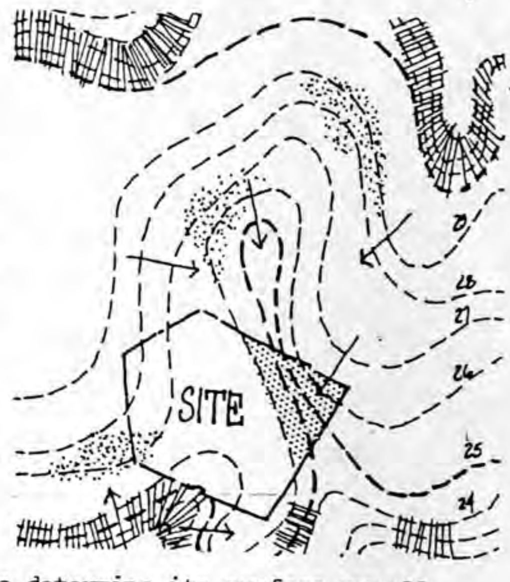
11. Always design a secondary drainage route to handle runoff should the primary system become clogged or constricted.

GRADING PROCEDURE

It should be obvious that drainage is simply a matter of COLLECTING water, CONDUCTING it, and DISPOSING of it. You must, in preparation of a drainage plan, determine where all the runoff will be coming from, where you will eventually put it, and how to get it there.

In addition to determining where water is coming from, you must determine which areas you want to keep drained. Normally all level use areas should be properly drained so they are useable - this would include paved surfaces, playfields, entrances, parking, roads, etc. Additionally all sloping areas should be designed so as not to dump runoff on adjoining level use areas. Provide a small swale between the slope and the level area to carry runoff away.

Runoff can originate on the site you are concerned with, or from an adjoining higher property. Your first task is to analyze the topography, including adjoining lands to determine the overall large scale drainage pattern. What existing patterns of runoff affect the site, where are the high points, the ridges, valleys, streams, swales, etc. This will show where water will be coming from, what quantities you must deal with, and how they will affect your planning. In large projects, you may want to prepare a large scale drainage pattern plan to guide you. (Remember, water always travels perpendicular to the contour and faster as contours are spaced closer.)



Check in greater detail the on-site conditions to determine its surface runoff pattern. Include high points, low points, ridges, valleys, streams, swales, points of concentration, etc. Note any unusual soil types such as gravelly or sandy soil which will percolate well, and clay or silt soils which will not percolate properly.

> These steps are too easily overlooked and forgotten, or considered trivial and time-consuming and therefore ignored. However, exactly the opposite is true - for it is not unusual for answers or solutions to drainage problems to be discovered during this process. You must take the time and consciously locate the factors mentioned. With practice you will develop a skill to do it quickly.

Overlay your proposed development on these study sheets. Note again where water is coming from (the highest point) and where it is going (the lowest point). This information will be helpful in designing your drainage system, for to go against it is foolhardy. Outline all level areas you want to keep dry. Next, determine all fixed elevations such as existing adjacent buildings, trees, roads, etc., for these must also be satisfied. This information forms the primary data necessary to COLLECT runoff - our next step will be to determine where we can DISPOSE of it.

Runoff is disposed of either on-site or off-site. Low density projects with large natural open spaces can usually accommodate their own runoff needs by directing runoff from areas to be drained onto the naturally vegetated open spaces or into natural streams (called on-site disposal). Your main task will be to avoid concentrating runoff onto one location which may cause erosion (rather devise a number of locations to dispose of runoff).

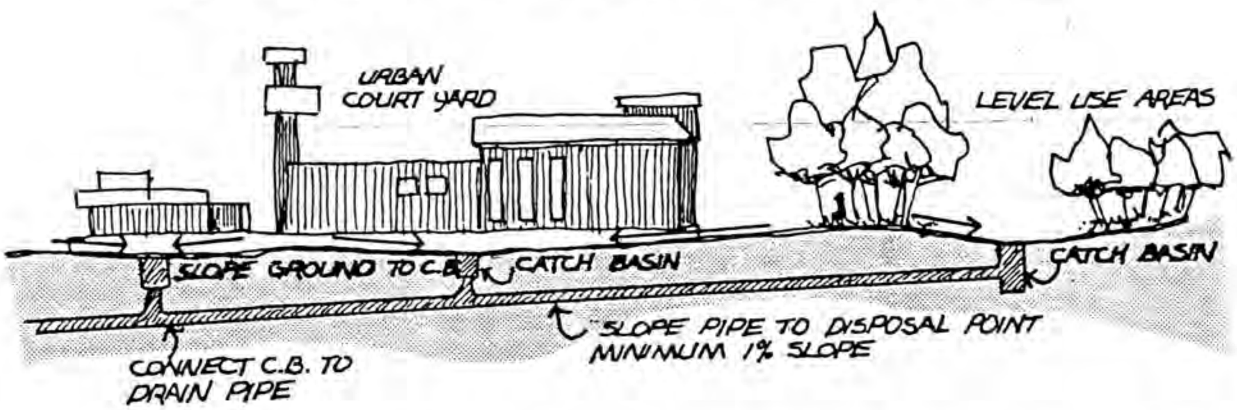
Higher density developments will usually have a public storm drainage system located in the street which abutting projects can tie into (called off-site disposal). This system consists of an underground pipe (buried 3' to 24' deep), usually with laterals connecting each property. Your on-site runoff can be collected and placed in this lateral for disposal by the responsible public agency. It is normal in many areas of high rainfall to have building room drains and basements drains connected directly to this system. Runoff water from landscape development can often be included in this same connection. Some on-site water can be directed across the sidewalk for collection in the road gutter - but the amount must not make the walk impassable.

Once you have determined where the water is coming from, and where you can dispose of it, you have to determine how you can get it there. Three ways are possible:

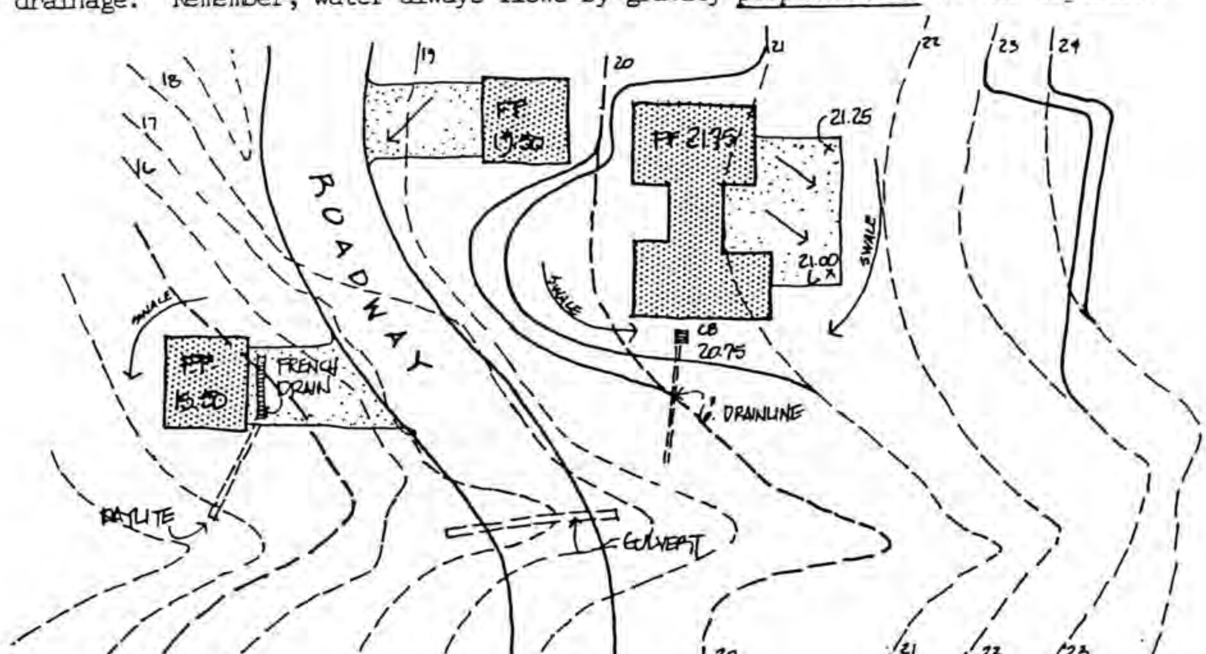
Open System - that is, "on-grade".

Closed System - being underground.

A Combination of Open and Closed Systems. Open systems are preferred as they are less expensive to install and maintain, but closed systems may be necessary where there is a large amount of water, or where gradients are minimum. Minimum gradient means there is not enough surface fall to allow proper drainage - thereby necessitating creating steeper slopes underground. Roof gardens, many parking lots, urban court yards, staging areas typically require level dry surfaces which are possible only with closed system.



Drainage systems are shown graphically through contours, spot elevations, direction of drainage arrows, and symbols designating closed system elements catch basin, underground pipes, French drain, etc.). Ditches (or swales) are shown by pointing the contour uphill. The depth of the ditch is indicated by how far uphill the contour runs. Level areas are always tilted slightly and labeled at the corners with spot elevations to indicate directions and slope of drainage. Remember, water always flows by gravity perpendicular to the contours.



PROCEDURE

Factors which determine drainage needs are:

1. Land use - Your drainage system will vary depending on use and density. Obviously, in a built-up urban area where there is excessive runoff, water can run on the surface for only a short distance, and then must be placed in pipes underground (or in large ditches). In rural areas it is usually possible to drain away from use areas and structures, and let this water disperse over the landscape. Additionally, certain uses demand a dry area (parking, walks, play fields, etc.) while others can operate under wetter conditions (meadows, plantings, open space, etc.).

2. Topography - The steeper the area, the faster draining it will be; i.e., water will run off quickly as it cannot percolate or even travel overland slowly through the ground cover. Drainage must be provided above and below steep banks to collect and dispose of runoff. (All banks must be planted immediately following grading to prevent erosion.)

3. Size of area to be drained - This determines the amount of water likely after a rainfall (see Rational Formula) and determines the size of underground (or surface) structures. When we speak of size of area, we usually mean an area, which, because of development, has been sealed from percolation (such as roads, roofs, patios, drives, etc.). Typically the larger the area, the larger the underground structures or surface ditches.

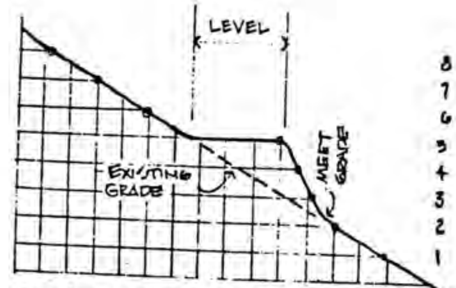
4. Type of soil - This determines the rate of percolation (movement of water through pore spaces in the ground) or amount of water the soil will absorb. Fine particled soil (clays, silts, etc.) do not percolate well, while large particled soils (sands, gravels) do. Therefore, if you had a very sandy soil, you would expect much of the water to percolate down into the soil, and the runoff requirement to be minimum. One must also check the geology, for often there is a layer of clay below the sand - which limits the amount of percolation.

5. Vegetative cover - Any thick, matty ground cover will slow down the rate of runoff and reduce the need for elaborate drainage systems. If you must channel water from an area or roadway, it is best to channel it to an area where there is heavy ground cover vegetation, which will reduce the chance of erosion.

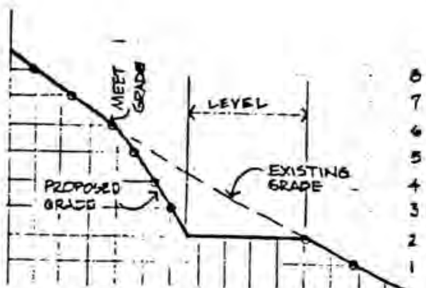
6. Amount of water and intensity of rainfall - In Seattle we have a dry summer - but rain in small amount almost constantly during winter. This affects the type of drainage system when combined with the preceding factors.

<u>Getting On With It</u> - Once the runoff source and disposal methods are clearly understood, divide the total area into reasonably sized drainage areas. This is a common sense step involving many small decisions. Normally the design will suggest a pattern; size of the area will be important with larger sizes being broken into smaller units; topography will be a consideration and may define units; use will be important; low points of concentration are obvious places for drainage structures, slopes should be outlined, etc.

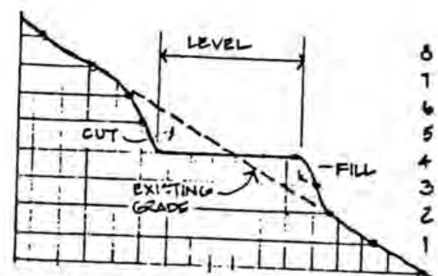
A diagramatic section through each of the preceding plans can perhaps clarify what we are talking about. Note the steep slopes and how one meets grade.



Section showing grading a level area by <u>fill</u>



Section showing grading a level area by <u>cut</u>



Section showing grading a level area by both <u>cut and fill</u>

These three methods, though simplified, are the basic principles for manipulation of all ground form. You must be completely familiar with their use, the way they look, and manipulation necessary to achieve various results. As the course progresses we will learn ways to avoid grading by using retaining walls, terraces, steps, pole construction, etc., but the basic principles of substitute grading techniques still rely on a complete understanding of these three basic grading methods.

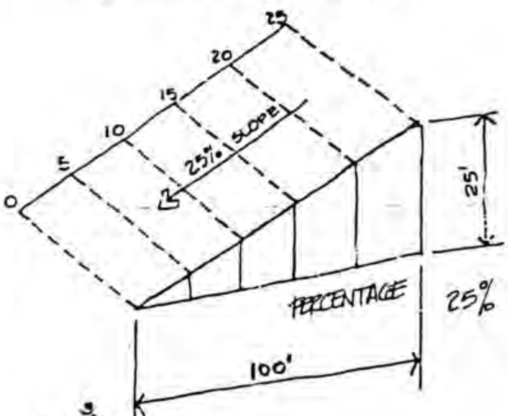
Several points are worth reviewing:

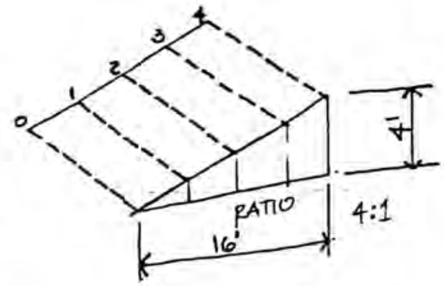
Fractions are never used in grading and drainage and should be converted to <u>decimals</u>. Decimals permit rapid addition or subtraction of elevations and are easier to keep straight than fractions. Most grading computations carried to 2 places are adequate (i.e., 10.12, or 25.10, etc.).

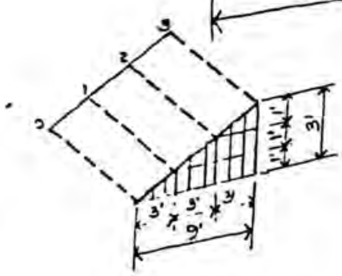
The proposed location of a level area is often an arbitrary decision and should be made quickly. If grading doesn't work, is excessive, damages trees, etc., the level area should be shifted and another grading scheme tested. This trial and error method indicates the close relationship between design and construction. Your speed in selecting the proper location with respect to grading problems will improve rapidly if you maintain a flexible trial and error approach.

VARIATIONS IN SLOPE

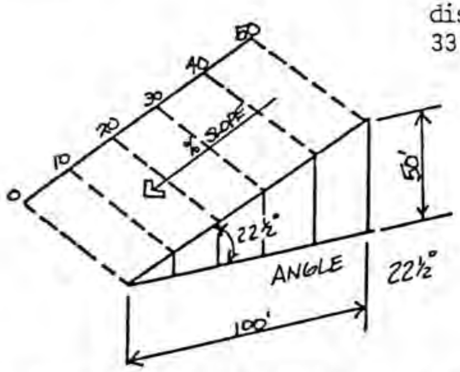
In the preceding examples we have talked about 2 to 1, or 3 to 1 slope and have described the manner to depict this by using contours. These slopes are necessary as it is not possible to pile earth, sand, soil, clay, etc., vertically, so we must slope these materials and the slope becomes either a 2 to 1, 3 to 1, 4 to 1, etc., slope (typically shown 3:1). By 3:1 we mean three feet horizontal space is required for each one foot vertical change in elevation. As contours are shown in plan view, to maintain a 3:1 slope the contours (assuming 1' contour interval) would have to be spaced 3 feet apart. (In another section we will discuss ways to determine what the maximum and minimum slope, called gradient, should be.)







Slope proportion can be expressed as a ratio, in percentage, or as an angle. When expressed in percentages, a 3:1 slope becomes 33 1/3%, a 4:1 becomes 25%, etc. Percentage slope is easiest to understand if you think of the slope being 100 feet long (measure horizontally). Then the vertical distance becomes the percent. To determine the percentage of any slope, divide the vertical distance by the horizontal distance (a 3:1 slope would be 1/3 or 33 1/3%).



VD / HD — Vertical Distance / Horizontal Distance

Angles are seldom used to describe slopes as mathematical conversion of ratios to angles is difficult. Angles can be measured with a protractor, or converted from direct reading tables. To set the bounds, a 90° angle is straight up (0:1 ratio), a 45° angle is a 1:1 ratio, a 22½° angle is 2:1 ratio, etc.

It may be worth noting that the ratio is expressed by some with the rise first, thereby a slope which I would designate 3:1 would be designated 1:3. If the ratio seems excessive, check to see if it is backwards.

RECOMMENDED GRADING STANDARDS AND CRITICAL GRADES

GRADING STANDARDS (Primarily for Northern ½ of USA)	IDEAL (First class work, institutional, etc.		ALLOWABLE (Utilitarian work)	
TYPE OF AREAS	MAX.	MIN.	MAX.	MIN.
STREETS AND DRIVES				
Concrete (crowned section with curbs or concrete gutter)	5%	1%	11%	0.5%
Bituminous crowned section with concrete gutter	5%	1%	11%	0.5% (3) 0.25%
Bituminous crowned section with bituminous gutter	5%	1%	11%	1%
CONCRETE WALKS				
Approaches, platforms, etc.	5%	0.5% (1)	8%	0.5% (1)
Service Areas	8%	0.5% (1)	10%	0.5% (1)
TERRACE AND SITTING AREAS				
Concrete	2%	0.5%	3%	0.5%
Flagstone, Slate, Brick	2%	1%	3%	1%
LAWN AREAS				
Recreational (games, etc.)	3%	2%	5%	1%
MOWED BANKS (with grass)	3:1	--	3:1	--
UNMOWED BANKS (with cover of vines, meadow, etc.	2:1 (2)	--	2:1 (2)	--

(1)--Flat if cross pitch is provided for, cross pitch of ¼" per ft. (2%) is customary.
(2)--Varies with type of soil.
(3)--If approved by local Department of Streets can use 0.25% (¼%)

RECOMMENDED HIGHWAY GRADIENTS

3%	The gradient at which slope becomes obvious (less than 3% normally tends to appear level); Maximum gradient for Pennsylvania Turnpike, New Jersey Turnpike, etc.; gradient at which heavy trucks slow down
5%	Practically every car can go up without changing gears, down without using brakes; desirable maximum for high class work in city conditions; maximum ramp gradient (down-grade) for New Jersey Turnpike Interchange.
7%	Maximum grade recommended by American Association of State Highway Officials for Class D (lowest type) public road. Maximum ramp gradient (up-grade) for New Jersey Turnpike Interchanges.
10%	Acceptable if justified by topography. Steeper grades are sometimes used but are too steep.

GRADING AND DECIMAL EQUIVALENTS

On grading plans spot elevations are calculated and shown in feet and decimals rather than inches. This chart lists gradients (from 0.5% to 3%) and shows a change in elevation at various distances from 1 foot to 100 feet in both inches and decimal equivalents.

1" in 16'			1" in 8'			1" in 5'-4"		
0.5% Grade 1/16" fall in 1'0"			1% Grade 1/8" fall in 1'0"			1 1/2% Grade 3/16" fall in 1		
Absolute minimum. Can use only with the smoothest of pavings such as smooth concrete, terrazzo or marble.			Normal minimum for pavings such as smooth and exposed aggregate concrete, brick, tile, slate and wood block. Suitable for asphalt only if water is already flowing and installation is exact.			Normal minimum for asphalt, redrock, flagstone, earth, and very rough exposed aggregate concrete.		
1/16"	.0052	1'	1/8"	.0104	1'	3/16"	.0156	1'
1/8 "	.0104	2'	1/4"	.0208	2'	3/8 "	.0313	2'
1/4 "	.0208	4'	1/2"	.0417	4'	3/4 "	.0625	4'
1/2 "	.0417	8'	1"	.0833	8'	1-1/2 "	.1250	8'
1 "	.0833	16'	2"	.1667	16'	3 "	.0522	16'
1-9/16"	.1302	25'	3-1/8 "	.2604	25'	4-11/16"	.3907	25'
2-1/16"	.1719	33-1/3'	4-3/16"	.3490	33-1/3'	6- 1/4 "	.5208	33-1/3'
3-1/8 "	.2604	50'	6-1/4 "	.5208	50'	9- 3/8 "	.7813	50'
4-1/8 "	.3438	66-2/3'	8-3/8 "	.6980	66-2/3'	1'-1/2 "	1.0417	66-2/3'
4-11/16"	.3907	75'	9-3/8 "	.7813	75'	1'-2-1/16"	1.1719	75'
6-1/4 "	.5208	100'	1'-1/2"	1.0417	100'	1'-6-3/4 "	1.5625	100'

1" in 4'			1" in 3'-2 1/2"			1" in 2'-8 1/2"		
2% Grade 1/4" fall in 1'0"			2.5% Grade 5/16" fall in 1'0'			3% Grade 3/8" fall in 1'		
Desirable minimum for grass, tanbark and planting areas. Maximum grade for terrace paving. Slightly noticeable grade when related to level construction.			Desirable not to go above this on parking areas if you want them to appear level. Looks generally level though it is quite a noticeable slope.			Very noticeable in relation to level construction.		
1/4"	.0208	1'	5/16"	.0260	1'	3/8"	.0313	1'
1/2"	.0417	2'	5/8 "	.0521	2'	3/4"	.0625	2'
1"	.0833	4'	1-1/4 "	.1041	4'	1-1/2"	.1250	4'
2"	.1667	8'	2-1/2 "	.2084	8'	3"	.2500	8'
4"	.3335	16'	5 "	.4167	16'	6"	.5000	16'
6-1/4"	.5208	25'	7-5/8 "	.6345	25'	9-3/16"	.7656	25'
8-3/16"	.6824	33-1/3 '	10-7/16"	.8697	33-1/3'	1'-1/2"	1.0417	33-1/3'
1'-1/2"	1.0417	50'	1'-3-5/8 "	1.3021	50'	1'-6-3/4"	1.5625	50'
1'-4-3/8"	1.3542	66-2/3 '	1'-8-7/8 "	1.7396	66-2/3'	2'-1"	2.0833	66-2/3'
1'-6-3/4"	1.5625	75'	1'-11'5/8"	1.9688	75'	2'-3'15/16"	2.3281	75'
2'-1"	2.0833	100'	2'-7-1/4 "	2.6041	100'	3'-1-1/2"	3.1250	100'

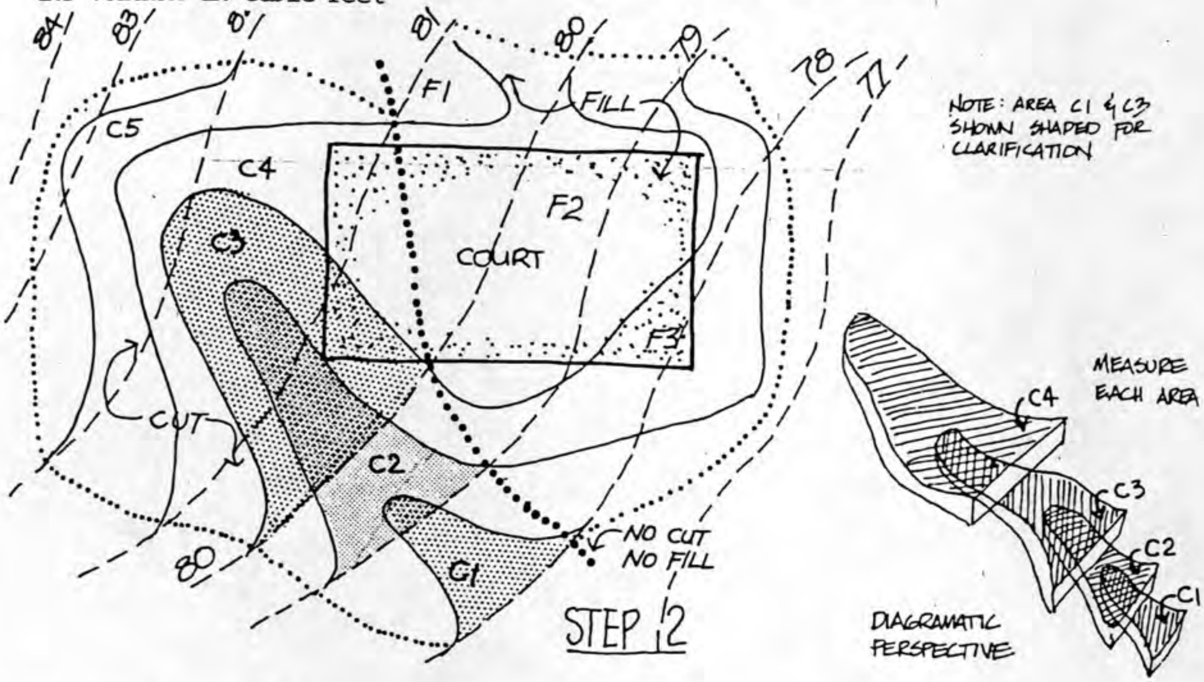
DECIMAL EQUIVALENTS - inches to feet

1" = .083'
2" = .166'
3" = .250'
4" = .333'
5" = .416'
6" = .5'
7" = .583'
8" = .667'
9" = .75'
10" = .833'
11" = .916'
12" = 1.0'

Gradients. This chart lists the change in grade required for uniform slopes over a specific distance. The top line is % of slope (.5 = .5%, .75 - .75%, etc.), and end vertical line is distance in feet. To use the chart, select your % slope and follow down the line to the distance which will be the change in grade required. Change in grade for distances 1' - 10' can be added to the change in grade for distances such as 40', 50', 60' to determine the exact change for an odd distance such as 66'.

% / DISTANCE	.5	.75	1.0	1.25	1.5	.75	2.0	2.5	3.0	3.5	4.0	4.5	5.0	6.0	7.0	8.0	9.0
1'	.005	.08	.01	.013	.015	.018	.02	.025	.03	.035	.04	.045	.05	.06	.07	.08	.09
2'	.01	.015	.02	.025	.03	.035	.04	.05	.06	.07	.08	.09	.10	.12	.14	.16	.18
3'	.015	.023	.03	.38	.045	.05	.06	.075	.09	.105	.12	.135	.15	.18	.21	.24	.27
4'	.02	.03	.04	.05	.06	.07	.08	.10	.12	.14	.16	.18	.20	.24	.28	.32	.36
5'	.025	.04	.05	.063	.075	.09	.10	.125	.15	.175	.20	.225	.25	.30	.35	.40	.45
6'	.03	.05	.06	.075	.09	.105	.12	.15	.18	.21	.24	.27	.30	.36	.42	.48	.54
7'	.035	.05	.07	.088	.10	.123	.14	.175	.21	.245	.28	.329	.35	.42	.49	.56	.63
8'	.04	.06	.08	.10	.12	.14	.16	.20	.24	.28	.32	.36	.40	.48	.56	.64	.72
9'	.045	.064	.09	.113	.14	.158	.18	.225	.27	.315	.36	.405	.45	.54	.63	.72	.81
10'	.05	.75	.10	.125	.15	.175	.20	.25	.30	.35	.40	.45	.50	.60	.70	.80	.90
15'	.075	.11	.15	.188	.23	.265	.30	.375	.45	.53	.60	.655	.75	.90	1.05	1.2	1.35
20'	.10	.15	.20	.25	.30	.35	.40	.50	.60	.70	.80	.90	1.0	1.2	1.40	1.6	1.8
25'	.125	.19	.25	.31	.38	.44	.50	.63	.75	.88	1.0	1.12	1.25	1.5	1.75	2.0	2.25
30'	.150	.23	.30	.376	.45	.53	.60	.75	.90	1.05	1.2	1.35	1.50	1.8	2.1	2.4	2.7
35'	.175	.26	.35	.409	.53	.62	.70	.88	1.05	1.24	1.4	1.58	1.75	2.1	2.45	2.8	3.15
40'	.20	.30	.40	.50	.60	.70	.80	1.0	1.2	1.4	1.6	1.71	2.0	2.4	2.8	3.2	3.6
45'	.225	.34	.45	.56	.68	.79	.90	1.13	1.35	1.58	1.8	2.03	2.25	2.7	3.15	3.6	4.05
50'	.250	.38	.50	.62	.75	.88	1.0	1.25	1.5	1.76	2.0	2.24	2.50	3.0	3.50	4.0	4.5
55'	.275	.41	.55	.68	.83	.97	1.1	1.38	1.65	1.94	2.2	2.47	2.75	3.3	3.85	4.4	4.95
60'	.30	.45	.60	.75	.90	1.06	1.2	1.5	1.8	2.12	2.4	2.7	3.0	3.6	4.2	4.8	5.4
65'	.325	.48	.65	.81	.98	1.15	1.3	1.63	1.95	2.30	2.6	2.93	3.25	3.9	4.55	5.2	5.85
70'	.350	.53	.70	.82	1.0	1.24	1.4	1.76	2.10	2.48	2.8	3.16	3.50	4.2	4.9	5.6	6.3
75'	.357	.57	.75	.94	1.1	1.33	1.5	1.89	2.25	2.66	3.0	3.39	3.75	4.5	5.25	6.0	6.75
80'	.40	.60	.80	1.0	1.2	1.4	1.6	2.0	2.4	2.8	3.2	3.6	4.0	4.8	5.6	6.4	7.2
85'	.425	.64	.85	1.06	1.3	1.49	1.7	2.13	2.55	2.98	3.4	3.83	4.25	5.1	5.95	6.8	7.65
90'	.45	.676	.90	1.12	1.35	1.58	1.8	2.26	2.7	3.16	3.6	4.06	4.5	5.4	6.3	7.2	8.1
100'	.50	175	1.0	1.25	1.50	1.75	2.0	2.5	3.0	3.5	4.0	4.5	5.0	6.0	7.0	8.0	9.0

To measure the area, use either a planimeter or overlay the area with a fine transparent graph paper and count the squares. Do this for each contour, noting the area of each in square inches. Finally, it will be necessary to convert these measurements to the proper scale. This usually involves multiplying square inches (planimeter reading or graph paper count) by the drawing scale squared. FOR INSTANCE, if you have a measurement or planimeter reading of 2 square inches, and the drawing scale is 20 (1" = 20'), you will find the square foot measure by multiplying 20 x 20 x 2 or 800 square feet. This measurement can then be multiplied by the contour interval to determine the volumne in cubic feet



In practice, cut and fill calculations are kept separate so they can be compared for balance. To determine the total amount of earth to be moved, simply add the two totals. Cubic foot measure can be converted to cubic yards by dividing by 27.

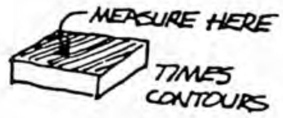
The method just described will produce a rough calculation of cut and fill. You can see in the section the area of Contour 2, if projected up would include an amount not actually graded, and not include an amount which will be graded. This calculation can be refined by averaging the two adjacent contours, and dividing the sum by 2. This will produce an area average which is accurate and can then be multiplied by the contour interval. Therefore, Area C-1 and C-2 would be added together and divided by 2, Area C-2 and C-3 the same, etc., and the same procedure for fill areas.

$$\left(\frac{C1+C2}{2} + \frac{C2+C3}{2} + \frac{C3+C4}{2} + \frac{C4}{2}\right)$$

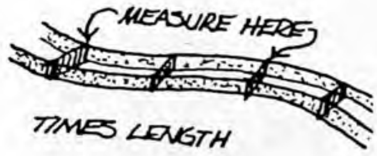
TIMES CONTOUR INTERVAL TIMES SCALE (IN FEET) SQUARED = CUBIC FEET

CALCULATING VOLUME OF CUT AND FILL

All grading plans will eventually reach a point where it becomes necessary to determine feasibility by verifying a balance of cut and fill or to prepare a cost estimate. Both of these operations require calculating the volume of CUT and the volume of FILL. For our purposes there are two simple ways of calculating volume of cut and fill - one used when you have graded a level area to put something on, and the other used when you are grading a circulation route. Both utilize the standard formula for determining volume - width times length times height, and in principle follow these procedures.



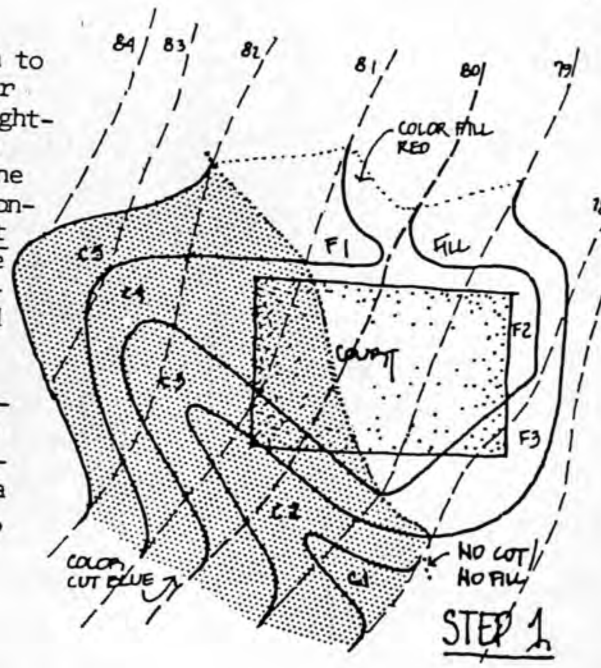
To calculate volume of cut and fill for a level area, measure the horizontal surface of all proposed cut and fill (essentially width times length) and multiply by the contour interval (height).



To calculate volume of cut and fill for a circulation route, measure the vertical surface (cross-sectional profile) of both cut and fill (essentially the width times the height) and multiply that by the distance between measurements (length).

This over-simplification can be clarified more completely by following the procedure:

When a grading scheme is complete enough to test, place a piece of thin tracing paper over it and color all the area of cut lightly in blue, and all the areas of fill in red. (There will be a No Cut/No Fill line between.) Next, outline each proposed contour within the cut area with a different color pencil (to do this, start where the proposed contour leaves the existing contour, trace over the proposed contour and reconnect along the existing contour.) Do the same in the fill area - that is, outline each proposed contour in a different color. The different color will help you distinguish the size of each area during measurement. Number each contour area consecutively - that is, all the cuts C-1, C-2, C-3, etc., all the fills F-1, F-2, F-3, etc.



Now we must measure the area of each outlined contour separately. Start with the C-1 (cut contour), measure and record the area, do C-2, C-3, the same way, and then complete all the Fill areas.

SHRINKAGE AND EXPANSION OF SOILS

It is generally known a cubic yard of cut will not completely fill a cubic yard void when placed as fill. This is caused by loss during moving, shipment, etc., and can amount to about 10%. Therefore, when calculating for cut/fill balance, a cut figure exceeding fill requirements by approximately 10% will produce a balanced result. (The exact amount of shrinkage required varies with soil type and is listed in most Engineering manuals.)

Most soils will shrink after placement up to about 3%, which can cause settlement and present some construction problems. Additionally some clays expand when moistened, which can heave light buildings and most landscape elements.

COST ESTIMATING

A Brief Introduction. Project construction costs are estimated by applying known unit costs from previous projects to measured quantities from your present project. The procedure is in concept simple, yet requires great skill to combine the proper costs per measured unit. All quantities are determined as listed as either:

Square measure (sq. yard, foot, etc).

Lineal measure (lineal feet, yard, mile, etc.).

Cubic measure (cubic yard, foot, etc.).

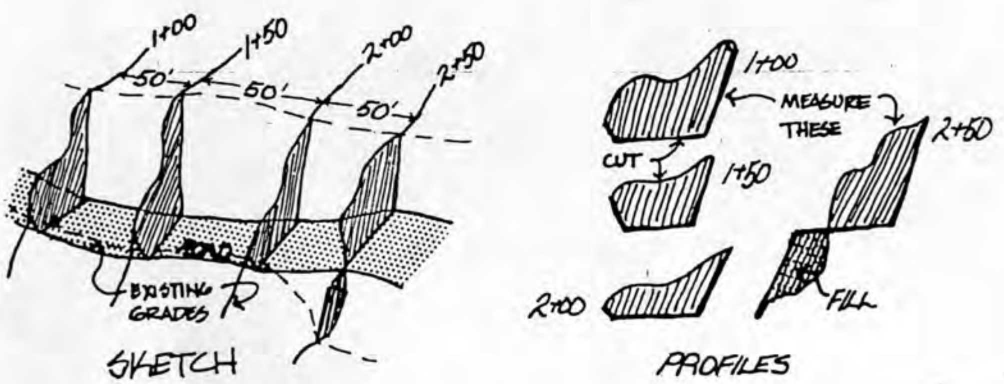
At each count (no unit of measure, just items).

The procedure requires recording on a take-off form each operation from the start of the job to its finish. For instance, a grading plan might include: Layout and staking, clearing, tree removal, tree relocation, pre-grading stabilization, topsoil stripping, quantity of soil to be moved (cut plus fill), soil to be removed, fill to be placed, compaction requirements, finish grading, drainage structures, culverts, topsoil placement, erosion control, etc. Once the list is complete, the units of measure can be determined -

Square measure
Lineal measure
Cubic measure
At each count

and the quantity take-off begins. This is a laborious process of carefully measuring each operation and recording it on the cost estimate form. Make sure to cross off each item on the plan so you don't forget anything. The degree of accuracy will depend on the state of planning with early estimates allowing perhaps 25% error while a final estimate would hope for only a 5% error.

To calculate volumes of cut and fill for circulation routes, it is customary to draw cross-sectional profiles at equal distances (say, 50 feet) showing the existing ground line and proposed ground line. Areas of cut should be colored blue, and areas of fill red. The procedure is first to measure the areas of cut and fill separately in square inches for both ends of the segment you are concerned with. This can be done with either a planimeter or by counting the squares of transparent graph laid over the area. Next, average these two measurements (add both measurements and divide by 2) and convert that figure from square inches to the proper scale (inches times the drawing scale squared). To complete the calculation, multiply this area (essentially width times height) by the interval between sections (the length).



Once volume of cut and fill have been determined, cost factors can be applied. Contractors may apply a unit cost per yard, but often gauge their costs by estimating the time it will take specific pieces of equipment to do the job. For instance, a 3-yd. loader can move 50 yards (for example) per hour, a dump truck can carry 5 yards, etc. The time required for each piece of equipment can be totaled and multiplied by the cost per hour for an accurate cost estimate.

The volumes of cut and fill just calculated will be in cubic feet - and can be converted to cubic yards by dividing by 27.

Methods for handling special calculations:

Topsoil stripping or replacing - can affect your results in large projects. To calculate the volume of this operation, simply outline all the areas to be stripped or replaced, measure this area with the planimeter, convert this square inch measurement to the proper drawing scale, and multiply times the depth of soil to be stripped or replaced. This cubic foot volume can be converted to cubic yards by dividing by 27.

Subgrading - can often throw off a cost estimate. Subgrading is removing soil, such as in roadways, which will later be replaced with gravel fill and asphalt. The method is exactly the same as calculating for topsoil stripping - simply outline the areas of subgrade, measure, convert to the proper scale, and multiply times the depth of subgrade.

Importing or Exporting of soil can be determined by subtracting total cut from fill (for import figure) or total fill from cut (for export figure).

COST ESTIMATE

Job:

Status:

Date: By:

SAMPLE COST ESTIMATE SHEET

Description	Quantities	Unit Price Labor	Total Estimated Labor Cost	Unit Price Mtl.	Total Estimated Material Cost	Unit Price	Sub-Bids		

SAMPLE COST ESTIMATE SHEET used for tabulating costs for a particular project. Note this sheet includes a list for both labor and materials, while the sample shown on page 82 combines both into one column.

After all take-offs have been completed, a unit price for each operation is determined. This is the guessing part of the operation, but can be aided by:

1. Keeping accurate records of all unit costs for previous projects as a starting point.
2. Using Cost Estimating Handbooks which list unit prices for many tasks.
3. Meeting with a contractor to review your take-off and have him apply unit prices he feels are proper.
4. Simulate the task by breaking it into smaller, more easily understood jobs, and determine that cost.

Whatever cost you initially arrive at will probably have to be adjusted because of specific site conditions. For instance, disposal of soil may be more difficult than last time, labor costs may have risen, details may be tricky and time-consuming, access may be restricted, etc. Allowances will have to be made for the contractor's overhead and profit, for contingencies (omissions, errors, etc.) and for miscellaneous operating costs (permits, insurance, sani-cans, etc.).

This type of cost estimate has real limitations - as it is a measure of only actual immediate out-of-pocket expenses. It doesn't measure any benefits, or costs which other people may have to bear, or costs which may be deferred, or other methods of accomplishing the desired goal. It is generally a measure of short term costs - which is okay to a point. However, most environmental and ecological considerations require a broader, long term perspective. Landscape Architects should find ways to include long range factors into typical short term estimates. Ecological long term benefits associated with site development may include:

1. Erosion costs (or benefits if prevention or control practices are undertaken.

2. Sedimentation reduction by proper grading may preserve a biologically productive stream or marsh.

3. Drainage techniques which reduce rapid runoff while balancing the water table are often expensive and should be measured against assumed benefits.

4. Vegetation can ameliorate many environmental pollutants, and have value beyond aesthetic terms.

5. Reduced grading or balanced cut/fill developments reduce energy demand and may preserve a disposal site.

Practical Grading/Drainage Cost Considerations - Moving earth is relatively inexpensive - we have the technology and equipment to move mountains at little actual costs. However, there are factors which influence these costs and can drive them up.

1. A balanced CUT and FILL proposal will always result in lower grading costs than an unbalanced solution.

2. Removing soil from the site and disposing it elsewhere is usually very expensive. Anything you can do (create earth mounds, etc.) to avoid this will put you dollars ahead.

3. Importing soil is generally not as expensive as exporting it, but enough of a problem to be concerned with. On a large project one will usually stockpile backfill material and topsoil for spreading later.

4. Grading involving removing and placing of soil in one motion is the most economical procedure. If it has to be unloaded and reloaded later, additional costs will be incurred.

5. Time of year affects costs - winter work will be difficult - muddy, wet, sloppy conditions slow down equipment, thereby increasing costs.

6. Inexpensive grading requires considerable room for large equipment to operate - therefore small urban projects will be relatively more expensive to grade than large rural projects.

7. Rock outcrops or any mechanical constraints can increase grading cost considerably.

8. Landscape Architect's Dilemmas. Because of the size of modern grading equipment, it often appears cheaper to blast ahead removing everything from the site. This short term cost should be compared with the installation and maintenance costs of rebuilding the landscape.

   a. The cost of rebuilding the landscape following grading should always be included - erosion control, replacing trees, shrubs, topsoil, sedimentation, etc.

   b. It is cheaper to remove trees than to save them - the Landscape Architect must be alert to assure that desirable trees will be saved.

   c. Topsoil is easily mixed with the subsoil, and may save several dollars; however, replacing it will always cost more.

SAMPLE COST ESTIMATE SHEET
see also page 80

COST ESTIMATE

JOB:

STATUS:

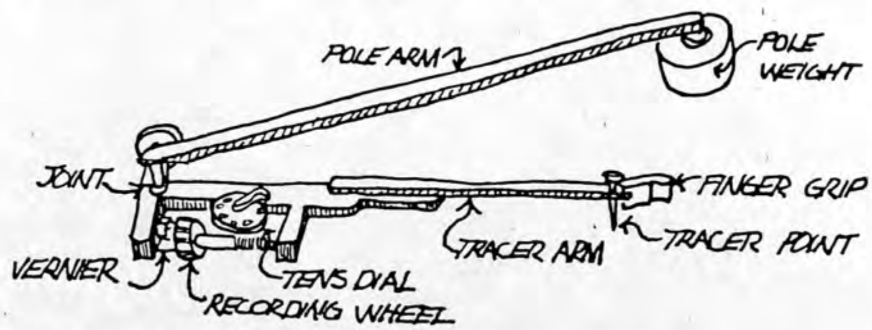
DATE BY

ITEM & DESCRIPTION	QUANTITY	UNIT	UNIT COST	ITEM TOTAL	SUB TOTAL

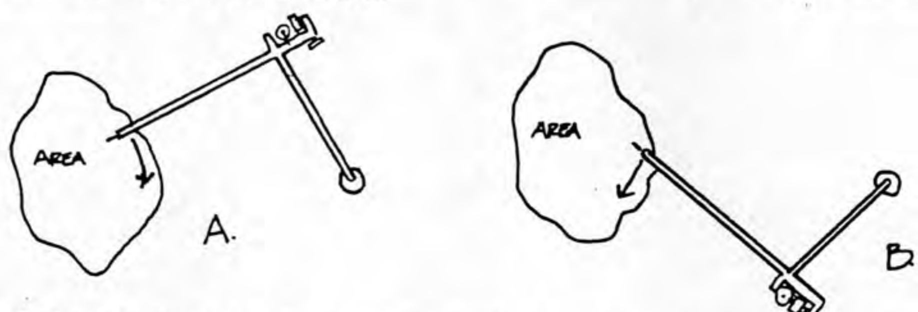
PLANIMETER OPERATIONS

A planimeter is an instrument used for the measurement of areas. If the areas are geometical in shape it is possible and often easier to calculate the areas methematically by multiplying width times length. If the boundaries are irregular, this is not possible and then the planimeter is most useful.

A polar planimeter (commonly used for earthwork calculations) is anchored to the drawing by a weighted needle-point about which the instrument is free to revolve (called pole weight). At the outer end of the tracer arm is a "tracer point" which is drawn around the figure to be measured following the boundary as accurately as possible. The area is measured by the revolution of the "measuring" wheel which is attached to the tracer arm.



As the tracer point is drawn around the boundary of an area the measuring wheel will move back and forth with a combination of revolving and slipping movements. The amount it has actually revolved will be a measure of the total area when the tracer point has been brought back exactly to the starting point. It is normal for two readings to be taken, the first in the "A" position and another from the "B" position (see illustration), without changing the location of the pole. The average of the two will give the true area as any instrument error will be plus in one position and minus in the other.



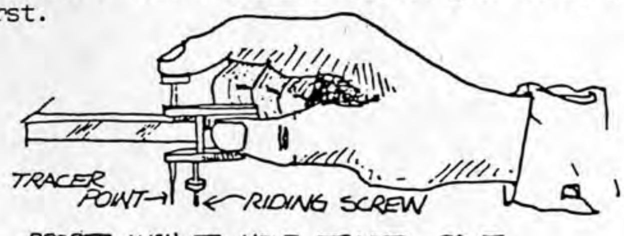
Care of the planimeter - The measuring wheel and bearings are very delicately made, so the instrument must be handled with at least the care given to a fine watch. The bearings should be kept clean and quite loose and should be occasionally touched with the smallest possible quantity of fine watch oil.

It is essential that the rim of the wheel remain absolutely clean and smooth. It must not be rusty or greasy nor nicked by being bumped against drafting instruments or straight edges. The joint between the pole and tracer arms must also be accurate and kept perfectly clean.

Operation of the planimeter - The surface of the drawing to be measured must be clean, even and free from creases. If not, the measuring wheel will give an incorrect reading. It will also give an inaccurate reading if made to run off and on the edges of the drawing. If the sheet is so small that this is bound to happen, readings may be taken through a large sheet of tracing paper placed over the original drawing. If the drawing is on heavy paper it is sometimes possible to butt sheets of equal thickness against the edges to avoid the bump, but even in this case you will have better results if a large sheet of tracing paper is used. The table should be nearly level. If it is not, the instrument may roll off or it may move slightly while the dial is being read, possibly creating serious errors.

When an area is ready to be measured, the instrument is placed on the drawing with the pole so located that it will be possible for the tracer point to reach all parts of the outline. The pole should ordinarily be outside of the area. The best position will be one in which the tracer point, if placed at the center of the area to be measured, will make approximately a right-angle with the pole arm. In starting to trace around the outline, choose some point which can be easily identified as the stopping point since it is important that the tracer point return exactly to the point from which it started. On all good instruments, there is a spring mounting which makes it possible to prick a hole in the paper for this purpose. If the outline is run in a clock-wise direction the reading will be positive; if counter-clockwise, it will be negative. In either case the difference between the starting and finishing readings will be the measure of the area. It is customary to measure every area twice in order to catch human or machine errors.

Set the instrument at zero to start so there is no possibility of error. The second reading can be taken without resetting to zero, and should be approximately twice the first.



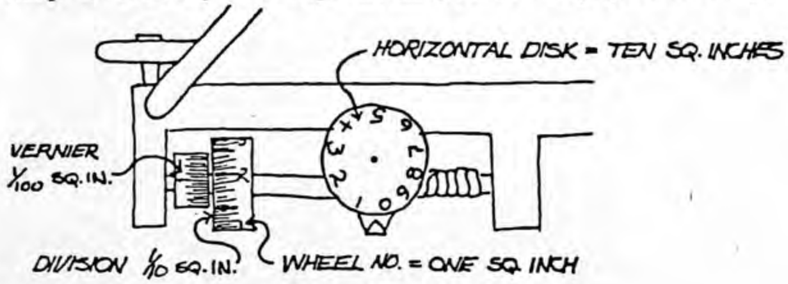
PROPER WAY TO HOLD TRACER POINT

Always guide the tracer point by eye, and try to run it away from the eye rather than toward it. Guiding along a scale or other straight surface tends to make the error constant in one direction; whereas, if guided freely, a deviation of the tracer point on one side of the line is usually compensated for by a deviation upon the other side.

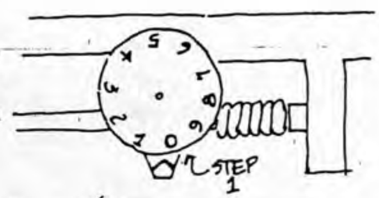
READING THE PLANIMETER

Planimeters in this country will be calibrated to read in square inches. If the instrument is in proper adjustment, one space on the horizontal disk will equal 10 square inches (10.00); one numbered division on the recording wheel will represent one square inch (01.00) and one small division, one-tenth of a square inch (00.10). One division of the vernier will then represent one one-hundredth of a square inch (00.01). The four figures are always entered in the record, even though the first three may be zeros to eliminate possible errors in the placing of the decimal point.

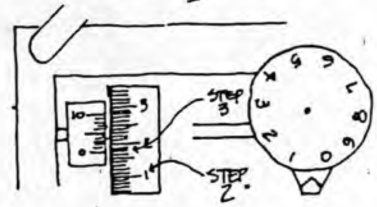
Four measurements are taken for each reading; one from the horizontal disk, two from the large vertical wheel, and one from the small vertical wheel. Each measurement is recorded to assure correct placement of the decimal. A 4-place tally sheet will help to clarify readings until you develop proficiency.



In the example:

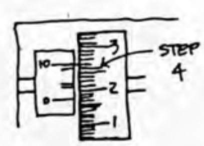


1. Read first from the horizontal disk and place the number in the Ten's column. For this example, the number is 0. The number must be past the pointer for all readings - a confusing point which can be verified by looking at the next reading. ■□.□□ 0



2. Read next from the large vertical wheel - choosing the whole number which is past the center vernier on the smaller disk. In this example the number is 1. □■.□□ 01

3. Read next on the large vertical wheel the largest division past the center vernier on the small disk - in this case the division represents 8. □□.■□ 01.8



4. The last reading is tricky - and is read on the small stationary wheel. The one division which perfectly lines up with a line on the larger wheel is the reading; in this case the number is 6. This reading may be clearer if you use a magnifying glass. □□.□■ 01.86

<u>Planimeter constant</u> - Most planimeters have a slight built-in error which must be compensated for at the end of all your calculations. This error is corrected by multiplying the total measured figure by the planimeter constant. The constant is usually marked on the instrument at the factory, or can be calculated by measuring a known area. There is usually a circular testing measure supplied with the planimeter so the test can be quickly made. The correction factor is known as the planimeter constant. It is easier to use a planimeter constant than to attempt to adjust the planimeter to read directly in inches.

For example, suppose the testing measure used is a 3-inch radius circle. The planimeter is run around the circle and measurements compared. The actual area of such a circle is 28.2743 square inches. Suppose the instrument gave a reading of 27.64. Then by dividing the correct area by the measured area, we have the constant

$$\frac{28.27}{27.64} = 1.0288, \text{ which represents planimeter constant}$$

and all readings taken from the drawing will be converted to exact square inches by <u>multiplying</u> the readings by the constant. The correction need be applied only once to the total sum of the readings.

CAUTIONS - Any planimeter is a very delicate instrument, and any injury, even when not apparent to the naked eye, will result in a loss of accuracy. Hence, observe the following precautions at all times.

Treat the axle of the measuring roller with the utmost care, protecting it against jar and pressure. If the fine bearing points of the measuring roller are damaged, the instrument will not be accurate.

The measuring roller should never be turned by hand when resting on a working surface. Lift the instrument to turn it.

The measuring roller is made of hardened steel. To avoid rust, which may affect accuracy, don't touch it with your fingers.

Use of Planimeter in Cut/Fill Calculations

1. Outline total areas of cut and areas of fill.
2. Label and outline each contour of cut and fill with a different color.
3. Measure each outlined contour with the planimeter (record separately in square inches).
4. Total all the areas of cut, all the areas of fill in separate lists.
5. Apply the correction factor (planimeter constant) to each amount.
6. Multiply the corrected total measurement by the drawing scale squared. (Squaring the scale converts it to square feet.)
7. Multiply these amounts by the contour interval to convert to cubic feet.
8. Divide by 27 to determine cubic yards.