CE419 – Construction Management

Chapter 2

Earthmoving Materials and Operations

2-1 INTRODUCTION TO EARTHMOVING

- **The Earthmoving Process**
- **Equipment Selection**
- **Production of Earthmoving Equipment**

The Earthmoving Process

- Earthmoving is the process of:
  - Moving soil or rock from one location to another, and
  - Processing it to meet construction requirements of location, elevation, density, moisture content, etc.

The Earthmoving Process

- Activities involved:
  - excavating,
  - loading,
  - hauling,
  - placing (dumping and spreading),
  - compacting,
  - grading, and
  - finishing.

The Earthmoving Process

- Efficient management of the earthmoving process requires :
  1. Accurate **estimating** of *work quantities* and *job conditions*
  2. Proper **selection** of equipment (capability and economy)
  3. Competent **job management**

Inputs for Earthwork Planning

- Analysis of **requirements** from plans and specs
- Identification of **work units**
- Detailed **work analyses** (productivity)
- **Field analysis** (site visit, geological data, meteorological data)
- Identification of **material sources** or wasting sites

Equipment Selection

What do we analyze?

What to be done
(quantities,
soil conditions,
haul distances,
grades for haul segments)

Equipment
(productivity, cost, etc.)

Equipment Selection

Important factors in choosing equipment:

- Ability to perform the job
- Profit maximization (lowest cost per unit of production)
- Possible future use
- Its availability and the availably of parts and service
- Effect of equipment downtime on other equipment and operations

Production of Earthmoving Equipment

Production = Volume per cycle × Cycles per hour (2-1)

- The cost per unit of production may be calculated as follows:

Cost per unit of production =

Equipment cost /hour ÷ Equipment production/hour (2-2)

Production of Earthmoving Equipment

Job Efficiency

There are two principal approaches to estimating **job efficiency** in determining the number of cycles per hour to be used in Equation 2-1.

- First method: using the number of effective working minutes per hour to calculate the number of cycles achieved per hour. This is equivalent to:

  Efficiency factor = No. of working minutes per hour / 60

- Second method:
  - Multiply the number of *theoretical* cycles per 60-min hour by a numerical efficiency factor (Table 2-1)

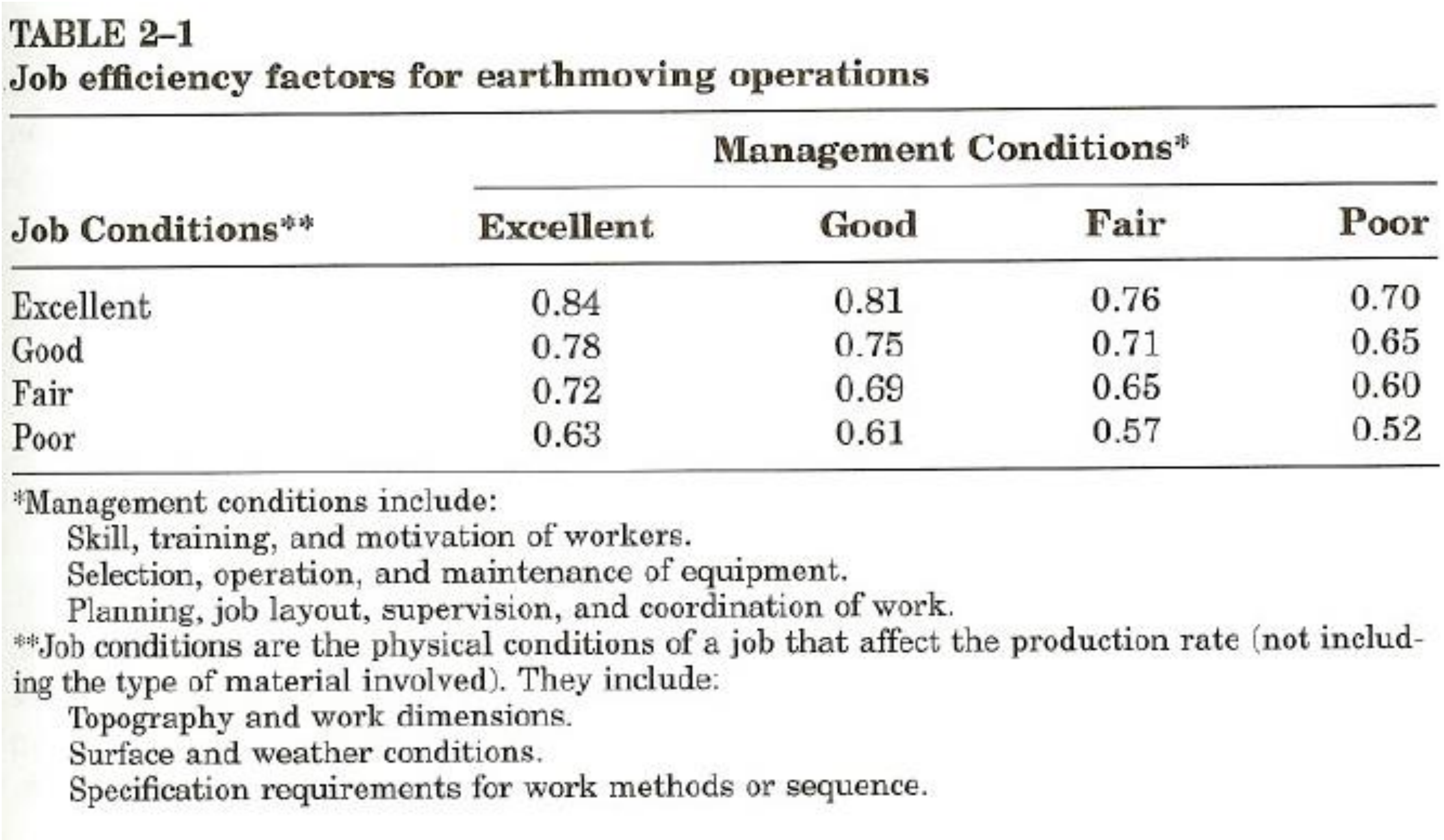


TABLE 2–1
Job efficiency factors for earthmoving operations

	Management Conditions*			
Job Conditions**	**Excellent**	**Good**	**Fair**	**Poor**
Excellent	0.84	0.81	0.76	0.70
Good	0.78	0.75	0.71	0.65
Fair	0.72	0.69	0.65	0.60
Poor	0.63	0.61	0.57	0.52

*Management conditions include:
  Skill, training, and motivation of workers.
  Selection, operation, and maintenance of equipment.
  Planning, job layout, supervision, and coordination of work.

**Job conditions are the physical conditions of a job that affect the production rate (not including the type of material involved). They include:
  Topography and work dimensions.
  Surface and weather conditions.
  Specification requirements for work methods or sequence.

2-2 EARTHMOVING MATERIALS

- **General Soil Characteristics**
- **Soil and Rock**

General Soil Characteristics

- Several terms relating to a soil's behavior in the construction environment should be understood.
  - *Trafficability.*
  - *Loadability.*

General Soil Characteristics

- *Trafficability :*
  - – The ability of a soil to **support the weight of vehicles** under repeated traffic (equipment within the construction area)
  - – Trafficability is primarily a function of:
    - Soil type, and
    - Moisture conditions

Trafficabailty may affect the selection of the track size

General Soil Characteristics

- *Loadability:*
  - A measure of the **difficulty in excavating and loading** a soil
    - Loose granular soils are highly loadable
    - Compacted cohesive soils and rock have low loadability

General Soil Characteristics

Moisture content

$$Moisture\ Contenet\ (\%) = \frac{Moist\ weight - Dry\ weight}{Dry\ weight} \times 100 \qquad (2\text{-}3)$$

Example:

a soil sample weighed 54.4 kg in the natural state and 45.3 kg after drying, the weight of water in the sample would be 9.1 kg and the soil moisture content would be 20%. Using Equation 2-3, this is calculated as follows:

Moisture content = (54.4 - 45.3) / 45.3 × 100 = 20%

2-4 SOIL VOLUME-CHANGE CHARACTERISTICS

- Soil Conditions
- Swell
- Shrinkage
- Load and Shrinkage Factors

Soil Conditions

- Example:

Plan

Volume= 2000 m^3

Plan

Volume= 30 m^3

Cost= 170 SR/trip

No. of trips ≈ 67

Total cost= **11,390** SR

Total price= **13,400** SR (200 SR/trip)

Actual

Total cost= **14,280** ???

Soil Conditions

- There are three principal conditions or states in which earthmoving material may exist:
  - Bank
  - Loose
  - Compacted

- *Bank:*
  - Material in its natural state before disturbance. Often referred to as "in-place" or "in situ."
  - A unit volume is identified as a *bank cubic meter* (BCM)
- *Loose:*
  - Material that has been excavated or loaded
  - A unit volume is identified as a *loose cubic meter* (LCM)
- *Compacted:*
  - Material after compaction
  - A unit volume is identified as a *compacted cubic meter* (CCM)

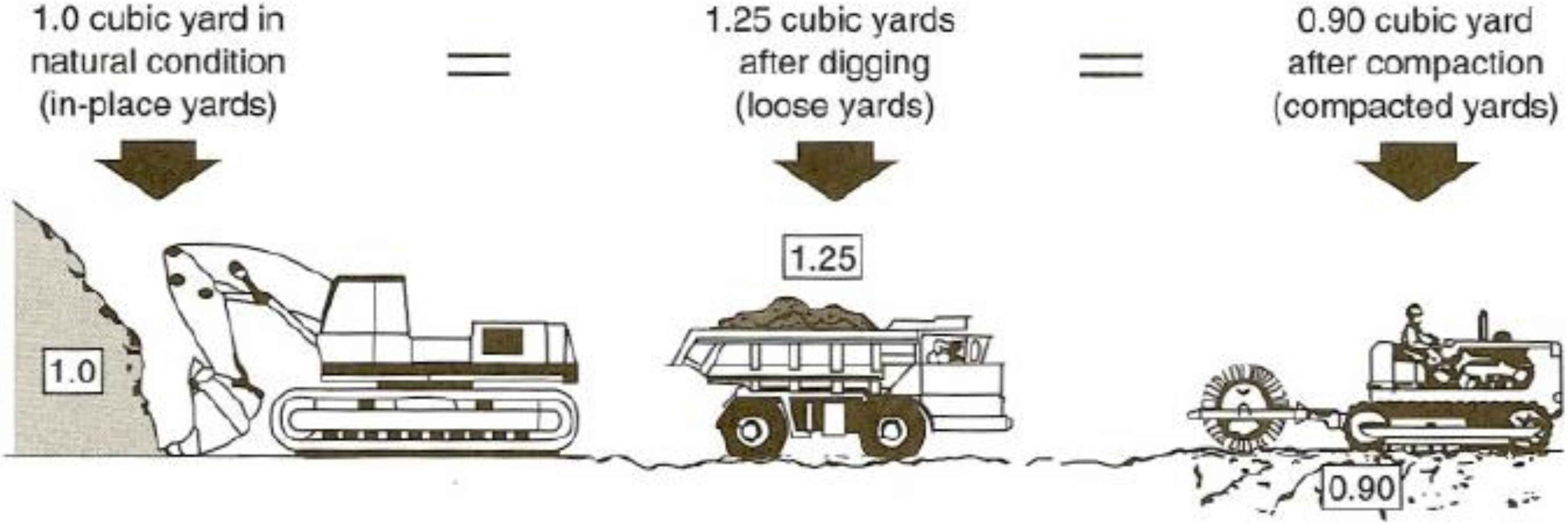


FIGURE 2-2 Typical soil volume change during earthmoving.

Swell

- A soil increases in volume when it is excavated because the soil grains are **loosened during excavation** and air fills the void spaces created
- As a result, a unit volume of soil in the bank condition will occupy **more than** one unit volume after excavation
- This phenomenon is called *swell*
- Swell may be calculated as follows:

$$Swell\ (\%) = \left(\frac{Weight\ /\ \mathbf{bank}\ volume}{Weight\ /\ \mathbf{loose}\ volume} - 1\right) \times 100 \qquad (2\text{-}4)$$

EXAMPLE 2-1

- Find the swell of a soil that weighs 1661 kg/m^3 in its natural state and 1186 kg/m^3 after excavation.

Solution

Swell = (1661/1186 – 1) × 100=40%

- That is, 1 bank cubic meter of material will expand to 1.4 loose cubic meters after excavation.

Swelling 40%

	Bank	**Loose**
Volume	1 m^3	1 m^3
Weight	1661 kg	1186 kg
	Bank	Loose
Weight	1661 kg	1661 kg
Volume	1 m^3	1.4 m^3

Shrinkage

- When a soil is compacted, some of the **air is forced out** of the soil's void spaces.
- As a result, the soil will **occupy less volume** than it did under either the bank or loose conditions.
- This phenomenon, which is the reverse of the swell phenomenon, is called *shrinkage.*

- The value of shrinkage may be determined as follows:

$$Shrinkage\ (\%) = \left(1 - \frac{Weight\ /\ \boldsymbol{bank}\ volume}{Weight\ /\ \boldsymbol{compacted}\ volume}\right) \times 100 \qquad (2\text{-}5)$$

- Note that both swell and shrinkage are calculated from the bank (or natural) condition.

EXAMPLE 2-2

- Find the shrinkage of a soil that weighs 1661 kg/m^3 in its natural state and 2077 kg/m^3 after compaction.

Solution

Shrinkage = (1– 1661/ 2077) × 100 = 20% (Eq 2-5)

- Hence 1 bank cubic meter of material will shrink to 0.8 compacted cubic meter as a result of compaction.

Shrinkage 20%

	Compacted	**Bank**
Volume	1 m^3	1 m^3
Weight	2077 kg	1661 kg

	Compacted	**Bank**
Weight	2077 kg	2077 kg
Volume	1 m^3	1.2 m^3

Load and Shrinkage Factors

- A *pay meter* is the volume unit specified as the **basis for payment** in an earthmoving **contract**. It may be any of the three volume units.

Load and Shrinkage Factors

- Haul unit and spoil bank volume are usually expressed in loose measures

- Therefore, ***load factor*** is used to conveniently convert from *loose* to *bank* volume

$$Load\ factor = \frac{Weight\ /\ \mathbf{loose}\ volume}{Weight\ /\ \mathbf{bank}\ volume} \qquad (2\text{-}6)$$

or

$$\text{Load factor} = 1/\ (1+\text{swell}) \qquad (2\text{-}7)$$

- Loose volume is multiplied by the load factor to obtain bank volume.

Load and Shrinkage Factors

- A factor used for the conversion of bank volume to compacted volume is sometimes referred to as a *shrinkage factor.*

$$Shrinkage\ factor = \frac{Weight\ /\ \boldsymbol{bank}\ volume}{Weight\ /\ \boldsymbol{compacted}\ volume} \qquad (2\text{-}8)$$

or

Shrinkage factor = 1 – shrinkage (2-9)

Load and Shrinkage Factors

- Bank volume may be multiplied by the shrinkage factor to obtain compacted volume
- Or, compacted volume may be divided by the shrinkage factor to obtain bank volume.

EXAMPLE 2-3

- A soil weighs 1163kg/LCM, 1661kg/BCM, and 2077 kg/CCM.

a) Find the load factor and shrinkage factor for the soil.

b) How many bank cubic meters (BCM) and compacted cubic meters (CCM) are contained in 593,300 LCM of this soil?

EXAMPLE 2-3

Solution

(a)

Load factor = 1163/1661 =0.70 (Eq 2-6)

Shrinkage factor = 1661/2077 = 0.80 (Eq 2-8)

(b)

Bank volume = 593300 x 0.70 = 415310 BCM

Compacted volume = 415310 × 0.80 = 332248 CCM

Load and Shrinkage Factors

- Typical values of unit weight, swell, shrinkage, load factor, and shrinkage factor for some common earthmoving materials are given in Table 2-5.

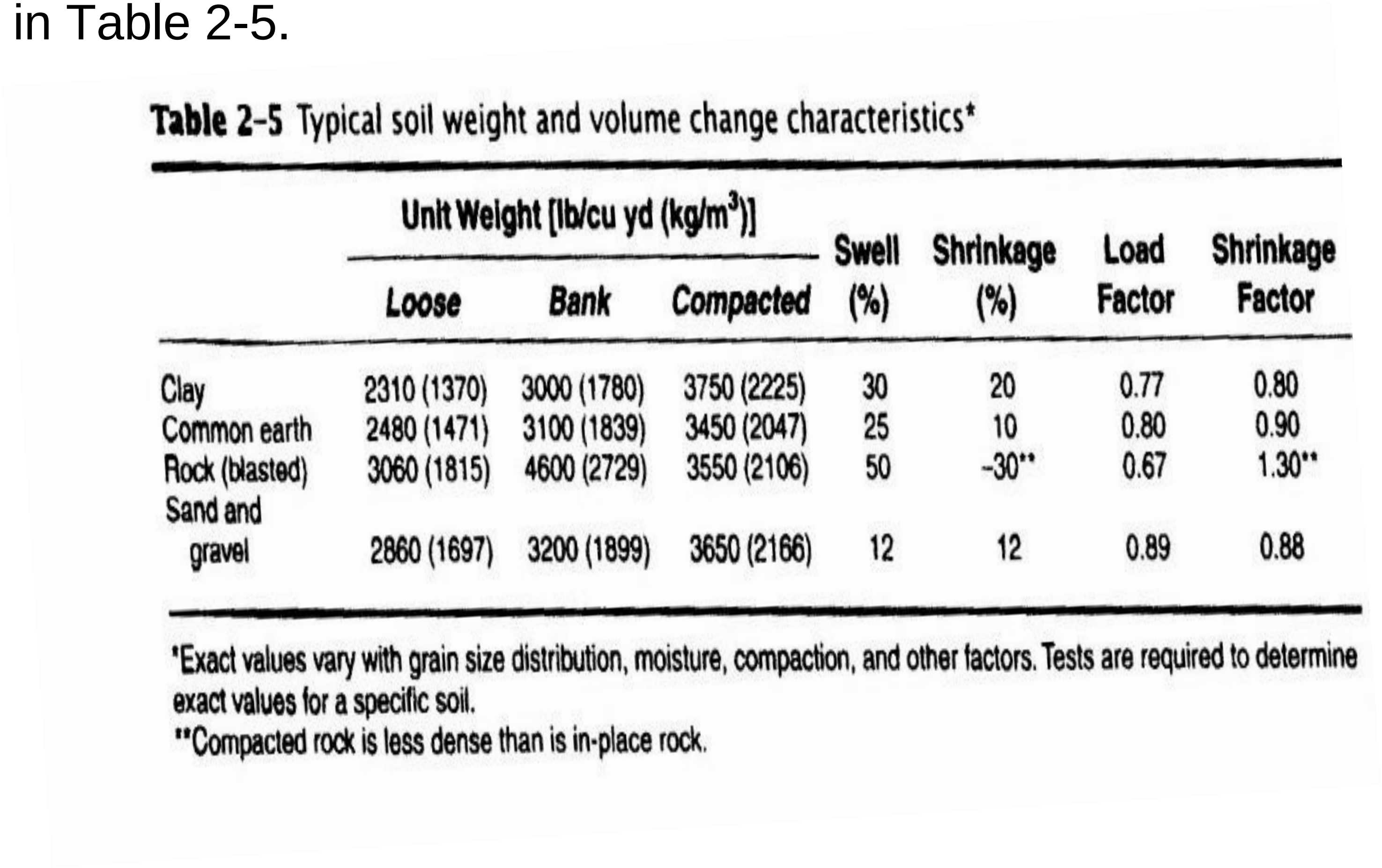


Table 2–5 Typical soil weight and volume change characteristics*

	Unit Weight [lb/cu yd (kg/m^3)]			Swell	Shrinkage	Load	Shrinkage
	Loose	*Bank*	*Compacted*	(%)	(%)	Factor	Factor
Clay	2310 (1370)	3000 (1780)	3750 (2225)	30	20	0.77	0.80
Common earth	2480 (1471)	3100 (1839)	3450 (2047)	25	10	0.80	0.90
Rock (blasted)	3060 (1815)	4600 (2729)	3550 (2106)	50	−30**	0.67	1.30**
Sand and gravel	2860 (1697)	3200 (1899)	3650 (2166)	12	12	0.89	0.88

*Exact values vary with grain size distribution, moisture, compaction, and other factors. Tests are required to determine exact values for a specific soil.

**Compacted rock is less dense than is in-place rock.

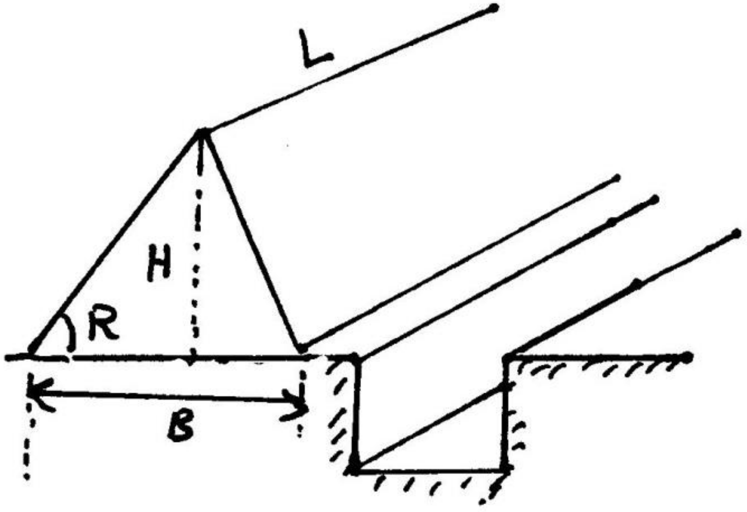
2-5 SPOIL BANKS

- Excavated material either:
  - Loaded in trucks/haul units, or
  - Stockpiled (spoil bank or spoil pile)

- When planning and estimating earthwork, it is necessary to determine the size of the pile of material that will be created by the material removed from the excavation.

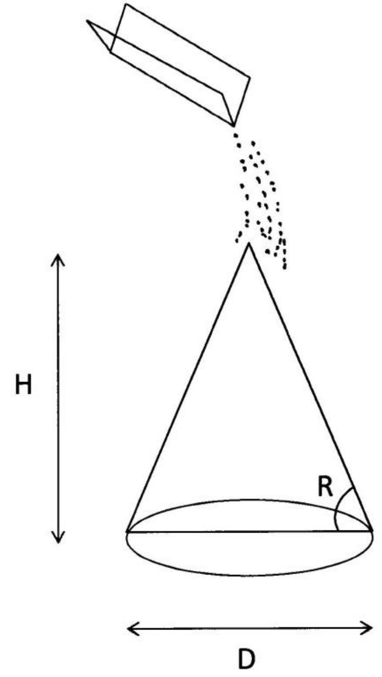
Spoil banks

- If the pile of material is long in relation to its width, it is referred to as a *spoil bank.* Spoil banks are characterized by a *triangular* cross section



Spoil Pile

- If the material is dumped from a fixed position, a *spoil pile* is created which has a *conical* shape.



Dimension of Spoil bank or spoil pile

- To determine the dimensions of spoil banks or piles, it is first necessary to convert the volume of excavation from in-place conditions (BCM) to loose conditions (LCM).

- Bank or pile dimensions may then be calculated using Equations 2-10 to 2-13 if the soil's ***angle of repose*** is known.

Soil's angle of repose

- A soil's *angle of repose* is the angle that the sides of a spoil bank or pile **naturally** form with the horizontal when the excavated soil is dumped onto the pile.
- The angle of repose (which represents the equilibrium position of the soil) varies with the soil's physical characteristics and its moisture content.

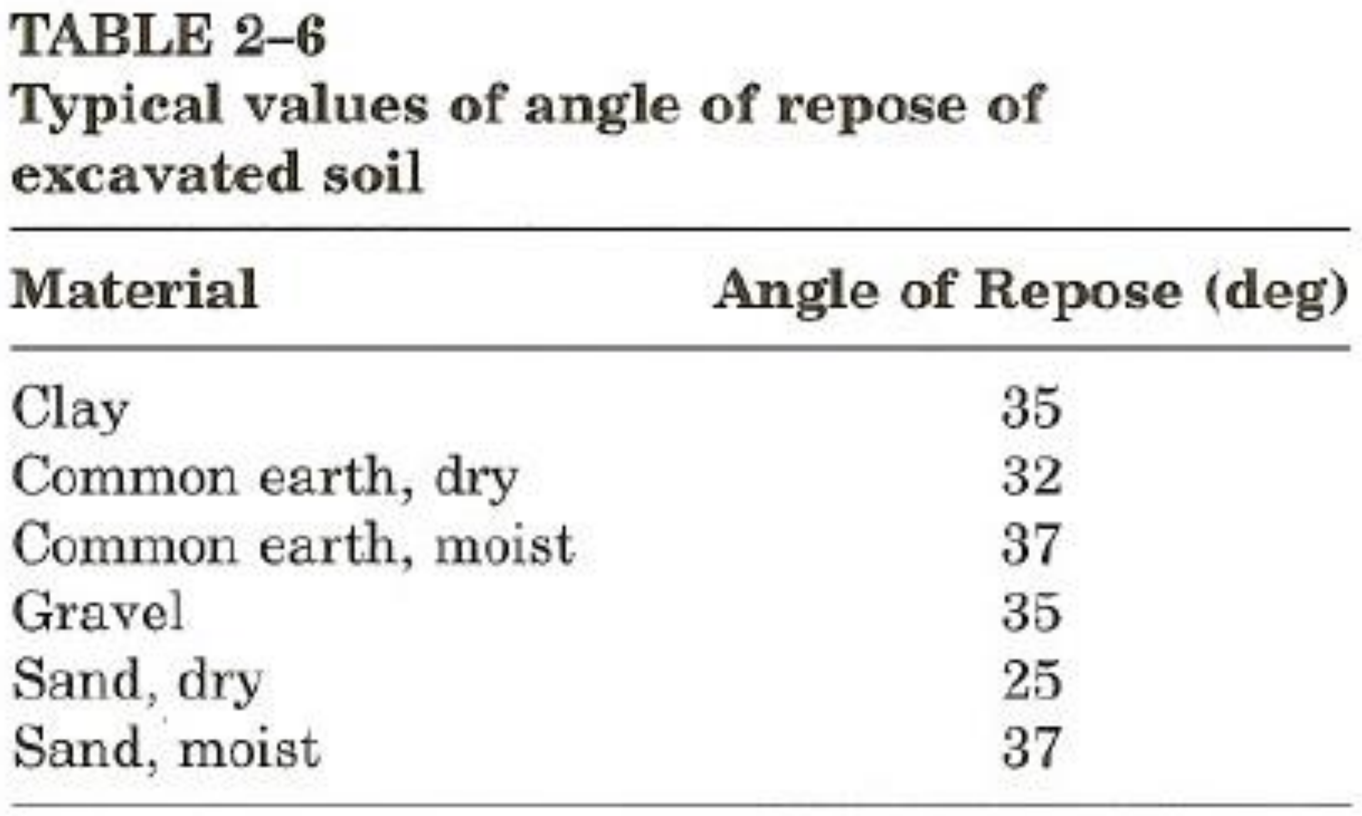


TABLE 2–6
Typical values of angle of repose of excavated soil

Material	Angle of Repose (deg)
Clay	35
Common earth, dry	32
Common earth, moist	37
Gravel	35
Sand, dry	25
Sand, moist	37

Triangular Spoil Bank

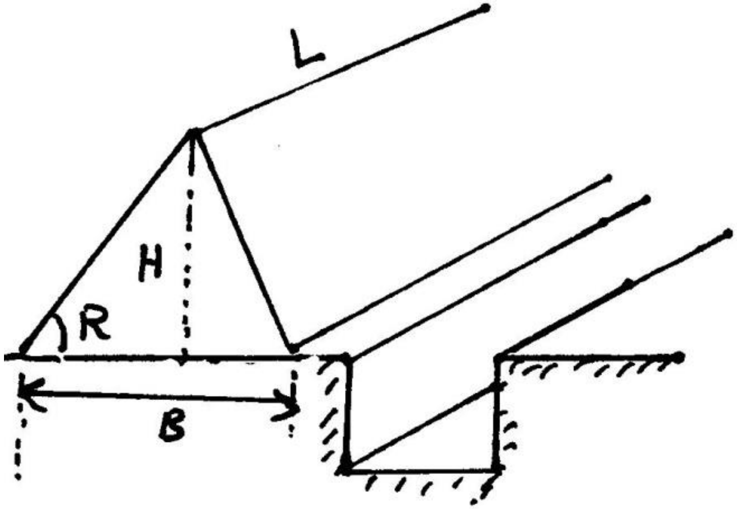
Volume = Section area x Length

$\tan R = H / (B / 2)$

$V = (B \times H/2) \times L$

$B = (4V / (L \times \tan R))^{1/2}$ (2-10)

$H = (B/2) \times \tan R$ (2-11)



where

B =base width (ft or m)

H =pile height (ft or m)

L =pile length (ft or m)

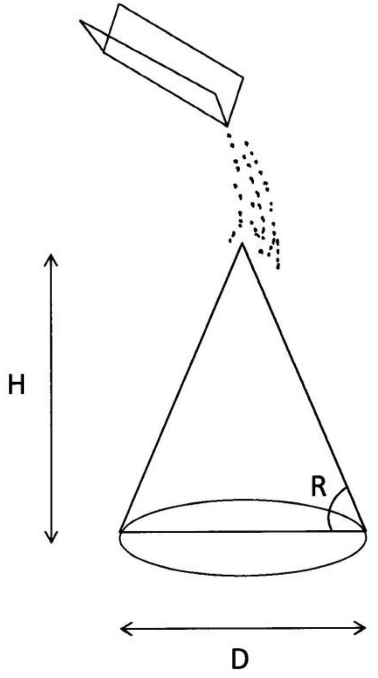
R =angle of repose (deg)

V =pile volume (cu ft or m^3)

Conical Spoil Pile

Volume = ⅓ × Base area × Height

$\tan R = H / D/2$



$D = (7.64\ V / \tan R)^{1/3}$ (2-12)

$H = D/2 \times \tan R$ (2-13)

where

D is the diameter of the pile base (ft or m).

EXAMPLE 2-4

- Find the base width and height of a triangular spoil bank containing 76.5 BCM if the pile length is 9.14 m , the soil's angle of repose is 37°, and its swell is 25%.

Solution

Loose volume = 76.5 × 1.25 = 95.6 LCM

$B = (4V / (L \times \tan R))^{1/2}$

Base Width $= (4 \times 95.6 / (9.14 \times \tan 37°))^{1/2} = 7.45$ m (Eq 2-10)

$H = (B/2) \times \tan R$

Height = 7.45 / 2 × tan 37° = 2.80 m (Eq 2-11)

EXAMPLE 2-5

- Find the base diameter and height of a conical spoil pile that will contain 76.5 BCM of excavation if the soil's angle of repose is 32° and its swell is 12%.

Solution

Loose volume = $76.5 \times 1.12 = 85.7$ LCM

$D = (7.64\ V / \tan R)^{1/3}$

Base diameter = $(7.64 \times 85.7 / \tan 32°)^{1/3} = 10.16$ m

$H = D/2 \times \tan R$

Height = $10.16 / 2 \times \tan 32° = 3.17$ m

2-6 ESTIMATING EARTHWORK VOLUME

- When planning or estimating an earthmoving project it is often necessary to estimate the volume of material to be excavated or placed as fill.

- The procedures to be followed can be divided into three principal categories:

  1. Pit excavations (small, relatively deep excavations such as those required for basements and foundations),
  2. Trench excavation for utility lines, and
  3. Excavating or grading relatively large areas.

2-6 ESTIMATING EARTHWORK VOLUME

- Procedures suggested for each of these three are as follows:
  - The estimation of the earthwork volume involved in the construction of roads and airfields is customarily performed by the design engineer.
  - The usual method is to calculate the cross-sectional area of cut or fill at regular intervals (such as *stations* [l00 ft or 33 m]) along the centerline.
  - The volume of cut or fill between stations is then calculated, accumulated, and plotted as a *mass diagram.*

2-6 ESTIMATING EARTHWORK VOLUME

- When making earthwork volume calculations,
  - Cut volume is normally calculated in bank measure
  - The volume of compacted fill is calculated in compacted measure.
- Both cut and fill must be expressed in the same volume units before being added.

Pit Excavations

- Simply multiply the horizontal area of excavation by the *average depth* of excavation (Equation 2-14).

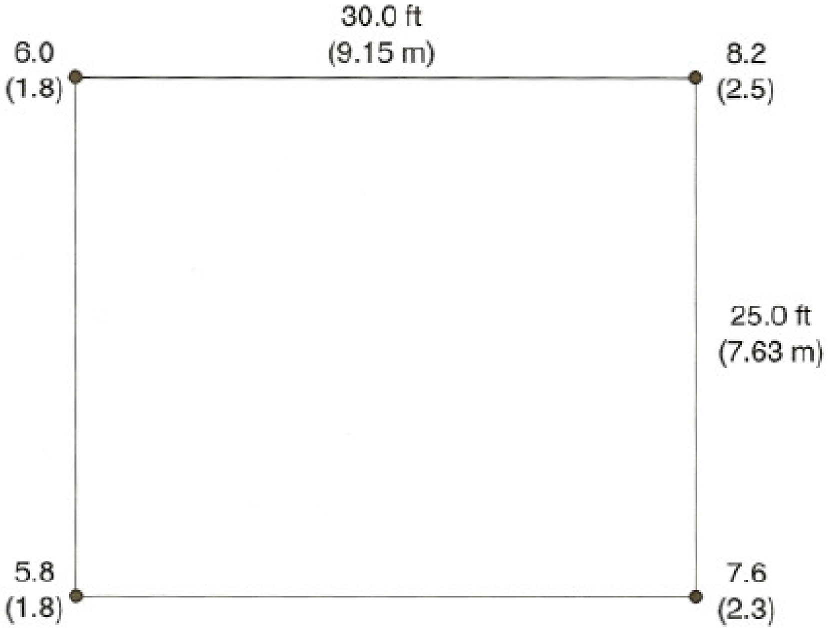
$$\text{Volume} = \text{Horizontal area} \times \text{Average depth} \qquad (2\text{-}14)$$

Pit Excavations

- To perform these calculations,
  - First divide the horizontal area into a convenient set of rectangles, triangles, or circular segments.
  - The total area is found as the sum of the segment areas.
  - The average depth is then calculated (arithmetic average).
  - For simple rectangular excavations, the average depth can be taken as simply the average of the four corner depths.
  - For more complex areas, measure the depth at additional points along the perimeter of the excavation and average all depths.

EXAMPLE 2-6

- Estimate the volume of excavation required (bank measure) for the basement shown in Figure 2-4. Values shown at each corner are depths of excavation. All values are in feet (m).



Solution

Area = 7.63 x 9.15 = 69.8 m^2

Average depth = (1.8 + 2.5 + 2.3 + 1.8)/4 = 2.1 m

Volume = 69.8 × 2.1 = 146.6 BCM

Trench Excavations

- The volume of excavation required for a trench can be calculated as the product of the trench cross-sectional area and the linear distance along the trench line (Equation 2-15).

$$\text{Volume} = \text{Cross-sectional area} \times \text{Length} \qquad (2\text{-}15)$$

Trench Excavations

- For rectangular trench sections where the trench depth and width are relatively constant, trench volume can be found as simply the product of trench width, depth, and length.
- When trench sides are sloped and vary in width and/or depth,
  - Cross sections should be taken at frequent linear intervals and the volumes between locations computed.
  - These volumes are then added to find total trench volume.

EXAMPLE 2-7

- Find the volume (bank measure) of excavation required for a trench 0.92 m wide, 1.83 m deep, and 152 m long. Assume that the trench sides will be approximately vertical.

Solution

Cross-sectional area = 0.92 x 1.83 = 1.68 m^2

Volume = 1.68 × 152 = 255 BCM

Large Areas

- To estimate the earthwork volume involved in large or complex areas, one method is
  - To divide the area into a grid indicating the depth of excavation or fill at each grid intersection.

Large Areas

- Assign a weight to the depth at each corner or segment intersection according to its location (number of segment lines intersecting at the point):
  - Interior points (intersection of 4 segments): **weight of 4**
  - Exterior points at the intersection of 2 segments: **weight of 2**
  - Corner points: **weight of 1**

- Average depth (weighted average) is then computed using Equation 2-16 and multiplied by the horizontal area to obtain the volume of excavation.

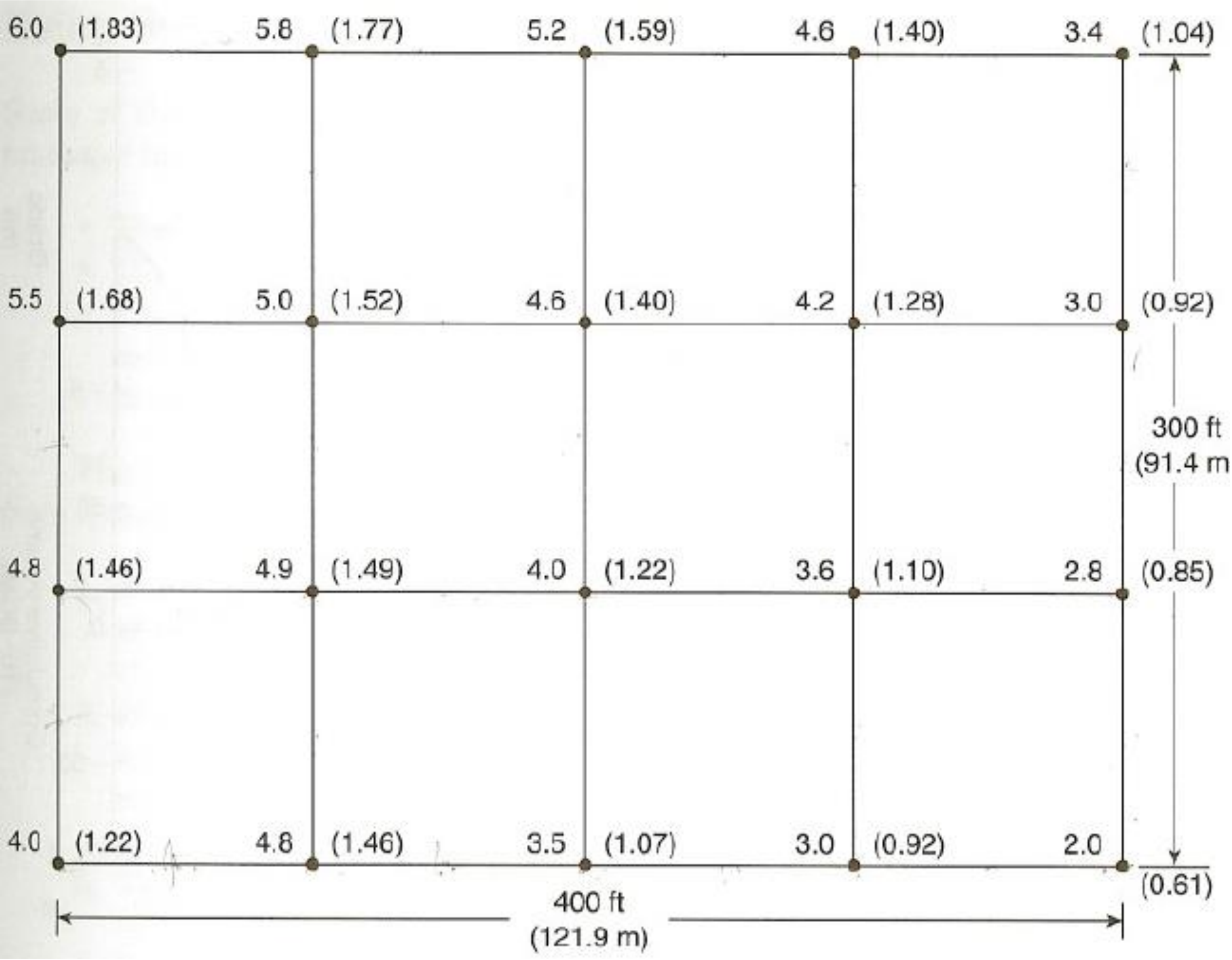
$$\text{Average depth} = \frac{\textit{Sum of products of depth} \times \textit{weight}}{\textit{Sum of weights}} \qquad (2\text{-}16)$$

- Note:

  Although this calculation yields the net volume of excavation for the area, any balancing of cut and fill within the area is not identified in the result.

EXAMPLE 2-8

- Find the volume of excavation required for the area shown below. The figure at each grid intersection represents the depth of cut at that location. Depths in parentheses represent meters.


6.0 (1.83)
5.8 (1.77)
5.2 (1.59)
4.6 (1.40)
3.4 (1.04)
5.5 (1.68)
5.0 (1.52)
4.6 (1.40)
4.2 (1.28)
3.0 (0.92)
4.8 (1.46)
4.9 (1.49)
4.0 (1.22)
3.6 (1.10)
2.8 (0.85)
4.0 (1.22)
4.8 (1.46)
3.5 (1.07)
3.0 (0.92)
2.0 (0.61)
300 ft
(91.4 m
400 ft
(121.9 m)

EXAMPLE 2-8

Solution

Corner points = 1.83 + 1.04 + 0.61 + 1.22 = 4.70 m

Border points = 1.77 + 1.59 + 1.40 + 0.92 + 0.85 + 0.92 + 1.07 + 1.46 + 1.46 + 1.68 =13.12 m

Interior points = 1.52+ 1.40+ 1.28+ 1.49+ 1.22+ 1.10= 8.01 m

Number of weights= 4*1 + 10* 2+ 6* 4= 48

Average depth (weighted) =

{1(4.70) + 2(13.12) +4(8.01)}/48 = 1.21 m

Area = 91.4 × 121.9 = 11,142 m^2

Volume= 11,142 x 1.21 = 13,482 BCM

2-7 CONSTRUCTION USE OF THE MASS DIAGRAM

- In *highway projects*, three kinds of views in the contract document:
  - Plan view
  - Profile view
  - Cross-section view

Stations: horizontal distances along the centerline of the project (distances between stations is 100 units (m or ft))

Source: Peurifoy, R. L., Schexnayder, C., Shapira, A., and Schmitt, R. L., Construction Planning, Equipment and Methods, edition 8, McGraw Hill, 2011.

Plan view

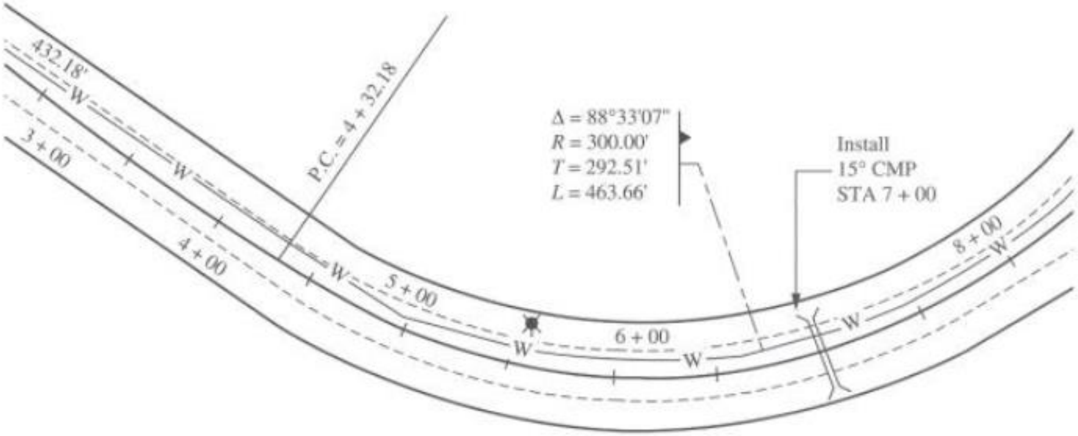


FIGURE 3.3 Plan view of a highway project

Proposed grade

Profile view

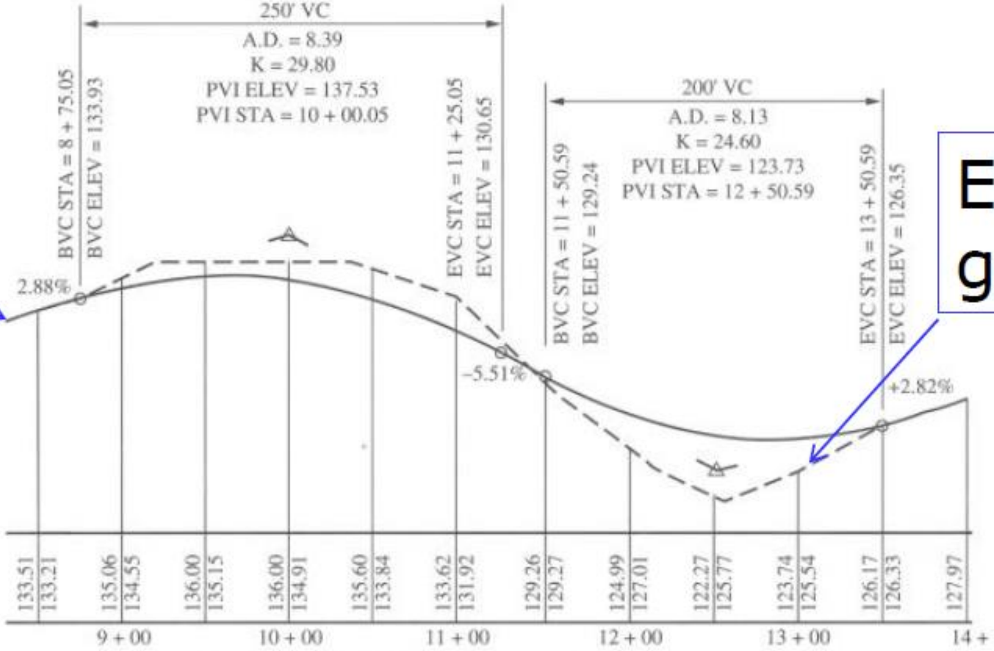


FIGURE 3.4 Profile view of a highway project

Existing ground

Source: Peurifoy, R. L., Schexnayder, C., Shapira, A., and Schmitt, R. L., Construction Planning, Equipment and Methods, edition 8, McGraw Hill, 2011.

Cross-section view

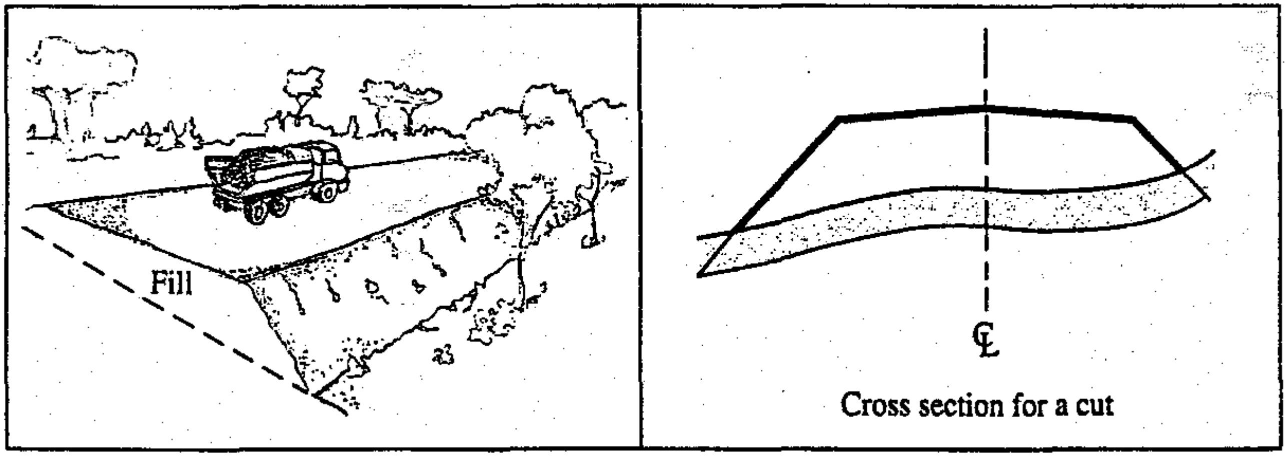


FIGURE 3.4 Earthwork cross section for a fill situation.

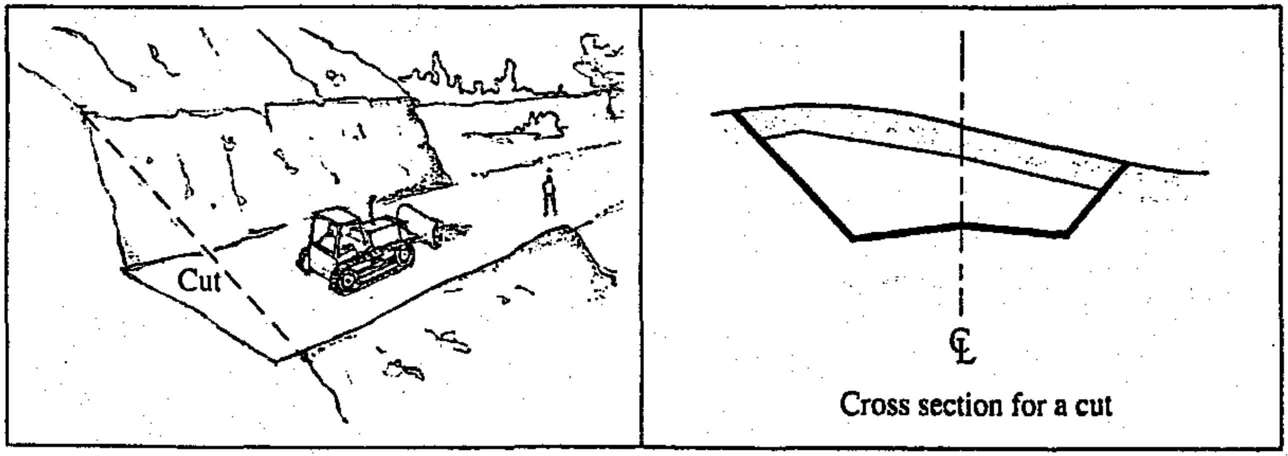
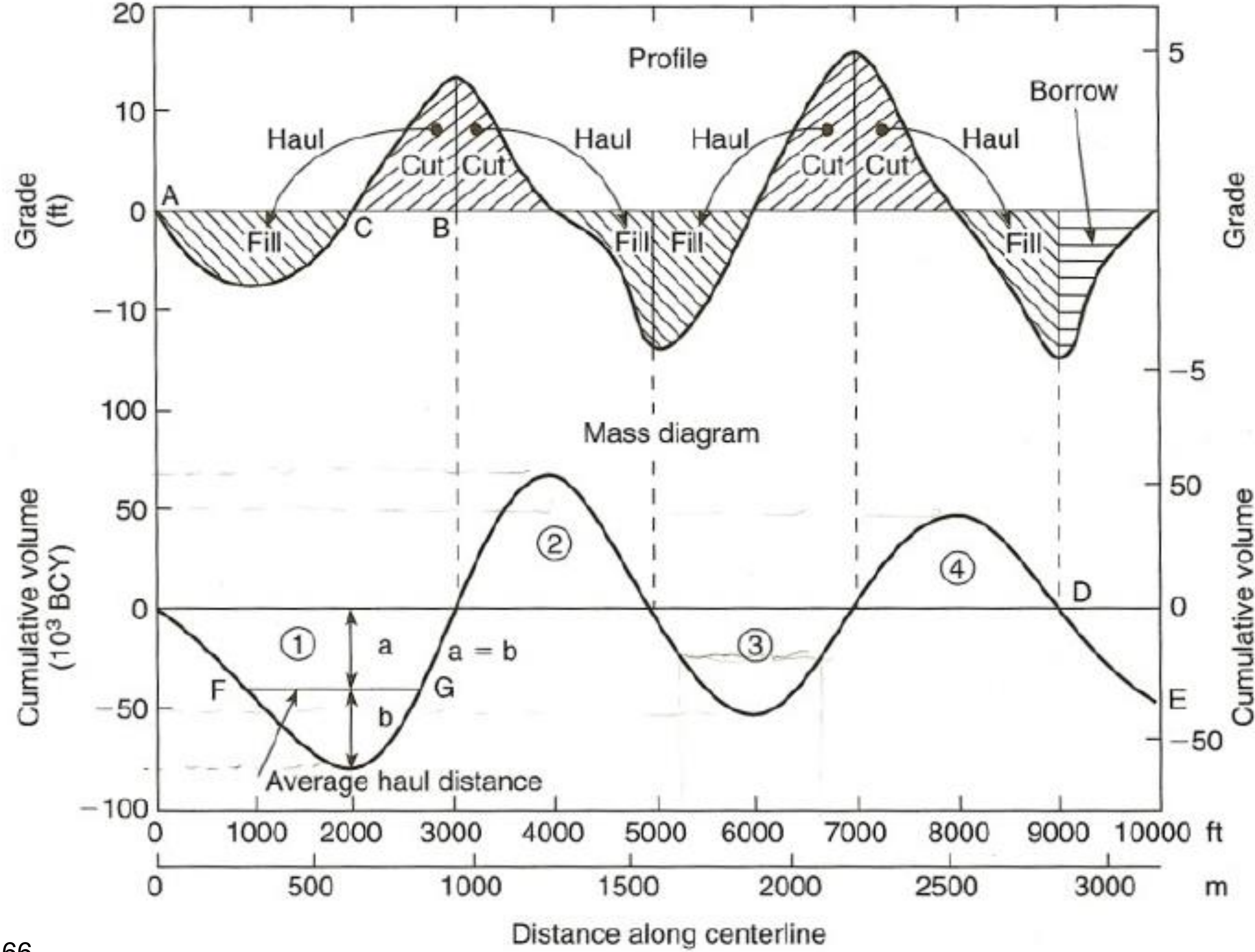


FIGURE 3.5 Earthwork cross section for a cut situation.

Source: Peurifoy, R. L., Schexnayder, C., Shapira, A., and Schmitt, R. L., Construction Planning, Equipment and Methods, edition 8, McGraw Hill, 2011.

2-7 CONSTRUCTION USE OF THE MASS DIAGRAM

- A *mass diagram* is a continuous curve representing the **accumulated** volume of earthwork plotted against the linear profile of a roadway or airfield.
- Mass diagrams are prepared by highway and airfield designers to assist in selecting an alignment which minimizes the earthwork required to construct the facility while meeting established limits of roadway grade and curvature.


Profile
Grade (ft)
Grade (m)
20
10
0
−10
5
−5
Borrow
Haul
Haul
Haul
Haul
Cut
Cut
Cut
Cut
Fill
Fill
Fill
Fill
A
C
B
Mass diagram
Cumulative volume (10³ BCY)
Cumulative volume (10³ BCM)
100
50
0
−50
−100
50
0
−50
②
④
①
③
a
b
a = b
F
G
D
E
Average haul distance
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
ft
0
500
1000
1500
2000
2500
3000
m
Distance along centerline

Accumulated soil quantity

Transition point

Balance Line

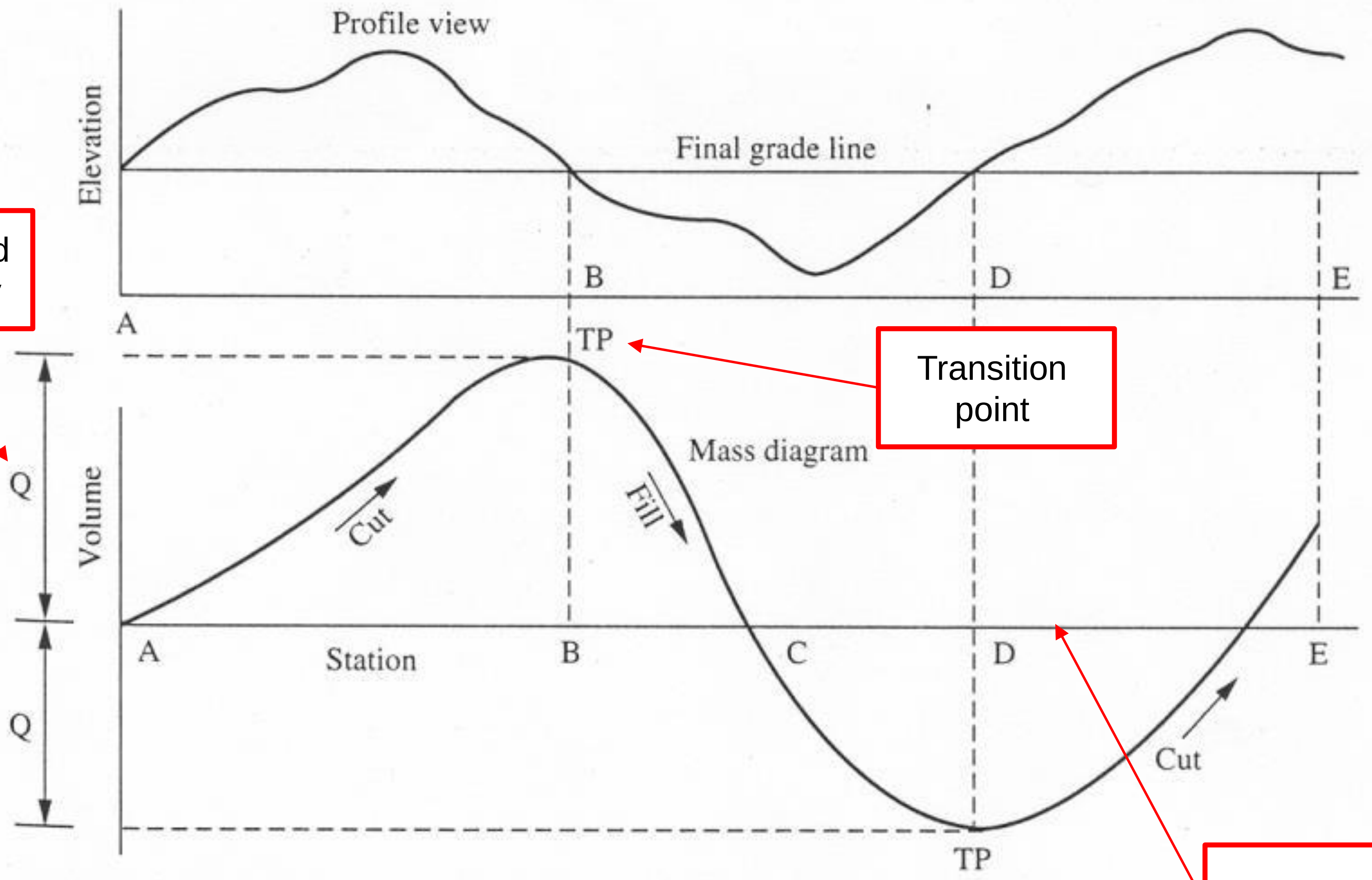


FIGURE 2.6 | Properties of a mass diagram.

Source: Peurifoy, R. L., Schexnayder, C., Shapira, A., and Schmitt, R. L., Construction Planning, Equipment and Methods, edition 8, McGraw Hill, 2011.

Properties of a Mass Diagram

- The vertical coordinate of the mass diagram corresponding to any location on the roadway profile represents the cumulative earthwork volume from the **origin** to that point.
- Within a cut, the curve rises from left to right.
- Within a fill, the curve falls from left to right.

Properties of a Mass Diagram

- A peak on the curve represents a point where the earthwork changes from cut to fill.
- A valley (low point) on the curve represents a point where the earthwork changes from fill to cut.
- When a horizontal line intersects the curve at two or more points, the accumulated volumes at these points are equal. Thus, such a line represents a balance line on the diagram.

Using the Mass Diagram

- Some of the information which a mass diagram can provide a construction manager includes the following:
  1. Quantities to be moved for cut and fill
  2. Length and direction of haul within a balanced section
  3. Average length of haul for a balanced section
  4. The location and amount of borrow (material hauled in from a borrow pit) and waste (material hauled away to a waste area) for the project.

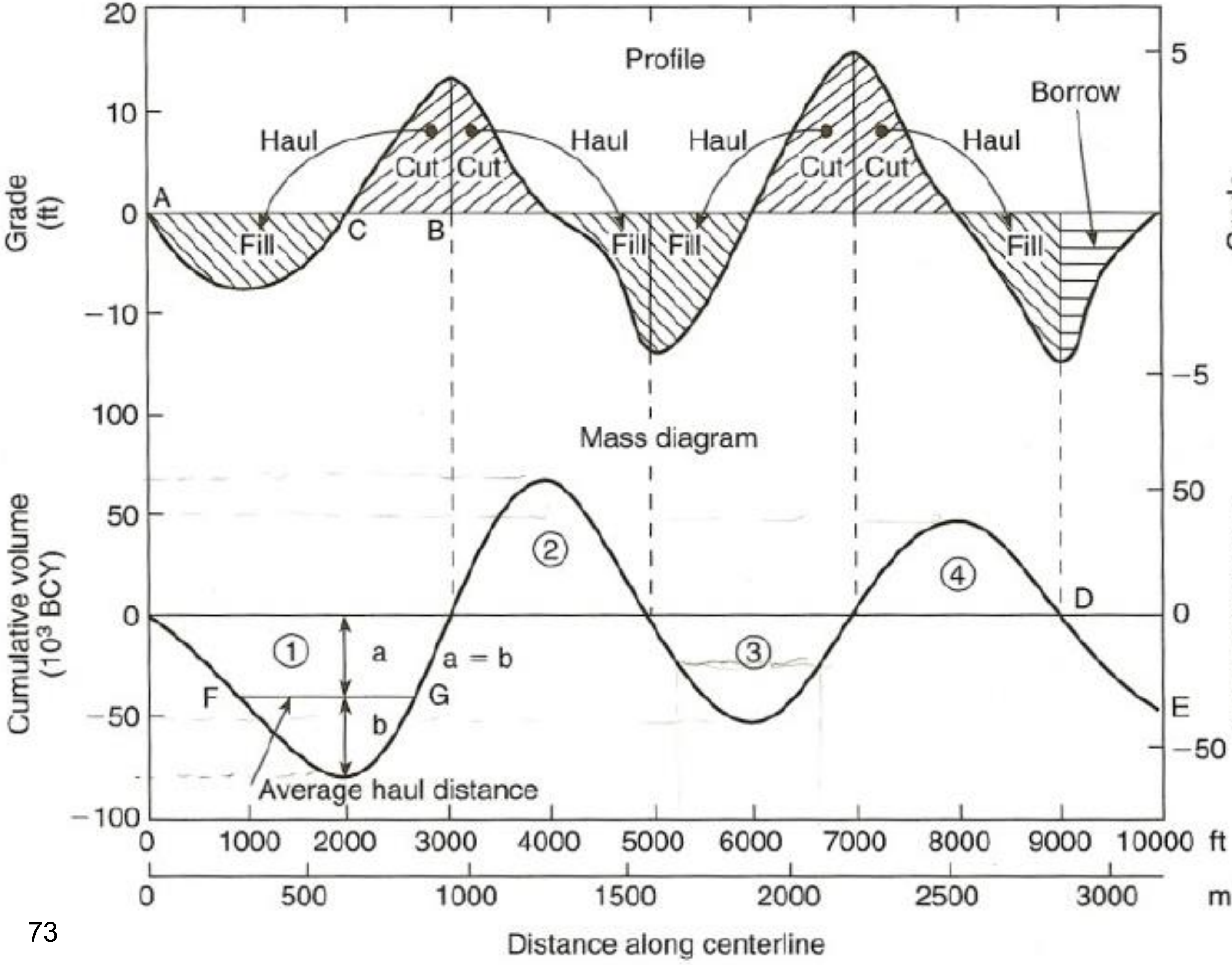
Using the Mass Diagram

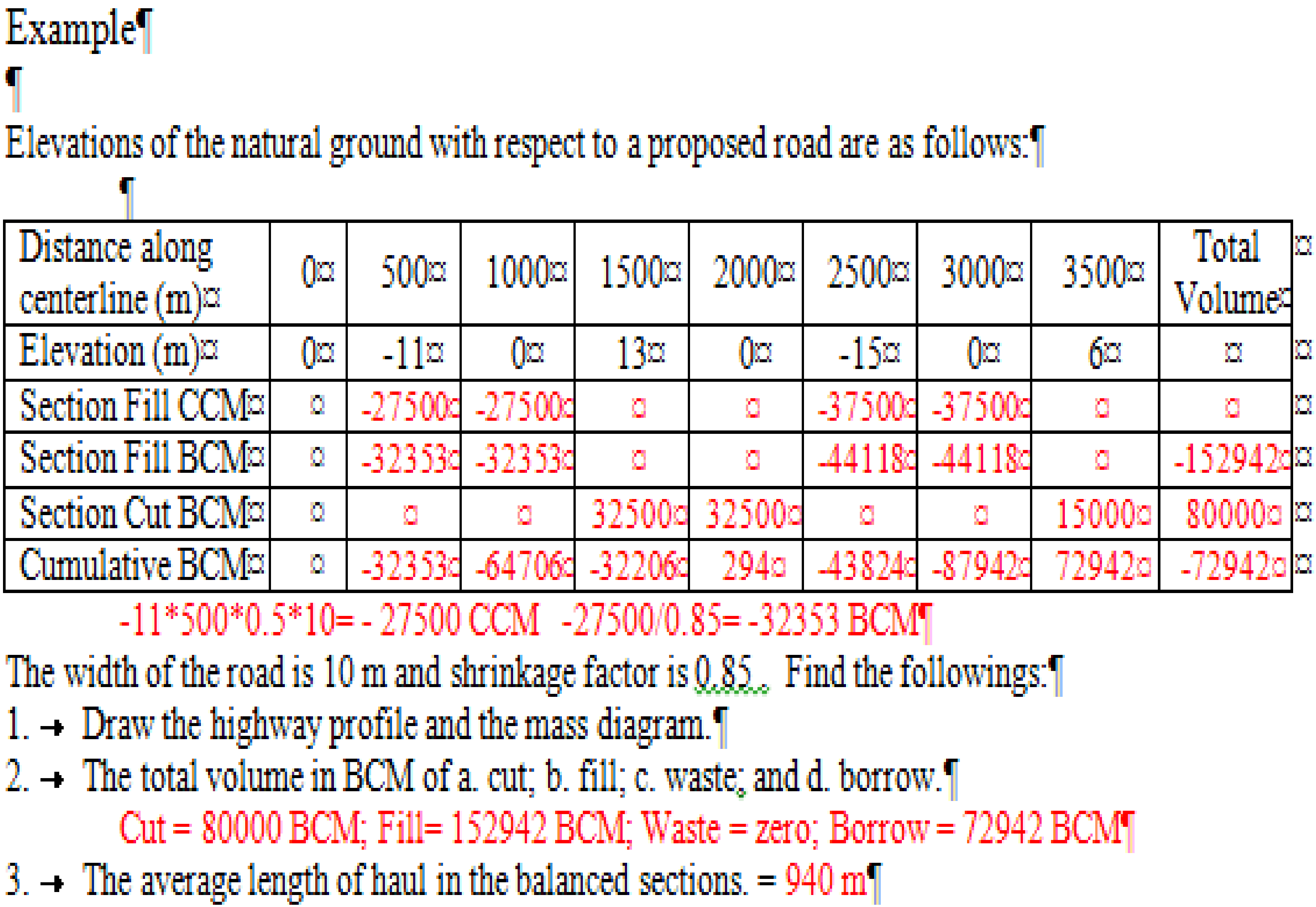
- The following explanation of methods for obtaining this information from a mass diagram will be illustrated using Figure 2-5.

   1. For a balanced section (section 1 on the figure), project the end points of the section up to the profile (points A and B). These points identify the limits of the balanced section.
   2. Locate point C on the profile corresponding to the lowest point of the mass diagram within section 1. This is the point at which the excavation changes from fill to cut. The areas of cut and fill can now be identified on the profile.
   3. The direction of haul within a balanced section is always from cut to fill.

Using the Mass Diagram

4. Repeat this process for sections 2, 3, and 4 as shown.
5. Since the mass diagram has a negative value from point D to the end, the ordinate at point E (-50,000 BCY or -38,230 BCM) represents the volume of material which must be brought in from a borrow pit to complete the roadway embankment.
6. The approximate average haul distance within a balanced section can be taken as the length of a horizontal line located midway between the balance line for the section and the peak or valley of the curve for the section. Thus, the length of the line F-G represents the average haul distance for section 1, which is 1800 ft or 549 m.


Profile
Grade (ft)
Grade (m)
20
10
0
−10
5
−5
Haul
Haul
Haul
Haul
Cut
Cut
Cut
Cut
Fill
Fill
Fill
Fill
Borrow
A
B
C
Mass diagram
Cumulative volume (10³ BCY)
Cumulative volume (10³ BCM)
100
50
0
−50
−100
50
0
−50
①
②
③
④
a
b
a = b
F
G
D
E
Average haul distance
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
ft
0
500
1000
1500
2000
2500
3000
m
Distance along centerline



Example

Elevations of the natural ground with respect to a proposed road are as follows:

Distance along centerline (m)	0	500	1000	1500	2000	2500	3000	3500	Total Volume
Elevation (m)	0	-11	0	13	0	-15	0	6	
Section Fill CCM		-27500	-27500			-37500	-37500		
Section Fill BCM		-32353	-32353			-44118	-44118		-152942
Section Cut BCM				32500	32500			15000	80000
Cumulative BCM		-32353	-64706	-32206	294	-43824	-87942	72942	-72942

-11*500*0.5*10= - 27500 CCM -27500/0.85= -32353 BCM

The width of the road is 10 m and shrinkage factor is 0.85. Find the followings:

1. Draw the highway profile and the mass diagram.
2. The total volume in BCM of a. cut; b. fill; c. waste; and d. borrow.

   Cut = 80000 BCM; Fill= 152942 BCM; Waste = zero; Borrow = 72942 BCM
3. The average length of haul in the balanced sections. = 940 m

Example

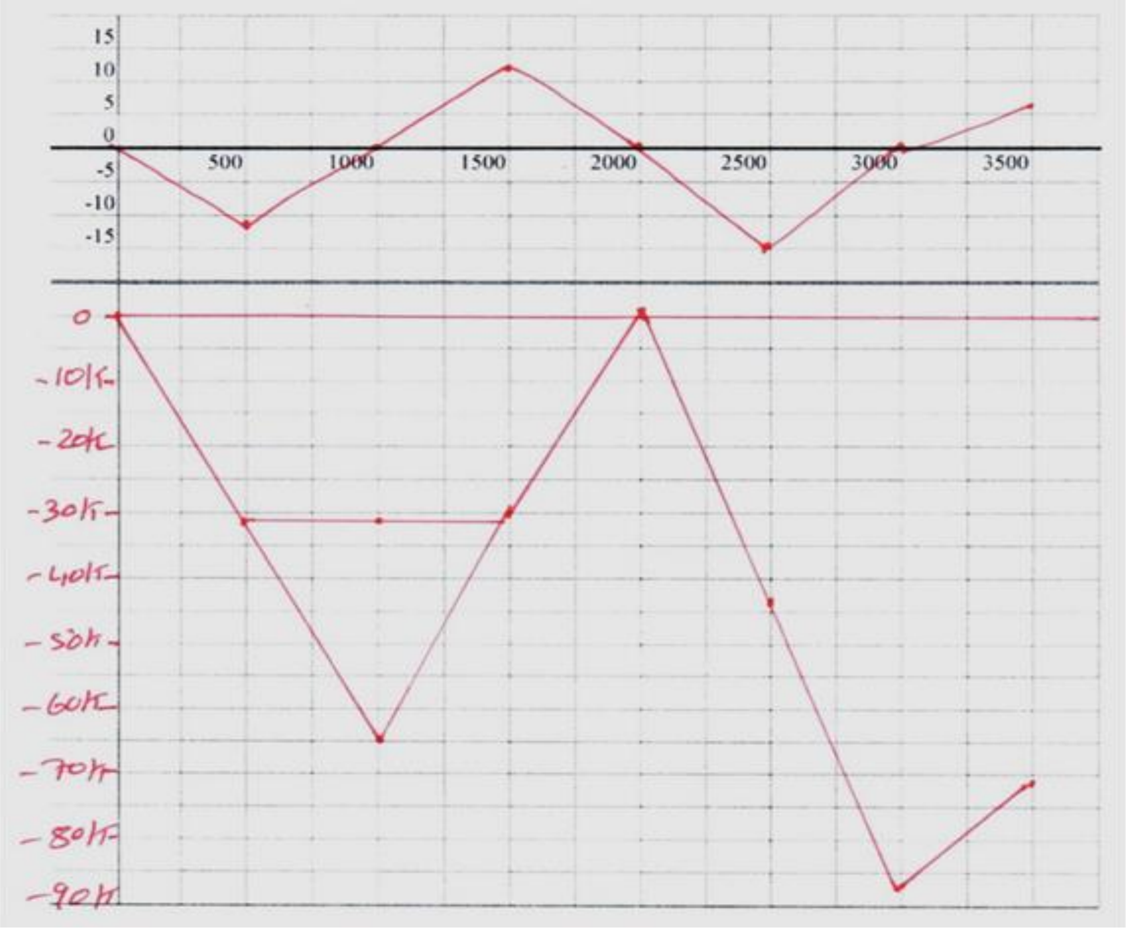
Elevations of the natural ground with respect to a proposed road are as follows:

Distance along centerline (m)	0	500	1000	1500	2000	2500	3000	3500	Total Volume
Elevation (m)	0	-11	0	13	0	-15	0	6	
Section Fill CCM		-27500	-27500			-37500	-37500		
Section Fill BCM		-32353	-32353			-44118	-44118		-152942
Section Cut BCM				32500	32500			15000	80000
Cumulative BCM		-32353	-64706	-32206	294	-43824	-87942	72942	-72942

-11*500*0.5*10= - 27500 CCM -27500/0.85= -32353 BCM

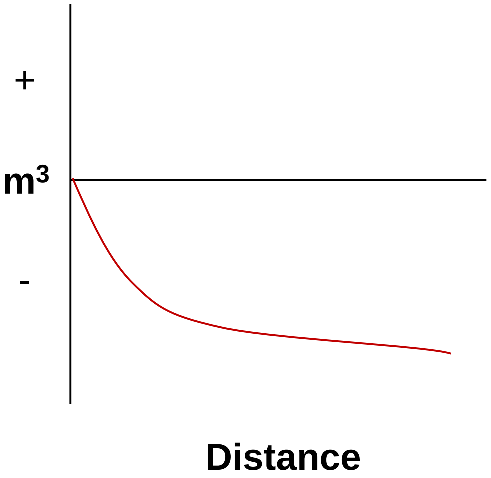
The width of the road is 10 m and shrinkage factor is 0.85. Find the followings:

1. → Draw the highway profile and the mass diagram.
2. → The total volume in BCM of a. cut; b. fill; c. waste; and d. borrow.
   Cut = 80000 BCM; Fill= 152942 BCM; Waste = zero; Borrow = 72942 BCM
3. → The average length of haul in the balanced sections. = 940 m

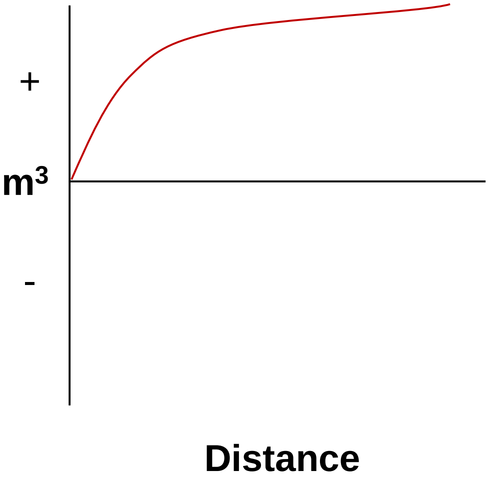


More cases (for illustration)

Given the mass diagrams, can you figure out the actual profile? (and the average hauling distance and direction?)



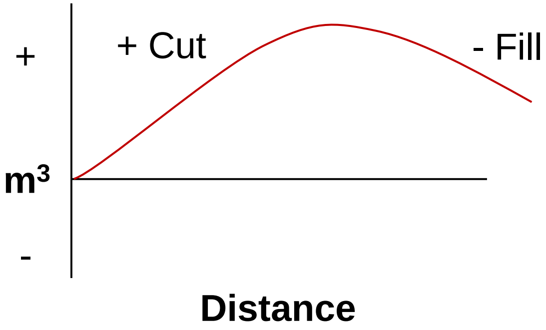
Fill-only

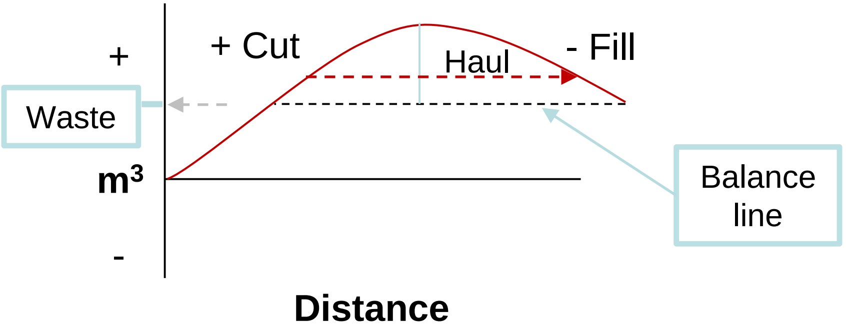


Cut-only

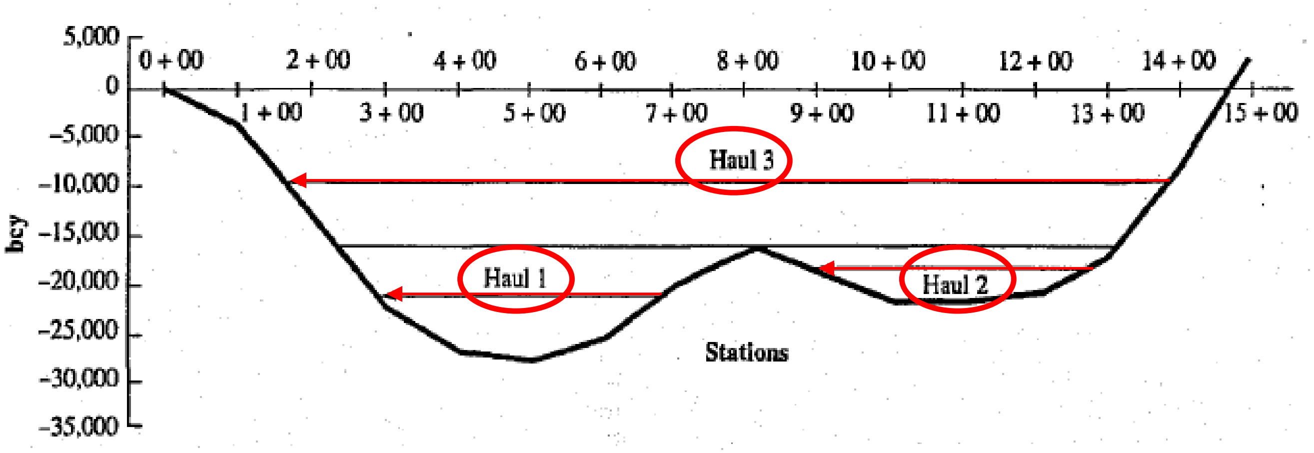
In these two cases, no hauling within the site

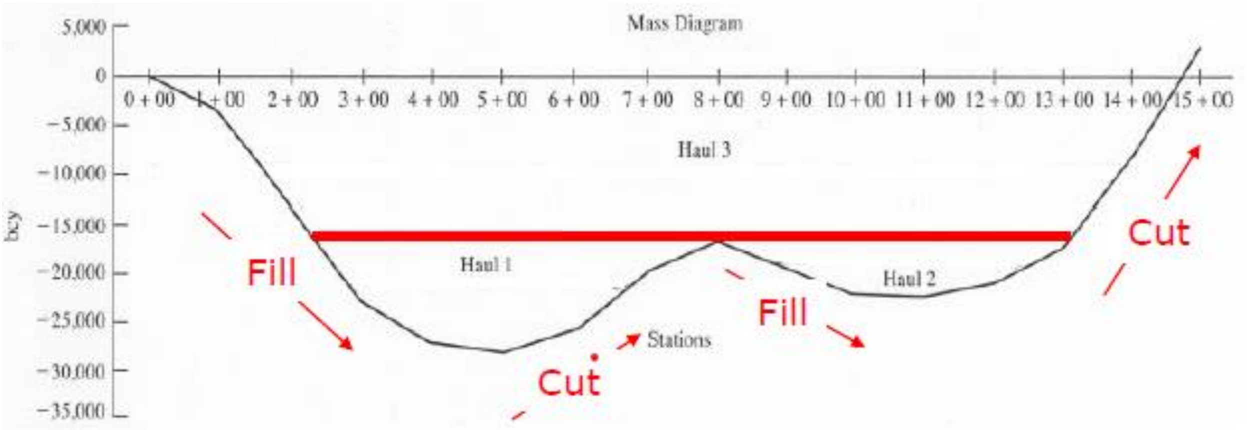
No balanced section





Multiple cut and fill section

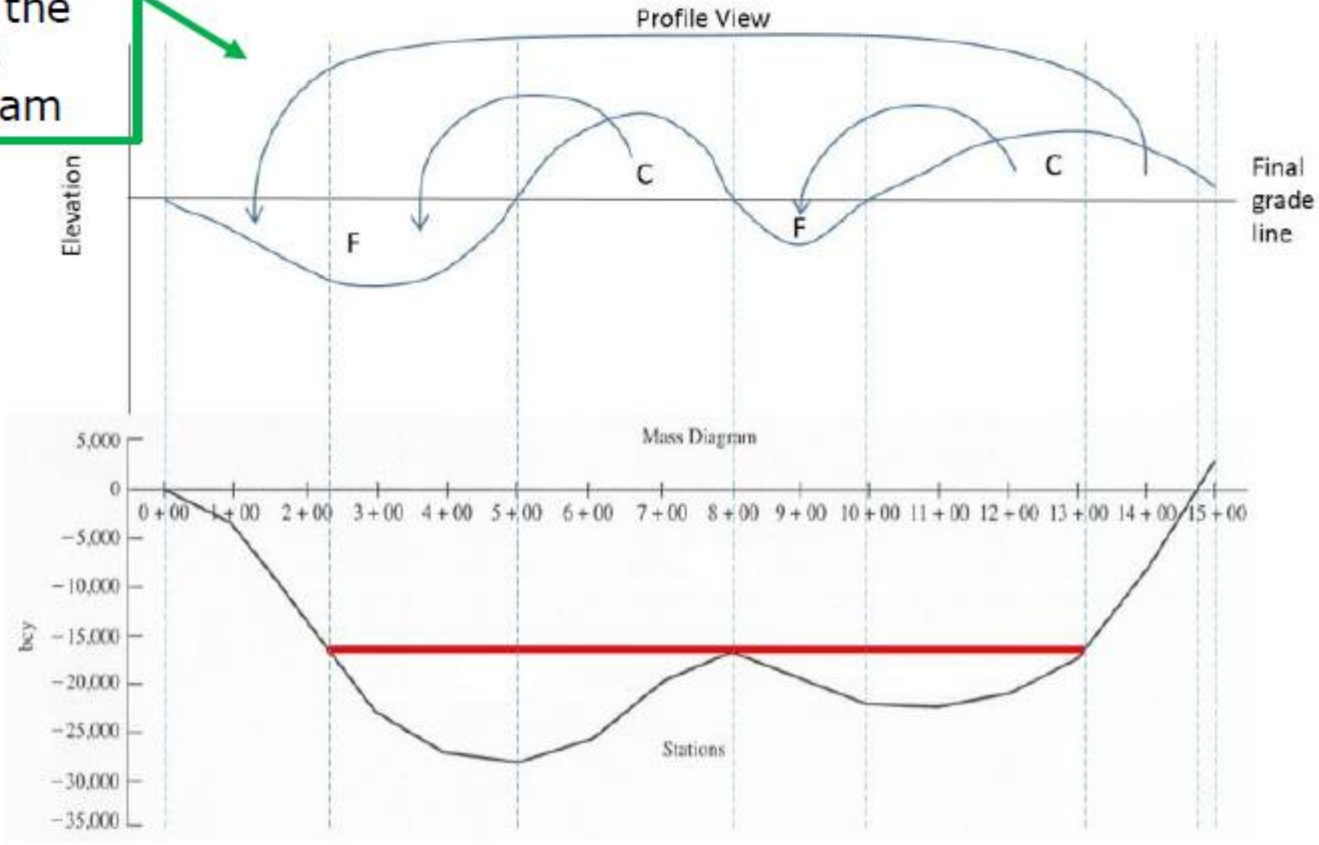




Source: Peurifoy, R. L., Schexnayder, C., Shapira, A., and Schmitt, R. L., Construction Planning, Equipment and Methods, edition 8, McGraw Hill, 2011.

Multiple cut and fill section (*continued*)

Profile view “imagined” from the mass diagram



Source: Peurifoy, R. L., Schexnayder, C., Shapira, A., and Schmitt, R. L., Construction Planning, Equipment and Methods, edition 8, McGraw Hill, 2011.