26 VOLUMES

Asterisks (*) indicate problems that have partial answers given in Appendix G.

26.1 Why is a roadway in cut normally wider than the same roadway in fill?

From Section 26.4, paragraph 2: The roadway is usually wider in cut than on fills to provide for drainage ditches.

26.2 Prepare a table of end areas versus depths of fill from 0 to 20 ft by increments of 2 ft for level sections, a 30-ft-wide level roadbed with side slopes of 1-1/2:1.

Area = $1.5h^2 + 30h$

Fill Depth (ft)	End Area (ft^2)
0	0
2	66
4	144
6	234
8	336
10	450
12	576
14	714
16	864
18	1026
20	1200

26.3 Similar to Problem 26.2, except use side slopes of 2-1/2:1.

Area = $2.5h^2 + 30h$

Fill Depth (ft)	End Area (ft^2)
0	0
2	70
4	160
6	270
8	400
10	550
12	720
14	910
16	1120

18	1350
20	1600

Draw the cross sections and compute V_e for the data given in Problems 26.4 through 26.7.

26.4* Two level sections 75 ft apart with center heights 4.8 and 7.2 ft in fill, base width 30 ft, side slopes 2:1.

$708\ yd^3 = 19{,}116\ ft^3$

End areas = 190.1 and 319.7 ft^2 computed as Area = $2h^2 + 30h$

26.5 Two level sections of 40-m stations with center heights of 4.24 and 3.25 m. in cut, base width 15 m, side slopes 3:1.

$2969.6\ m^3$

End areas = 117.5 m^2 and 80.4 m^2 computed as Area = $3h^2 + 15h$.

26.6 The end area at station $36 + 00$ is 265 ft^2. Notes giving distance from centerline and cut ordinates for station $36 + 60$ are C 4.8/17.2; C 5.9/0; C 6.8/20.2. Base is 20 ft.

$525.9\ yd^3 = 14{,}200\ ft^3$

x	y	−	+
−10	0		0
−17.2	4.8	−48	0
0	5.9	−101.5	119.2
20.2	6.8	0	68
10	0	0	0
−10	0	0	
		−149.5	187.2

End Area @ 36 + 60 = 168.3 ft^2

26.7 An irrigation ditch with b = 15 ft and side slopes of 2:1. Notes giving distances from centerline and cut ordinates for stations $52 + 00$ and $53 + 00$ are C 2.4/10.8; C 3.0; C 3.7/13.4; and C 3.1/14.2; C 3.8; C 4.1/14.2.

$290.3\ yd^3 = 7839\ ft^3$

x	y	−	+
−7.5	0		0
−2.4	10.8	−81	0
0	3	−7.2	40.2
13.4	3.1	0	23.25
7.5	0	0	0

x	y	−	+
−7.5	0		0
−14.2	3.1	−23.25	0
0	3.8	−54.0	54.0
14.2	4.1	0	30.75
7.5	0	0	0

−7.5	0	0	
		−88.2	63.45

−7.5	0	0	
		−77.2	84.7

End areas: 52 + 00 = 75.8 ft^2 and 53 + 00 = 81.0 ft^2

26.8 Why must cut and fill volumes be totaled separately?

From Section 26.2, last paragraph and Section 26.9, paragraph 3: To balance cuts and fills volumes so that materials is kept on site as much as possible and since contractors are generally paid for cuts only.

26.9* For the data tabulated, calculate the volume of excavation in cubic yards between stations 10 + 00 and 15 + 00.

Station	Cut End Area (ft^2)
10 + 00	263
11 + 00	358
12 + 00	446
13 + 00	402
14 + 00	274
15 + 00	108

<u>**6168.5 yd^3**</u>

Station	Cut End Area (ft^2)	Volume (yd^3)
10 + 00	263	
11 + 00	358	1150.0
12 + 00	446	1488.9
13 + 00	402	1570.4
14 + 00	274	1251.9
15 + 00	108	707.4

26.10 For the data listed, tabulate cut, fill, and cumulative volumes in cubic yards between stations 10 + 00 and 20 + 00. Use an expansion factor of 1.25 for fills.

	End Area (ft^2)	
Station	Cut	Fill
10 + 00	0	
11 + 00	168	
12 + 00	348	
13 + 00	371	
14 + 00	146	
14 + 60	0	0
15 + 00		142

16 + 00	238
17 + 00	305
18 + 00	247
19 + 00	138
20 + 00	106

	End Area (ft^2)		Volumes			
Station	Cut	Fill	Cut (yd^3)	Fill (yd^3)	1.25Fill (yd^3)	Cumulative (yd^3)
10 + 00	0					
11 + 00	168		311.1			311.1
12 + 00	348		955.6			1266.7
13 + 00	371		1331.5			2598.1
14 + 00	146		957.4			3555.6
14 + 60	0	0	162.2			3717.8
15 + 00		142		105.2	131.5	3586.3
16 + 00		238		703.7	879.6	2706.7
17 + 00		305		1005.6	1256.9	1449.7
18 + 00		247		1022.2	1277.8	171.9
19 + 00		138		713.0	891.2	−719.3
20 + 00		106		451.9	564.8	−1284.1

26.11 Calculate the section areas in Problem 26.4 by the coordinate method.

Areas: **190.1 ft^2** and **319.7 ft^2**

x	**y**	**−**	**+**
−15	0		0
−24.6	4.8	−72.0	118.1
24.6	4.8	−118.1	72.0
15	0	0	0
−15	0	0	
		−190.1	190.1

x	**y**	**−**	**+**
−15	0		0
−29.4	7.2	−108.0	211.7
29.4	7.2	−211.7	108.0
15	0	0	0
−15	0	0	
		−319.7	319.7

26.12 Compute the section areas in Problem 26.5 by the coordinate method.

Areas: **117.5 m^2** and **80.4 m^2**

x	y	−	+
−7.5	0		0
−20.22	4.24	−31.8	85.7
20.22	4.24	−85.7	31.8
7.5	0	0	0
−7.5	0	0	

x	y	−	+
−7.5	0		0
−17.25	3.25	−24.4	56.1
17.25	3.25	−56.1	24.4
7.5	0	0	0
−7.5	0	0	

−117.5 117.5 −80.4 80.4

26.13 Determine the section areas in Problem 26.7 by the coordinate method.

See solution to problem 26.7

26.14* Compute C_P and V_P for Problem 26.4. Is C_P significant?

$C_p = 3$ yd^3, $V_p = 705$ yd^3; represents on 0.3% of volume, so not significant.

By Equation (26.4): $C_p = \frac{75}{12(27)}(4.8-7.2)(39.6-44.4) = 2.7 \text{ yd}^3$

26.15 Calculate C_P and V_P for Problem 26.7. Would C_P be significant in rock cut?

$C_p = 1$ yd^3, $V_p = 290$ yd^3; represents on 0.34% of volume, so not significant.

By Equation (26.4): $C_p = \frac{100}{15(27)}(3.0-3.8)(23.4-28.4) = 1.0 \text{ yd}^3$

26.16 From the following excerpt of field notes, plot the cross section on graph paper and superimpose on it a design template for a 30-ft wide level roadbed with fill slopes of 2-1/2:1 and a subgrade elevation at centerline of 850.26 ft. Determine the end area graphically by counting squares.

HI = 845.69						
20 + 00 Lt	$\frac{5.2}{50}$	$\frac{4.8}{22}$	$\frac{6.6}{0}$	$\frac{5.9}{12}$	$\frac{7.0}{30}$	$\frac{8.1}{50}$

600.3 ft^2

```
Station: 20+00  Roadbed elevation:    850.260
  -39.03  -22.00    0.00   12.00   30.00   46.14   15.00  -15.00
  840.65  840.89  839.09  839.79  838.69  837.80  850.26  850.26
    Fill End Area = 600.3
```

26.17 For the data of Problem 26.16, determine the end area by plotting the points in a CAD package, and listing the area.

600.3 ft^2

26.18 For the data of Problem 26.16, calculate slope intercepts, and determine the end area by the coordinate method.

Slope intercepts at (-39.03, 840.65) and (46.14, 837.80)

Area = 600.3 ft^2; See Problem 26.16

26.19 From the following excerpt of field notes, plot the cross section on graph paper and superimpose on it a design template for a 40-ft wide level roadbed with cut slopes of 3:1 and a subgrade elevation of 1240.88 ft. Determine the end area graphically by counting squares.

HI = 1252.66 ft						
46 + 00 Lt	8.0 / 60	7.9 / 27	5.5 / 10	4.9 / 0	6.6 / 24	7.5 / 60

310.3 ft^2

```
Station: 46+00  Roadbed elevation:   1240.88
  -31.60  -27.00  -10.00    0.00   24.00   34.73   20.00  -20.00
 1244.75 1244.76 1247.16 1247.76 1246.06 1245.79 1240.88 1240.88
    Cut End Area = 310.3
```

26.20 For the data of Problem 26.19, calculate slope intercepts and determine the end area by the coordinate method.

Slope intercepts are (-31.60, 1244.75) and (34.73, 1245.79)

Area = 310.3 ft^2

From WOLFPACK

```
Station: 46+00  Roadbed elevation:   1240.88
  -31.60  -27.00  -10.00    0.00   24.00   34.73   20.00  -20.00
 1244.75 1244.76 1247.16 1247.76 1246.06 1245.79 1240.88 1240.88
    Cut End Area = 310.3
```

26.21* Complete the following notes and compute V_e and V_P. The roadbed is level, the base is 30 ft.

Station 89 + 00	C3.1 / 24.3	C4.9 / 0	C4.3 / 35.2
Station 88 + 00	C6.4 / 34.2	C3.6 / 0	C5.7 / 32.1

V_e = **761.8 yd^3 = 20,568.3 ft^3**; V_p = **759.1 yd^3**

89 + 00

x	y	−	+
0	4.9		172.5
35.2	4.3	0	64.5
15	0	0	0.0
−15	0	0	0.0
−24.3	3.1	−46.5	0.0
0	4.9	−119.1	
		−165.6	237.0

88 + 00

x	y	−	+
0	3.6		115.6
32.1	5.7	0.0	85.5
15	0	0.0	0.0
−15	0	0.0	0.0
−34.2	6.4	−96.0	0.0
0	3.6	−123.1	
		−219.1	201.1

Area of 88 + 00 = 210.1 ft^2 Area of 89 + 00 = 201.3 ft^2

$$C_p = \frac{100}{12(27)}(4.9 - 3.6)(59.5 - 66.3) = -2.7 \text{ yd}^3$$

26.22 Similar to Problem 26.21, except the base is 36 ft.

V_e = 816.0 yd^3; V_p = 813.3 yd^3

89 + 00

x	y	−	+
0	4.9		172.5
35.2	4.3	0	77.4
18	0	0	0.0
−18	0	0	0.0
−24.3	3.1	−55.8	0.0
0	4.9	−119.1	
		−174.9	249.9

88 + 00

x	y	−	+
0	3.6		115.6
32.1	5.7	0.0	102.6
18	0	0.0	0.0
−18	0	0.0	0.0
−34.2	6.4	−115.2	0.0
0	3.6	−123.1	
		−238.3	218.2

Area: 89+00: 212.4 ft^2

Area: 228.2 ft^2

$V_e = 22{,}030.8\ ft^3 = 816.0\ yd^3$

$$C_p = \frac{100}{12(27)}(4.9 - 3.6)(59.5 - 66.3) = -2.7 \text{ yd}^3$$

26.23 Calculate V_e and V_P for the following notes. Base is 30 ft.

12 + 90	$\frac{C6.4}{43.6}$	$\frac{C3.6}{0}$	$\frac{C5.7}{40.8}$
12 + 30	$\frac{C3.1}{30.4}$	$\frac{C4.9}{0}$	$\frac{C4.3}{35.2}$

V_e = 509.9 yd^3; V_p = 505.4 yd^3

12 + 90

x	y	−	+
0	3.6		146.9
40.8	5.7	0	85.5
15	0	0	0.0
−15	0	0	0.0
−43.6	6.4	−96	0.0
0	3.6	−157	
		−253	232.4

12 + 30

x	y	−	+
0	4.9		172.5
35.2	4.3	0.0	64.5
15	0	0.0	0.0
−15	0	0.0	0.0
−30.4	3.1	−46.5	0.0
0	4.9	−149.0	
		−195.5	237.0

Area = 242.7 ft^2;

Area = 216.2 ft^2

V_e = 13,766.7 ft^3 = 509.9 yd^3

$$C_P = \frac{60}{12(27)}(4.9-3.6)(65.6-84.4) = -4.5 \text{ yd}^3$$

26.24 Calculate V_e, C_P, and V_P for the following notes. The base in fill is 20 ft and base in cut is 30 ft.

46 + 00	$\frac{C3.4}{20.1}$	$\frac{C2.0}{0}$	$\frac{C0.0}{6.0}$	$\frac{F2.0}{13.0}$
45 + 00	$\frac{C2.2}{18.3}$	$\frac{0.0}{0}$	$\frac{F3.0}{14.5}$	

Cut: **V_e = 401.1 yd^3; C_p = 1.1 yd^3; V_p = 400 yd^3**

Fill: **V_e = 35.2 yd^3; C_p = −1.0 yd^3; V_p = 36.2 yd^3**

46 + 00 cut

x	y	−	+
0	2		12.0
6	0	0	0.0
−15	0	0	0.0
−20.1	3.4	−51	0.0
0	2	−40.2	
		−91.2	12.0

45 + 00 cut

x	y	−	+
0	0		0.0
−15	0	0.0	0.0
−18.3	22	−330.0	0.0
0	0	0.0	0.0
		−330.0	0.0

46 + 00: Cut area 51.6; Fill area 4

45 + 00: Cut area 165; Fill area 15

46 + 00 fill

6	0		0.0
13	2	12	20.0
10	0	0	0.0
6	0	0	
		12	20.0

45 + 00 fill

0	0		0
14.5	3	0	30
10	0	0	0
0	0	0	
		0	30

	ft^3	yd^3
Cut Volume	10830	401.1
Fill Volume	950	35.2

Cut: $$C_P = \frac{100}{12(27)}(0-2.0)(18.3-20.1) = 1.1 \text{ yd}^3$$

Fill: $C_P = \frac{100}{12(27)}(0-2.0)(14.5-13) = -1.0\ \text{yd}^3$

For Problems 26.25 and 26.26, compute the reservoir capacity (in acre-ft) between highest and lowest contours for areas on a topographic map.

26.25*

Elevation (ft)	860	870	880	890	900	910
Area (ft^2)	1370	1660	2293	2950	3550	4850

<u>**3.1136 ac-ft**</u>

Contour	Area	Volume (ft^3)
860	1370	
870	1660	0.34780
880	2293	0.45374
890	2950	0.60181
900	3550	0.74610
910	4850	0.96419
		3.11364

26.26

Elevation (ft)	1015	1020	1025	1030	1035	1040
Area (ft^2)	1815	2097	2391	2246	2363	2649

<u>**2.6001 ac-ft**</u>

Contour	Area	Volume (ft^3)
1015	1815	
1020	2097	0.44904
1025	2391	0.51515
1030	2246	0.53225
1035	2363	0.52904
1040	2649	0.57530
		2.60078

26.27 State two situations where prismoidal corrections are most significant.

From Section 26.8, paragraph 1: When paying for expensive cuts, such as in rock.

26.28* Distances (ft) from the left bank, corresponding depths (ft), and velocities (ft/sec), respectively, are given for a river discharge measurement. What is the volume in ft^3/sec? 0, 1.0, 0; 10, 2.3, 1.30; 20, 3.0, 1.54; 30, 2.7, 1.90; 40, 2.4, 1.95; 50, 3.0, 1.60; 60, 3.1, 1.70; 74, 3.0, 1.70; 80, 2.8, 1.54; 90, 3.3, 1.24; 100, 2.0, 0.58; 108, 2.2, 0.28; 116, 1.5, 0.

419.3 ft^3/s

Distance	Depth	Area	Velocity	V_{avg}	Discharge
0	1.0		0.00		
10	2.3	16.5	1.30	0.65	10.73
20	3.0	26.5	1.54	1.42	37.63
30	2.7	28.5	1.90	1.72	49.02
40	2.4	25.5	1.95	1.93	49.09
50	3.0	27.0	1.60	1.78	47.93
60	3.1	30.5	1.70	1.65	50.33
70	3.0	30.5	1.70	1.70	51.85
80	2.8	29.0	1.54	1.62	46.98
90	3.3	30.5	1.24	1.39	42.40
100	2.0	26.5	0.58	0.91	24.12
108	2.2	16.8	0.28	0.43	7.22
116	1.5	14.8	0.00	0.14	2.07
					419.3