CHAPTER 8

EARTHWORK

INTRODUCTION

Earthwork computations can be performed either manually or with the computer. It is Department policy to utilize modern computer techniques and procedures for earthwork computations whenever possible.

DEFINITIONS

The following is a list of excavation types and related items and bid items that can be used:

Unclassified Excavation: Excavations including but not limited to the following: normal excavation (includes RC Box Culvert Installation Excavation, Deep Pipe & RC Box Culvert Removal Excavation, Added Diversion Excavation and Unstable Material Excavation), Undercut Excavation, and Select Subgrade Topping Excavation. Excavations not included in Unclassified Excavation include Muck Excavation, Pipe Culvert Undercut, Borrow Excavation, Contractor Furnished Borrow and Option Borrow Excavation.

Unclassified/Rock Excavation: If rock is expected to be encountered the Unclassified/Rock Excavation bid item will be used instead of the Unclassified Excavation bid item. Rock consists of a sound and solid mass of inplace mineral matter of such hardness and texture that it cannot be effectively loosened or broken down by ripping in a single pass with a tractor mounted hydraulic ripper. The ripper shall be one digging point of standard manufacturer's design and adequately sized for use with and propelled by a later model crawler-type tractor. The tractor shall be rated between 370 and 460 net flywheel horsepower, operated in low gear with sufficient downward force on the ripper. The Materials and Surfacing (Geology) letter will state when to use the unclassified/rock excavation bid item and the Materials and Surfacing (Geology) Office will draw the seismic data on the final set of cross sections. Unclassified/Rock Excavation includes all the excavations as listed above under Unclassified Excavation, along with rock excavation. Excavations not included in Unclassified/Rock Excavation include Muck Excavation, Pipe Culvert Undercut, Borrow Excavation, Contractor Furnished Borrow and Option Borrow Excavation.

Muck Excavation: Excavation of saturated soils and organic matter which require work or equipment not normally required for Unclassified Excavation. The Materials and Surfacing (Geology) letter will state the areas of Muck Excavation. Muck excavation is typically wasted. This item is a separate bid item.

Select Subgrade Topping Excavation: Material provided to replace unsatisfactory material in the upper earth subgrade. Areas that require select subgrade topping material and the areas from which Select Subgrade Topping Excavation is obtained are provided in the Soils letter from Materials and Surfacing. This item is a separate bid item as well as being included in the Unclassified Excavation.

Undercutting: Excavating, replacing and compacting the material immediately below the finished subgrade surface. The Soils letter from Materials and Surfacing states locations and depths to be removed. This quantity is a separate bid item as well as being included in the Unclassified Excavation.

Contractor Furnished Borrow: Material furnished by the Contractor, from a pit or other source. Typically Contractor Furnished Borrow is used when the amount of borrow needed is small or the State can't obtain the borrow. The decision of which type of borrow to obtain is a joint decision made with the Materials and Surfacing Office and the Region Materials Engineer. This item is a separate bid item.

Borrow Unclassified Excavation: Material, furnished by the State, from a pit or other source. The Contractor must use this material. This item is a separate bid item.

Option Borrow Excavation: Material, furnished by the State, from a pit or other source. The Contractor may use this material at his option, or he may find a source of his own. This item is a separate bid item.

Deep Pipe/Box Culvert Removal Excavation: Excavation of material required to remove a pipe or RCBC. Applies where existing pipe or RCBC depths are 10' (3m) or greater as measured from the flow line to the undercut elevation or to the existing finished elevation (whichever is less). This quantity is included in the Unclassified Excavation and is not a bid item.

Reinforced Concrete Box Culvert Installation Excavation: Excavation of material required to construct a **new** box culvert. See Figure 8-2. This quantity is included in the Unclassified Excavation and is not a bid item. Do not use for installation of cattle passes if the cattle pass is bid with "furnish" and "install" bid items.

Unstable Material Excavation: Excavation of unstable material. The Materials and Surfacing (Geology) letter will state locations and depths to be removed. This quantity is included in the Unclassified Excavation and is not a bid item. Unstable material excavation is typically used in the embankment.

Out-of-Balance Excavation: Material obtained from waste generated from excavation from other balances. The quantity of Out-of-Balance Excavation is paid for once as Unclassified Excavation.

Contaminated Excavation: Excavation of petroleum contaminated material. Information such as contaminated material location, possible disposal site, etc. will need to be supplied in a plan note. Consult with the Environmental Office for additional guidance whenever there is a possibility of encountering contaminated material. This item is a separate bid item.

Pipe Culvert Undercut: Removal of unstable material and rock, either in ledge or boulder formation, below the bedding grade of pipe or plate pipe culverts. This item is a separate bid item.

Salvage Material: Removal of in place asphalt mix and granular material from the existing roadbed to be used as part of the new surfacing base. This quantity a separate bid item as well as being included in the Unclassified Excavation.

Shrinkage Factor: The material placed in roadway embankments usually is compacted more densely than it was in its natural state. In effect each cubic yard of excavation "shrinks" slightly by the time it is compacted in an embankment. This shrinkage is compensated for in the calculation by increasing the volume of embankment to represent the volume of "natural state" material required.

Conversely, solid rock and large stones will "swell" when transferred from their natural state to a constructed embankment. Swell is compensated for in the calculations by slightly reducing the theoretical volume of embankment, thus reflecting the actual volume of "natural state" material needed.

The Soils Report from Materials and Surfacing will indicate the proper percentage to be used for shrinkage or swell. Until the report is available, an “estimated” shrinkage can be used (typically 40%) for preliminary design.

Waste: Material which will not be used in the embankment. This is excess excavation material or undesirable material which shouldn’t be used in the embankment. Muck excavation is typically wasted. This material is typically wasted at a location provided by the Contractor as approved by the Engineer. Not a bid item.

Internal Balances: If the distance between balance points is less than 8-10 stations (250-300m), then include this balance in one of the adjacent balances. These closely spaced balance points are known as internal balances. Balance points should be as frequent as one half mile or less (800m) desired and one mile (1600m) maximum.

Haul: The product obtained by multiplying the number of units of excavation removed from its original position by the mean distance hauled. The distance between the center of gravity of the excavation and the center of gravity of the embankment shall be the haul distance. Not a bid item. No haul is figured for Contractor Furnished Borrow (because the location of the source is not known). Types of Haul are:

Haul: Estimated quantity (CuYdSta) for moving unclassified excavation material to the locations where it is needed throughout the earthwork balance.

Out-of-Balance Haul: Estimated quantity (CuYdSta) for moving Out-of-Balance Excavation material from one earthwork balance to another earthwork balance.

Option Borrow Haul: Estimated quantity (CuYdSta) for moving option borrow excavation material from the centerline mainline station listed in the Table of Borrow Pits to the locations where it is needed throughout the earthwork balance.

Borrow Haul: Estimated quantity (CuYdSta) for moving borrow excavation material from the centerline mainline station listed in the Table of Borrow Pits to the locations where it is needed throughout the earthwork balance.

Dead Haul: Estimated quantity (CuYdSta) for moving borrow excavation material or option borrow excavation material from the borrow or option borrow site to the centerline mainline station listed in the Table of Borrow Pits.

Extra Haul: Haul which is more than the necessary haul or Average Haul. In regards to Extra Haul compensation, no Extra Haul compensation will be made for haul distances of less than 5 stations. When payment for "Extra Haul" is authorized, the distance used for "Extra Haul" calculations will be that in excess of 5 stations.

For Purpose of Extra Haul Computations:

Average Haul = Haul + Out of Balance Haul/(Unclassified Excavation – Waste(this is waste from regular excavation, not muck waste)) = xxxx/xxxx = xx.x Sta

Average Option Borrow Haul = (Option Borrow Haul + Dead Haul)/Total Option Borrow Excavation = xxxx/xxxx = xx.x Sta

Average Borrow Haul = (Borrow Haul + Dead Haul)/Total Borrow Excavation = xxxx/xxxx = xx.x Sta

Match Line: Match lines are shown in plan view when cross sections from separate alignments intersect. The purpose of the match lines is to avoid duplication or omission of earthwork quantities. See Chapter 13 – Interchanges for additional information.

EARTHWORK COMPUTATIONS - COMPUTER METHOD

Example of Earthwork Quantities with Moisture & Density Control (Undercut)

Baseline Station	Cut Shrink/ Swell Factor	Station Cut (Sq. Ft.)	Station Cut (Cu. Yd.)	Adjusted Station Cut (Cu. Yd.)	Fill Shrink/ Swell Factor	Station Fill (Sq. Ft.)	Station Fill (Cu. Yd.)	Adjusted Station Fill (Cu. Yd.)	Cut (Cu. Yd.)	Added Quantities Adjusted Cut (Cu. Yd.)	Fill (Cu. Yd.)	Adjusted Fill (Cu. Yd.)
136+00.00	1.00	2845.69	6322	6322	1.200	182.81	0	0	- 51	- 51	20	24
		Moisture & Density		677			677	826				
		Station Total:		6999				826		-51		24
137+00.00	1.00	0.0	7231	7231	1.200	0	0	0	- 27	- 27	0	0
		Moisture & Density		350			350	424				
		Station Total:		7581				424		-27		0
BALANCE POINT TOTALS – Distance from previous station 53.03												
	Cut		54889	54889[A]		Fill	41188[B]	49426	-805[C]	-805	1490[D]	1788
	Moisture and Density			9233			9233	11079				
	Balance Total			64122			50421	60505				

A = Normal Cross Section Excavation
B = Normal Cross Section Embankment
C = Miscellaneous Additional Excavation (Example-Channel Change, Outlet Ditch, Intersecting Road Excavation, Unstable Material, Muck Excavation (rare case), Salvage Material above undercut, Borrow, Option Borrow, Contractor Furnished Borrow)
D = Miscellaneous Additional Embankment (Example-Entrances, Intersecting Roads, Ditch Blocks, Salvage Material below undercut, Muck Excavation (to fill void), Unstable Material (to fill void))

Undercut is listed as Moisture & Density (MDC).

Added Quantities: Fill

1. Miscellaneous additional embankment such as entrances, intersecting roads, ditch blocks, muck void and unstable material excavation void is added as a plus(+) fill at those stations.

2. Salvage material located below the bottom of the undercut (fill section) is added as a plus(+) fill between those stations (to fill void).

3. Additional undercut that is not included in the Moisture and Density quantity is added as a plus(+) fill between those stations (also an Added Cut quantity).

Added Quantities: Cut

1. Miscellaneous additional excavation such as channel change, outlet ditch, intersecting road excavation, unstable material excavation is added as a plus(+) cut at those stations. In rare situations unstable material and muck excavation will be added as a minus(-) cut.

2. All Borrow types are added as a plus(+) cut at those stations.

3. Salvage material located above the bottom of the undercut (cut section) is added as a minus(-) cut between those stations.

4. Waste is added as a minus(-) cut when needed. This waste is NOT muck or unstable material.

5. Additional undercut that is not included in the Moisture and Density quantity is added as a plus(+) cut between those stations (also an Added Fill quantity).

Procedure for Muck and Unstable Material Added Quantities

1. Muck or unstable material located below the proposed roadway embankment line, refer to following:

If use material in Embankment	∗ If Waste material
Unstable Material Added as a plus (+) fill and added as a plus (+) cut.	Unstable Material Added as a plus (+) fill. When figuring earthwork computations, add this amount to the excavation.
Muck: (Muck is rarely used in embankment) Added as a plus (+) fill and added as a plus (+) cut. When figuring earthwork computations subtract this amount from the excavation and add to the muck excavation.	Muck: Added as a plus (+) fill. When figuring earthwork computations add this amount to the muck excavation.

2. Muck or unstable material located above the proposed roadway excavation line, refer to following (this is rare, especially for Unstable Material):

If use material in Embankment	∗ If Waste material
Unstable Material Do nothing.	Unstable Material Added as a minus (-) cut. When figuring earthwork computations add this amount to the excavation.
Muck: Do nothing. When figuring earthwork computations subtract this amount from the excavation and add it to the muck excavation.	Muck: Added as a minus (-) cut. When figuring earthwork computations add this amount to the muck excavation.

∗ Waste is material which will not be used in the embankment.

EARTHWORK BALANCE FORMAT

Some projects may require a combination of the balance notes shown, but the general format should remain the same.

Earthwork Balance Format

Excavation		Embankment
Undercut	_____	+XX %_____
	Total	Undercut
		+XX %_____
		Total

Haul _____ CuYdSta

****

Excavation = A + C

Undercut = Moisture and Density

Note: If your undercut is being replaced with subbase or some other material, there will be no undercut for the replacement. The replacement will be paid for by the replacement item (i.e. Subbase or Select Topping).

Embankment = B + D

Undercut = Same as the Excavation side

____ %= Percent Shrinkage= $\frac{\text{(Excavation + Undercut)}}{\text{(Embankment+ Undercut)}}$ X (100) - (100) (Rounded to the nearest tenth)

Haul = measured from mass haul diagram = xx CuYdSta
(Round up to the nearest 100 CuYdSta)

Example 8-1 Earthwork Balance with Muck

Excavation	6247	Embankment	3247	
Undercut	4254	+40%	1298	4545
Muck	1267	Undercut	4254	
	11768	+40%	1702	5956
		Waste		1267
				11768

Haul = 141,300 CuYdSta
Waste is Muck Excavation to be disposed of at a site approved by the Engineer.

	Station Cut (CuYd)	Adjusted Station Cut (CuYd)		Station Fill (CuYd)	Adjusted Station Fill (CuYd)	Added Quantities Cut (CuYd)	Fill (CuYd)
Balance Point Totals – Distance from previous station			19.6600				
Cut	7778	7778 [A]	Fill	1625 [B]	2276	-1531 [C]	1622 [D]
Moisture and Density		4254		4254	5955		
Balance Total		12032		5879	8231		

Excavation = A + C
= 7778 + (-1531) = 6247

Undercut = 4254

Embankment = B + D
= 1625 + 1622 = 3247

Undercut = 4254

% Shrink = $\frac{6247+4254}{3247+4254} \times 100 - 100 = 40\%$

Haul = 141,240 → 141,300 CuYdSta

Earthwork Balance Format with Option Borrow & Waste

Excavation		Embankment
Undercut		+ %
Option Borrow	_____	Undercut
	Total	+ %
		Waste _____
		Total

Haul ___ CuYdSta
Option Borrow Haul ___ CuYdSta
Dead Haul ___ CuYdSta
Waste is excess material to be disposed of at a site approved by the Engineer.
Option Borrow may be obtained from Pit #
****

Excavation = A + C + Waste - Option Borrow

Note: In this case, waste is added as a - cut in the added quantities. This waste is NOT muck, unstable or chalk rock.

Undercut = Moisture and Density

Note: If your undercut is being replaced with subbase or some other material, there will be no undercut for the replacement. The replacement will be paid for by the replacement item (i.e. Subbase or Select Topping).

Option Borrow= C - (Miscellaneous Excavation - Waste + -Salvage in cut)

Embankment = B + D

Undercut = Same as the Excavation side

Waste = (Regular Excavation Waste)

$$\_\_\_\ \% = \frac{\text{Excavation + Undercut + Opt Borrow - Waste}}{\text{Embankment + Undercut}} \times (100) - (100)$$

Haul	= CuYdSta
	Note: (Round up to the nearest 100 CuYdSta)
Option Borrow Haul	Refer to Figure 8-1.
Dead Haul	Refer to Figure 8-1.

Borrow is handled the same as Option Borrow.
Contractor Furnished Borrow is handled the same as Option Borrow except that no borrow haul is calculated and no Pit # is given.

Example 8-2 Earthwork Balance with Option Borrow

Excavation	9127	Embankment	135405	
Undercut	1969	+20.6%	27921	163326
Option Borrow	154605	Undercut	1969	
	165701	+20.6%	406	2375
				165701

Haul, Option Borrow Haul and Dead Haul: Refer to Figure 8-1 (Mass Haul Diagram).

Option Borrow may be obtained from Pit # ___.

	Station Cut (CuYd)	Adjusted Station Cut (CuYd)		Station Fill (CuYd)	Adjusted Station Fill (CuYd)	Added Quantities Cut (CuYd)	Fill (CuYd)
Balance Point Totals – Distance from previous station 66.3000							
Cut	9427	9427 [A]	Fill	131405 [B]	170827	167189 [C]	4000 [D]
Moisture and Density		1969		1969	2560		
Balance Total		11396		133374	173387		

Excavation = A + C - Option Borrow
= 9427+167189 - 167489 = 9127

Undercut = 1969

Option Borrow = C - (Misc Exc + - Salvage in cut)
= 167189 - (0 - 300) = 167489

= In this case the mainline shrink is 30% and the borrow pit shrink is 20%. To find the correct Borrow Quantity necessary the weighted averaged is figured as follows:

$$\frac{\text{Option Borrow from above(167489) x 1.2 (20\% shrink pit shrinkage)}}{\text{1.3 (30\% mainline shrinkage)*}} =$$

= 154605 yd^3

*Note: If the mainline shrinkage for the balance contains more than one shrinkage value (i.e. 20% & 30%) the weighted average mainline shrinkage must be calculated to use here. One way of calculating this shrinkage is by following the shrinkage calculation shown in the previous example for "Earthwork Balance Format with Option Borrow and Waste". For this shrinkage calculation use the "opt borrow" number that is coded in as an added quantity.

Example 8-2 Earthwork Balance with Option Borrow (continued)

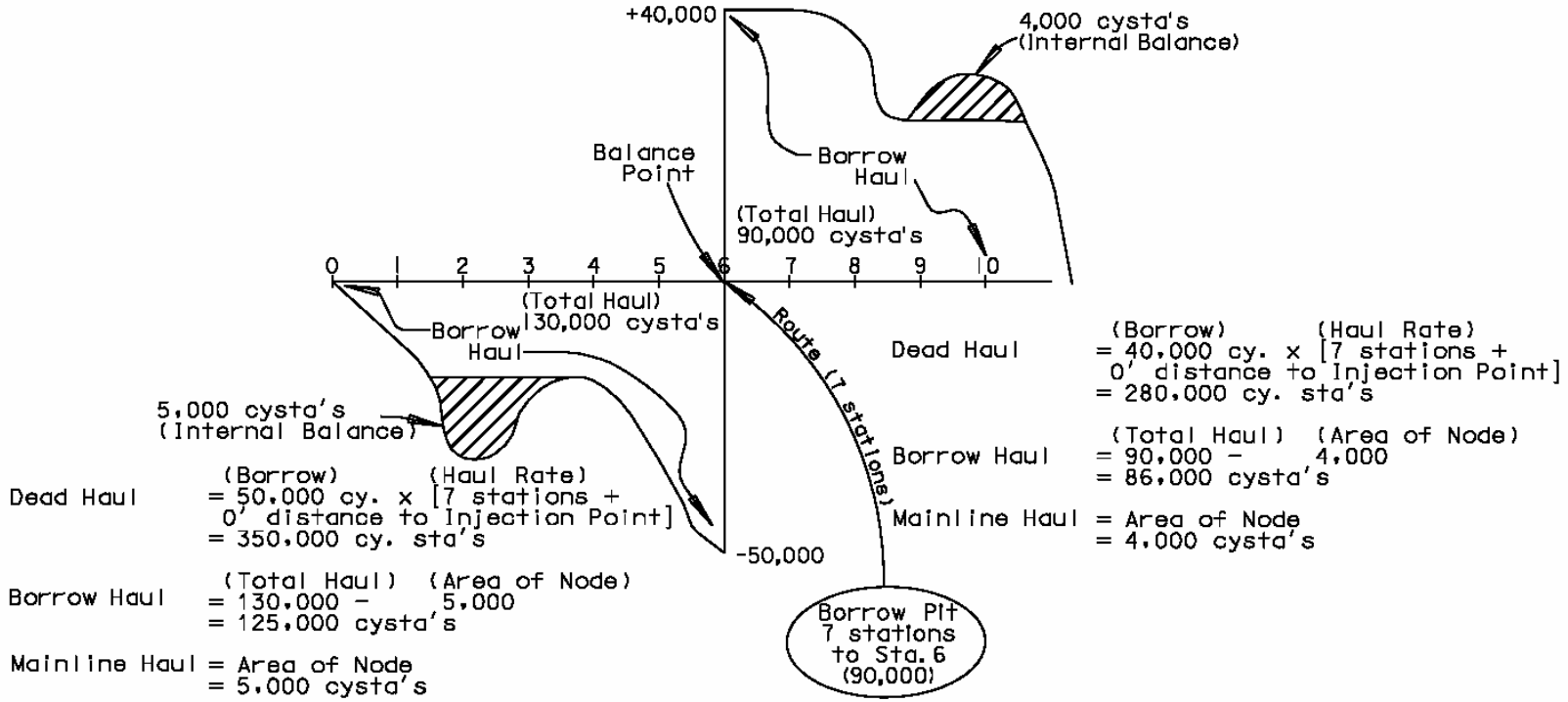
Embankment = B + D
= 131405 + 4000 = 135405

Undercut = 1969

$$\% \text{ Shrink} = \frac{\text{Excacation+Undercut+OptionBorrow-Waste*}}{\text{Embankment+Undercut}} = \frac{9127+154605+1969}{135405+1969} = 20.62\%$$

*Waste is regular excavation waste, not muck excavation waste

Haul = Refer to Figure 8-1.



If a horizontal line intersects the mass curve at two points, the excavation and embankment are in balance(equal in amount) between those points

Figure 8-1 Mass Haul Diagram

Earthwork Balance Format with Select Topping

Excavation		Embankment
Undercut		+ %
Undercut Select Topping		Undercut
Select Topping Excavation	_____	+ %
	Total	Select Topping
		+ %
		_____
		Total

Haul ___ CuYdSta
Select Topping Haul ____ CuYdSta

Undercut Select Topping is to be used between _____ to _____ outside of the shoulder limits (or below a certain depth whichever is recommended on the Materials and Surfacing letter).

Select Topping Excavation is to be obtained from ____ to ____. (And if pertinent)___ CuYd Select Topping from ____ in the (next or previous) balance to be exchanged with the same amount of dirt from this balance.

****

Excavation = A + C - (Select Topping Excavation)

Undercut = Undercut - (Undercut Select Topping)

Embankment = B + D - Select Topping +Undercut Select Topping (Note: All are w/o shrink)

Undercut = Same as the Excavation Side

When Moisture & Density Control is used:

A = Normal Cross Section Excavation
B = Normal Cross Section Embankment (No Shrinkage Added)
C = Misc Add Exc + (-Salvage Material Above Subgrade)
D = Misc Add Emb + Salvage Material Below Subgrade

Example 8-3 Earthwork Balance with Select Topping

Excavation	46730	Embankment	38553	
Undercut	7330	+22%	8469	47022
Undercut Select Topping	1903	Undercut	7330	
Select Topping Excavation	7354	+22%	1611	8941
	63317	Select Topping	6028	
		+22%	1325	7354
				63317

	Station Cut (CuYd)	Adjusted Station Cut (CuYd)		Station Fill (CuYd)	Adjusted Station Fill (CuYd)	Added Quantities Cut (CuYd)	Fill (CuYd)
Balance Point Totals – Distance from previous station 53.03							
Cut	54889	54889 [A]	Fill	41188 [B]	49426	-805 [C]	1490 [D]
Moisture and Density		9233		9233	11079		
Balance Total		64122		50421	60505		

Undercut Select Topping is top 2' of 3' Undercut in areas where there is Select Topping and shall be used below the top 2' of earth subgrade and is included in the Bid Item Undercutting.

Select Topping Excavation shall be obtained at the following locations: Sta. 124 +/- to 127 +/-

(If Select Topping is obtained from another balance use the following:) From Sta.___+__ to ___+__ in previous balance exchange 7354 CuYd Select Topping with same amount of dirt from this balance. The corresponding haul is included in the Select Topping Haul.

Steps For Calculating Numbers:
1 - Calculate Select Topping
2 - Calculate (Undercut Select Topping)
3 - Calculate Undercut
4 - Calculate Excavation & Embankment

Excavation Side

Excavation = A + C - (Select Topping Excavation)
= 54889 + (-805) - 7354 = 46730 CuYd

Example 8-3 Earthwork Balance with Select Topping (continued)

Undercut = Undercut - (Undercut Select Topping)
= 9233 - 1903 = 7330 CuYd

Undercut Select Topping = Volume that warrants select topping that is in the undercut
= Volume can be found by doing another earthwork run and changing the undercut depth to the depth of select topping
= 1903 CuYd (From 2' Undercut Run)

Select Topping Excavation = Quantity needed to fill select topping volume plus the shrinkage (method for calculation is explained below as Select Topping on Embankment Side)
= 6028(1.22) = 7354 CuYd

Note: Undercut Select Topping + Undercut = original undercut quantity

Embankment Side

Embankment = B + D – Select Topping +Undercut Select Topping (Note: All are w/o shrink)
= 41188 +1490 - 6028 + 1903 = 38553 CuYd

Undercut = Same as the Excavation side
= 7330 CuYd

Select Topping = Volume needed for replacement
= Cross sectional area of typical section needing select topping times length recommended for select topping in materials letter (Cross sectional area may be found by calculating the area of the typical section to a depth of the select topping)
= 108.50 Sq Ft X 1500 Ft = 6028 CuYd

Select Topping Haul

Select Topping Haul = Select Topping. Excavation Source X Distance (**See Note Below**)
Distance = Centroid of Select Topping Excavation Source to Centroid of Select Topping Area

Note: If the Select Topping Excavation Source does not fall within the Select Topping area, double the Select Topping Haul)

Estimate of Quantities

Excavation = Total from exc side of balance notes + Salvage = 64122 CuYd
Undercut = Undercut + Undercut Sel. Top. (Exc Side) = 9233 CuYd
Sel Sub Top = Total Sel Top + Shrink (Emb Side) = 7354 CuYd

TRAFFIC DIVERSION (On Site Detour)

The following is the earthwork format to be used for a Traffic Diversion. Refer to Chapter 16 - Miscellaneous for further details on how to design a Traffic Diversion.

Information Only

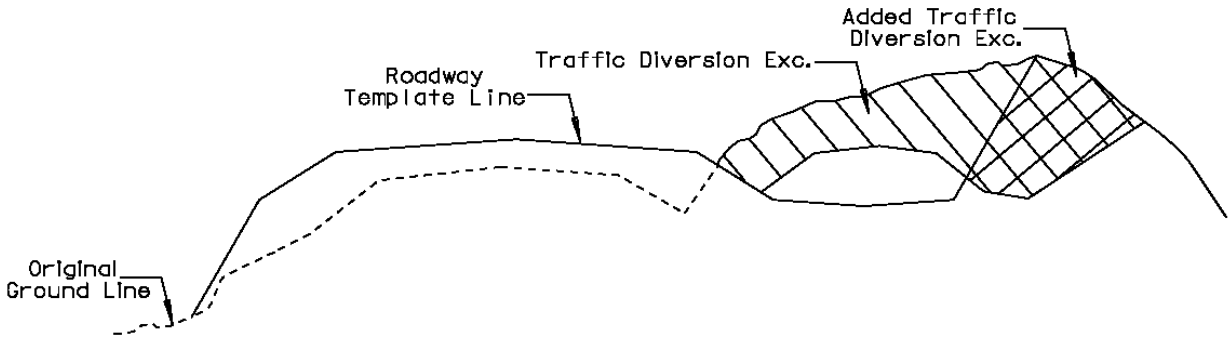
Traffic Diversion Excavation	Traffic Diversion Embankment
Added Traffic Diversion Excavation	+ %
Traffic Diversion Borrow	Riprap Class XX _____
Riprap Class XX _____	Total
Total	

Traffic Diversion Excavation is excavation required to build the Traffic Diversion that is located inside of the design cross section work limits and is included in the mainline quantities.

Added Traffic Diversion Excavation is excavation required to build the Traffic Diversion that is located outside of the design cross section work limits. This quantity is added to the **Unclassified Excavation** bid item as shown in the **Table of Excavation Quantities By Balances** note.

Traffic Diversion Borrow is obtained from Mainline Excavation (and/or Borrow Source) outside of the Traffic Diversion cross section work limits and is included in the mainline quantities.

Riprap Class XX is the material needed for the Traffic Diversion that is below the ordinary high water mark as defined by the Corp of Engineers (404 Permit). The ordinary high water mark information is obtained from the Hydraulics Office. The Class of riprap used is usually the same as that used around the structure for which the Traffic Diversion is being built. That way when the Traffic Diversion is removed the riprap can be reused for the structure riprap. Verify that this can be done with the Office of Bridge Design and if this is the case, adjust notes and quantities accordingly.



ESTIMATE OF QUANTITIES FOR BID ITEMS

Unclassified Excavation = Excavation + Undercut + Undercut Select Topping + Select Topping Excavation + Salvage Material + Added Traffic Diversion Excavation + Deep Pipe & RCBC Removal Excavation + RCBC Installation Excavation + Topsoil(not including option borrow or borrow pit topsoil)

The Unclassified Excavation quantities shall be placed in a table format.

Undercutting = Total Undercut from the balances (no shrinkage). An Undercut Table is shown as station to station for areas which have undercut. In long areas of continuous undercut break the table into ranges not exceeding 3000' in length.

Note: Make sure the total amount from the Table of Undercut agrees with the Table of Excavation Quantities by Balances.

Option Borrow Excavation = Option Borrow Quantity + Borrow Pit's Topsoil

Borrow Unclassified Excavation = Borrow Quantity + Borrow Pit's Topsoil

Note: The topsoil is obtained from the borrow pit sheet.

Contractor Furnished Borrow = Borrow Quantity(no topsoil is included)

Note: The Contractor shall obtain the borrow at an Engineer approved source.

Select Subgrade Topping = Total Select Topping (+ shrinkage) from embankment side of balance.

Water for Embankment =

$$\frac{\text{(Total Embankment(including shrink) - Waste)(Water Rate per Cu.Yd.)}}{1000}$$

Note: If the water is less than 100 MGAL it is absorbed in the bid item for Unclassified Excavation.

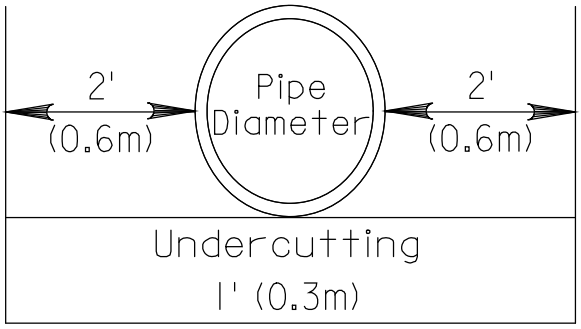
Salvage & Stockpile Asphalt Mix & Granular Base Material =

Salvage Material (Cu Yd) x 1.89 Ton/Cu Yd
(Make sure this quantity agrees with the quantity in the Surfacing plans)

Salvage Material (Cu Yd) = Length of existing highway from which salvage material is being removed (subtract out bridge length) X CuYd/Sta of salvage material (from Materials Letter). This quantity (CuYd) will be shown in the "Salvage and Stockpile Asphalt Mix and Granular Base Material" note. This quantity (CuYd) will also be added to the bid item UNCLASSIFIED EXCAVATION as shown in the "Table of Excavation Quantities by Balances" note. For finaling purposes the Salvage quantity is broken down into quantities from fill sections, cut sections and from off-alignment roadways and obliterated roads. The Salvage quantity is not shown in the balance notes. If the existing surfacing will not be salvaged then it is handled just like regular excavation.

PIPE CULVERT UNDERCUTTING

The illustration below is derived from the South Dakota Standard Specifications for Roads and Bridges.



Example of factor in Table 8-1:

$$\frac{(36"/12" + 8"/12 + 4) \times 1.0}{27} = 0.2840 \text{ CuYd/Ft}$$

The following is an example of calculating the undercutting for a pipe:

36" x 82' RC Pipe

[82 + 2(8)(for two flared ends)]0.2840 = 27.8320 Round up to 28 CuYd

On all cross pipe 36” in diameter and greater tabulate undercut quantities for each pipe by using the following on a per Linear Foot basis (Including Flared End Sections). **Storm sewer is not undercut unless specified in the Soils letter received from Materials and Surfacing.**

Table 8-1 provides culvert undercut quantities per foot to be used for calculations.

Table 8-1 Culvert Undercut Quantities Data

Diameter (In)	FE Length (Ft)	Round Pipe (CuYd/Ft.)	FE Length (Ft)	Arch Pipe (CuYd/Ft.)
36	8	0.2840	8	0.3110
42	8	0.3056	8	0.3337
48	8	0.3272	8	0.3596
54	8	0.3488	8	0.3827
60	8	0.3704	8	0.4105
66	8	0.3920	8	--
72	8	0.4136	8	0.4630
78	9	0.4352	9	--
84	9	0.4568	9	0.5123
90	9	0.4784	9	--

Table 8-1 is derived from the Standard Plates for Round Pipe, Arch Pipe and RCP Flared Ends . The Flared Ends are rounded to the nearest foot. The standard bid item is UNDERCUTTING CULVERT.

EXCAVATION FOR DEEP PIPE & RCBC REMOVAL & RCBC INSTALLATION

See previous definitions for when to use these excavation types. Figure 8-2 shows the limits of excavation.

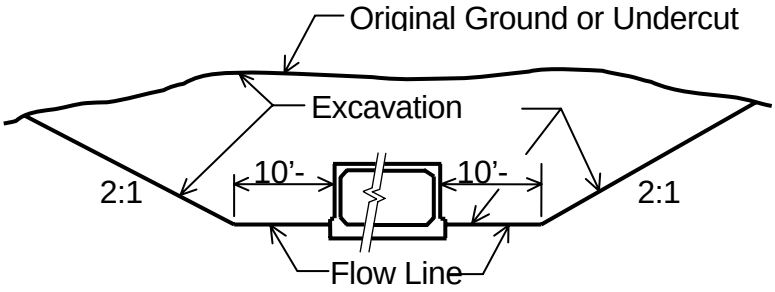


Figure 8-2 Limits of Unclassified Excavation for Deep Pipe or RCBC.

EARTHWORK NOTES AND TABLES

For final plans general notes and tables use the “TABLE OF EXCAVATION QUANTITIES BY BALANCES” note located at the SDDOT Engineering/Design Services ‘Downloadable files’ web site http://www.sddot.com/business/design/files/Default.aspx under ‘Plan Notes / Section B – Grading Notes’.

EARTHWORK COMPUTATIONS - MANUAL METHOD

Note: Most of the procedures in this section also apply to the computer method.

On certain types of projects manual computations of earthwork quantities is more satisfactory than using the computer. These steps are involved:

- Using the cross sections as developed in Chapter 7 - Cross Sections, determine end areas of cut and fill from cross sections.
- Compute volumes of excavation and embankment with the average end area method.
- Plot mass diagram and compute haul.

Cross Section End Areas

The end areas to be determined are defined by the groundline and the template line as depicted in Figure 8-3.

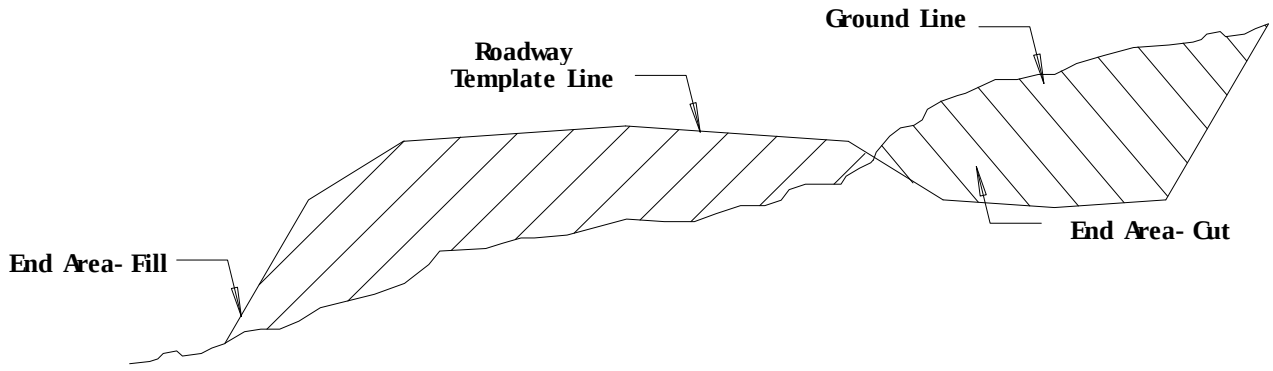


Figure 8-3 Groundline and Template Line Relationship

In cut areas, normal excavation, undercutting, select topping and select material shall be figured separately when required by the Soils Letter received from Materials and Surfacing Letter.

Subbase quantities should not be included in fill areas (See Figure 8-4). Subbase quantities should be included in cut areas (See Figure 8-5). Quantities of subbase material will be calculated separately by the Surfacing Office.

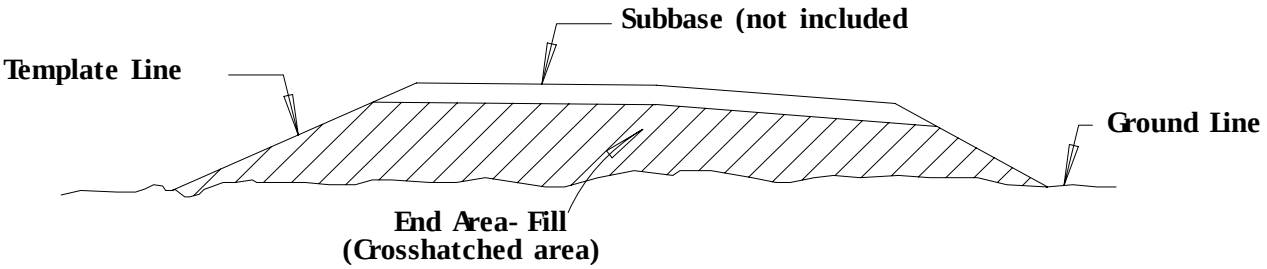


Figure 8-4 Fill Area

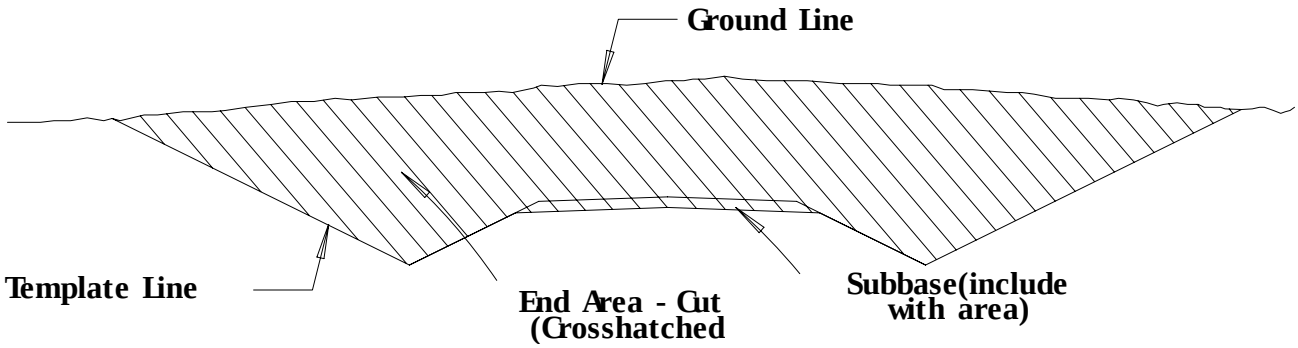


Figure 8-5 Cut Area

Calculations

Estimates of excavation and embankment quantities are determined by the average end area method. Cross sectional areas (end areas) of the excavation and embankment at each mainline cross section must be measured. This is done with a planimeter. Before using a planimeter, check the accuracy of the scales by tracing a known area.

Planimeters measure square inches of area. If the horizontal and vertical scales on the cross section are such that one square inch equals 100 square feet, the area is obtained by multiplying the planimeter reading by 100. The scales generally used are 1" = 5' vertically and 1" = 10' horizontally. One square inch of cross section thus equals 50 square feet making it necessary to multiply by 50.

Computation Sheet

Figure 8-6, on the following page, shows a typical computation sheet.

South Dakota Department of Transportation
Estimate of Earthwork Quantities

Computed by: **Date:**

Project:

Station	Areas		Quantities			Algebraic Sum
	Excavation	Embankment	Excavation	Embankment	Emb + %	

Figure 8-6 Computation Sheet

Calculations of Volumes

The average end area method of calculating volumes is performed by averaging the end areas of adjacent cross sections and multiplying the average end area by the distance between the cross sections. This is expressed by the formula

$$V \text{ (cu. yds.)} = \frac{\text{Area} + \text{Area}}{2} \times \text{Distance} \times \frac{1}{27}$$

where areas are expressed in square feet and the distance between sections in feet.

This calculation is performed for each class of excavation and embankment, between each adjacent pair of cross sections, with the volumes recorded in the appropriate columns of the computation sheet.

Shrinkage Factor

The Materials and Surfacing letter will indicate the proper percentage to be used for shrinkage or swell. This adjustment should be recorded in the Computation Sheet column headed Emb + %.

When the alignment is on a horizontal curve, a correction factor has to be applied to the volumes to account for the eccentricity of the areas. See Figure 8-7 for the curve correction factor.

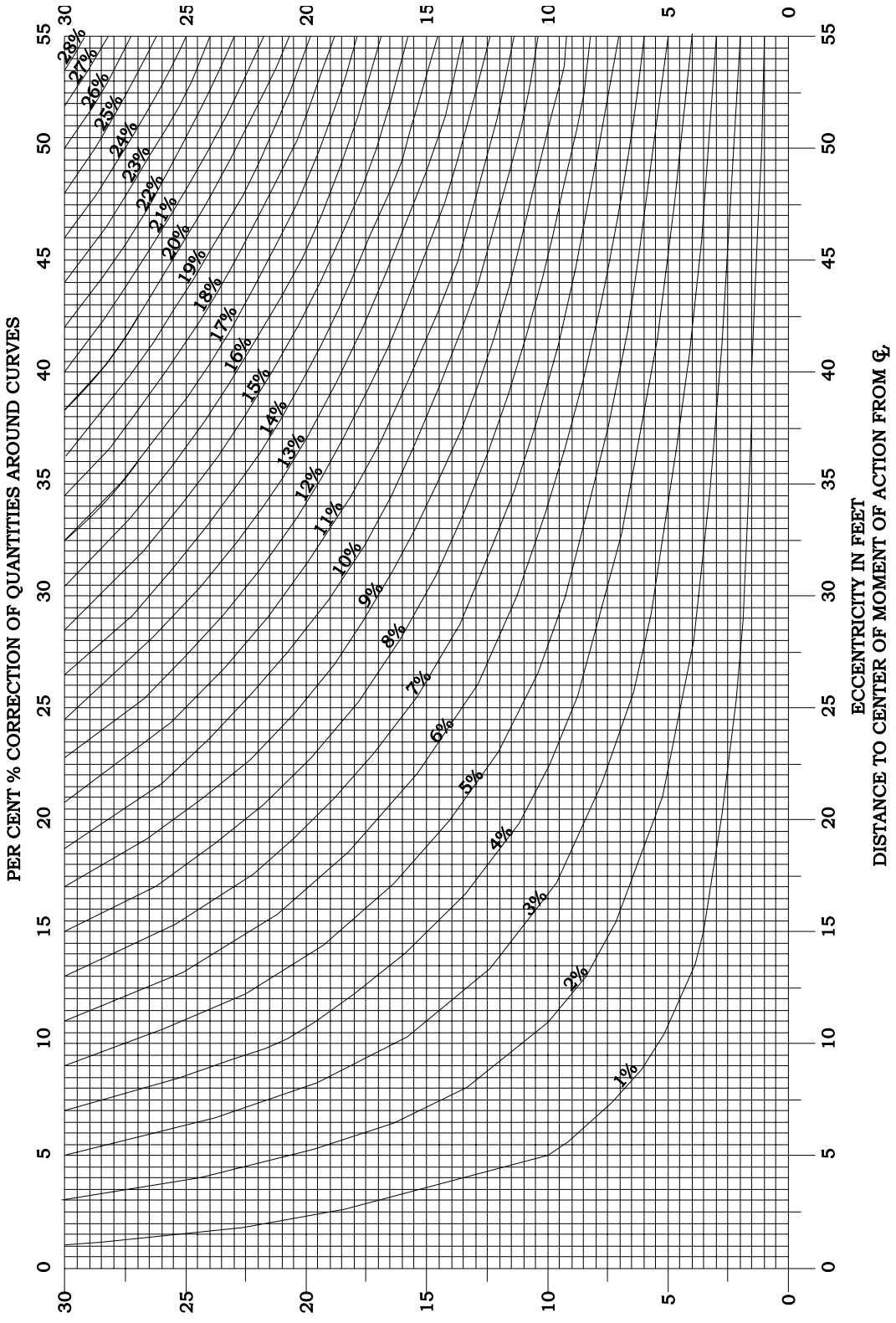


Figure 8-7 Curve Correction Factor

Balance Points

On the earthwork computation sheet, the column headed "Algebraic Sum" shows the accumulated balance between excavation and embankment at each station.
A plus quantity at any station indicates that up to that point the total accumulated excavation has exceeded the embankment. A minus quantity shows that accumulated embankment is larger than excavation quantities.

When all the algebraic sums or mass ordinates are calculated, determine the stationing of the balance points. A balance point occurs each time the algebraic sum changes from one algebraic sign to another (+ to -, - to +).

If the balance point falls between the stations listed, it is determined on the basis of a straight line relationship. For example:

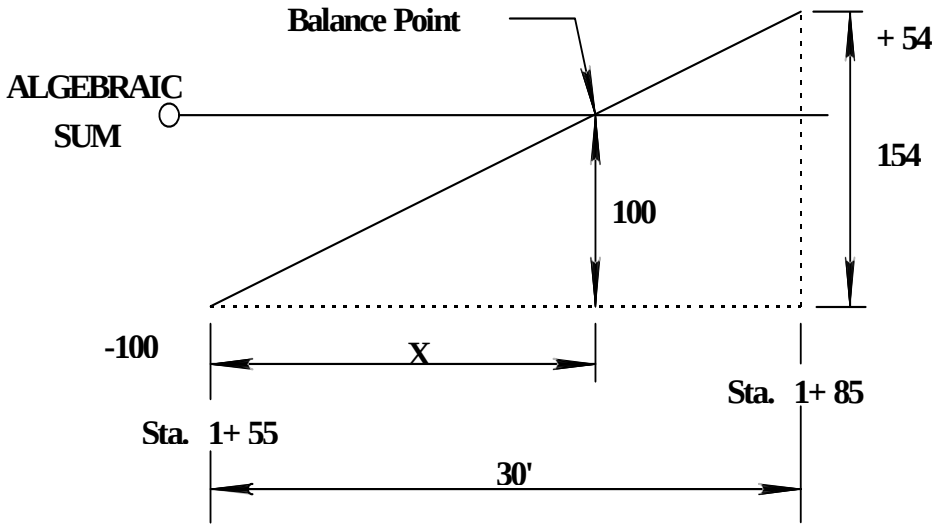


Figure 8-8 Relationship of Balance Point and Stations

The stationing of the balance point in the above sketch is equal to:

Sta. 1 + 55 plus X feet

$x = \frac{100}{154} \times 30 = 19'$

Sta. 1 + 55 plus 19' = Sta. 1 + 74

Between balance points excavation equals embankment adjusted for shrinkage.

Mass Diagram

Using cross section paper, plot the algebraic sum vs. the stationing. Select scales that make best use of the paper. The finished drawing is called a mass diagram. A portion of a mass diagram is shown in Figure 8-9.

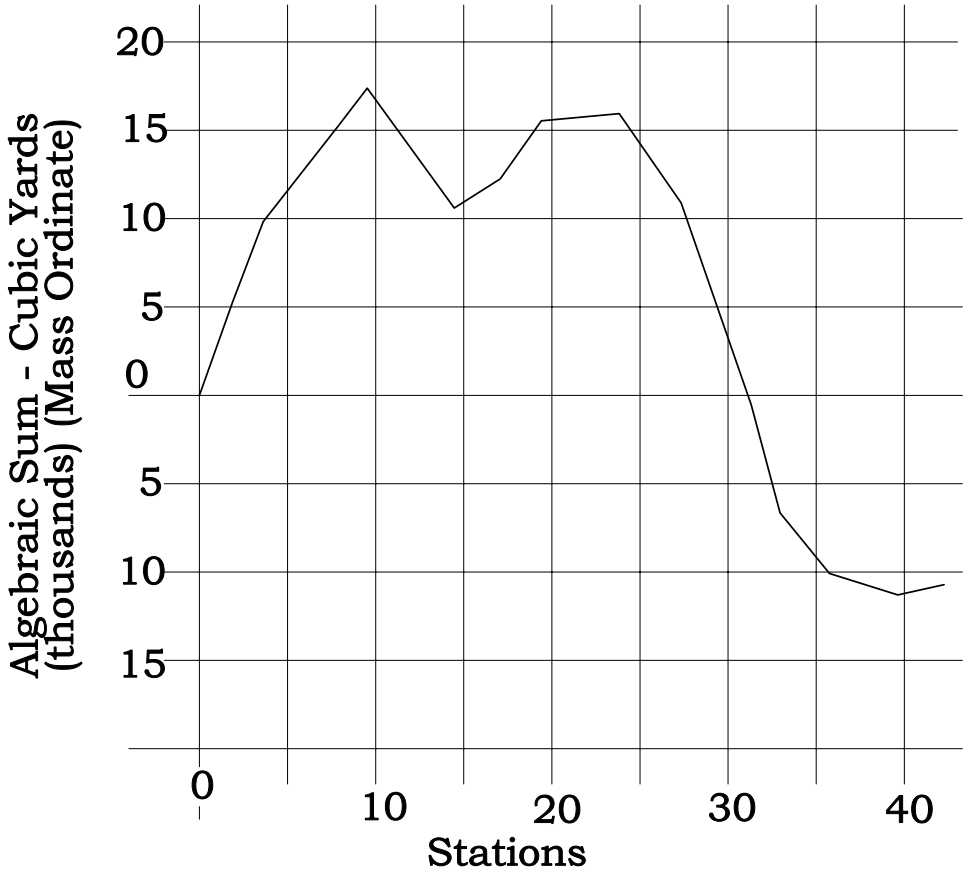


Figure 8-9 Portion of a Mass Diagram

Haul Calculation

Haul is expressed in cubic yard stations (one cubic yard hauled 100 ft). Haul quantities provide an estimate of the amount of hauling needed on a particular project. This information gives the estimator and the contractor a basis for estimating the unit cost of the excavation item. Haul is not a bid item or pay item. It is calculated and summarized as an informational guide.

The area between the mass diagram line and the balance line, provides a measure of the amount of the haul. This area can be measured with a planimeter. The square inches are converted to cubic yard stations by a factor based on the plotting scales. For example:

Horizontal Scale	Vertical Scale	Factor per sq. inch
1' = 1 Station	1" = 1000 CuYd	1000 CuYd sta.
1" = 1 Station	1" = 5000 CuYd	5000 CuYd sta.
1" = 5 Stations	1" = 10,000 CuYd	50,000 CuYd sta.