NDDOT Construction Conference 2011
East Conference: March 2 and 3, 2011
West Conference: March 7 and 8, 2011

Earthwork and Mass Diagrams

What Will We Cover?

- Earthwork
- Mass Diagrams
- How a Mass Diagram is Used

Note: All information is taken from the NDDOT Standard Specifications for Road and Bridge Construction and the Construction Manual unless otherwise noted.

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Earthwork

Earthwork

Earthwork Topics

- Cross Sections
- Quantities- Excavation and Embankment using average end area method
- Total Quantities- Topsoil
- Shrinkage

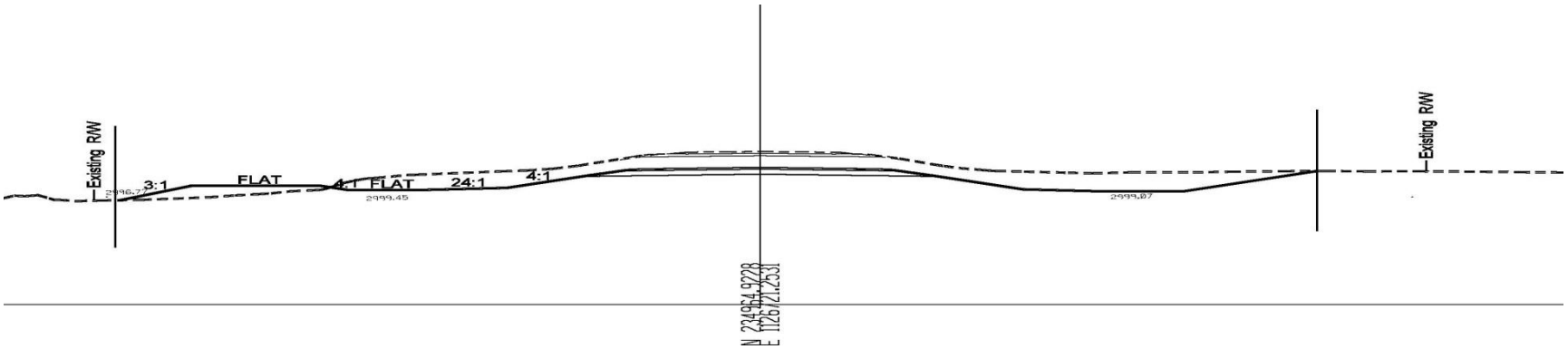
Earthwork

Cross Sections

- **Two Types**

1. Existing
2. Proposed

- Cross sections tell us the amount of cut and fill at each station.



Earthwork

Quantities

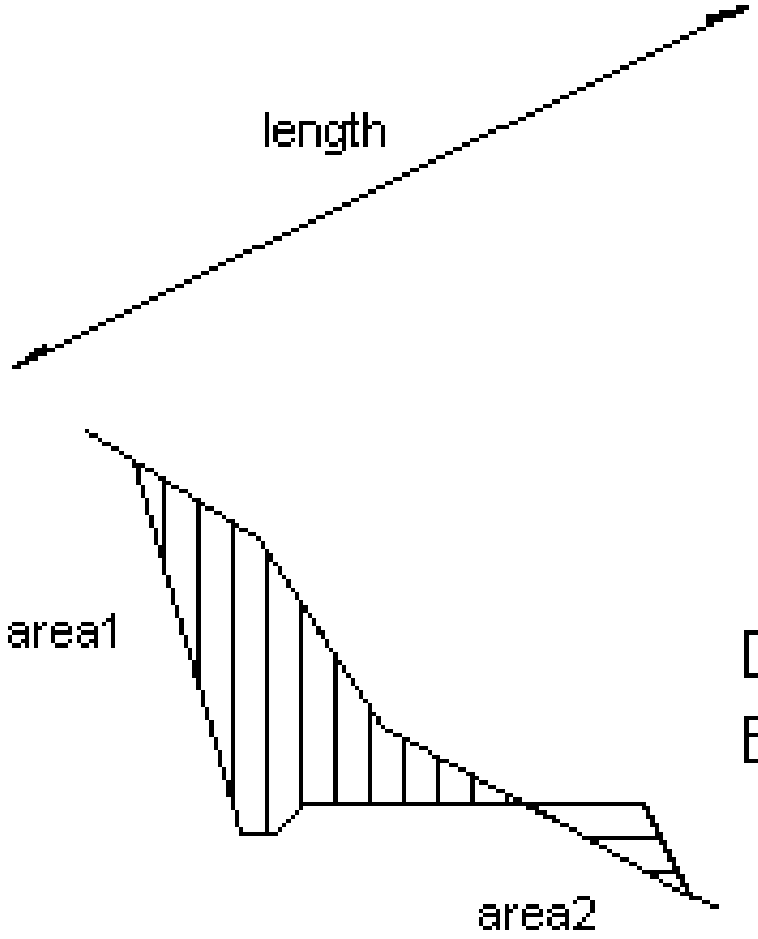
- Excavation- the amount of material that needs to be removed from the grade.
- Embankment- the amount of material that needs to be added to the grade.
- Excavation and embankment are calculated with cross sections using the average end area method.

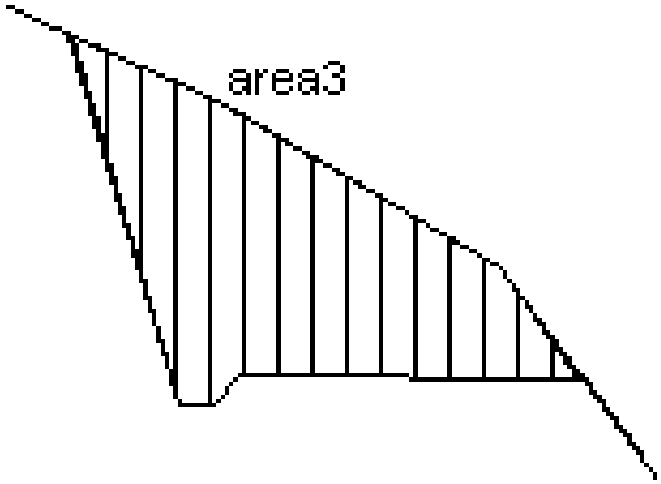
Earthwork

Average End Area Method

- The area between the existing ground and proposed ground is calculated at each cross-section.
- The area between two consecutive cross-sections is averaged.
- This area is multiplied by the distance between two cross-sections.

Earthwork





Cut volume = (area1 + area3)/2 * length

Fill volume = (area2 * length)/2

Earthwork

Total Quantities

- Topsoil- topsoil quantities are not calculated into the excavation or embankment. This is a separate value that has to be dealt with separately.
- Imported topsoil is needed if the stripping volume acquired does not fulfill the quantity of topsoil that is proposed.

Earthwork

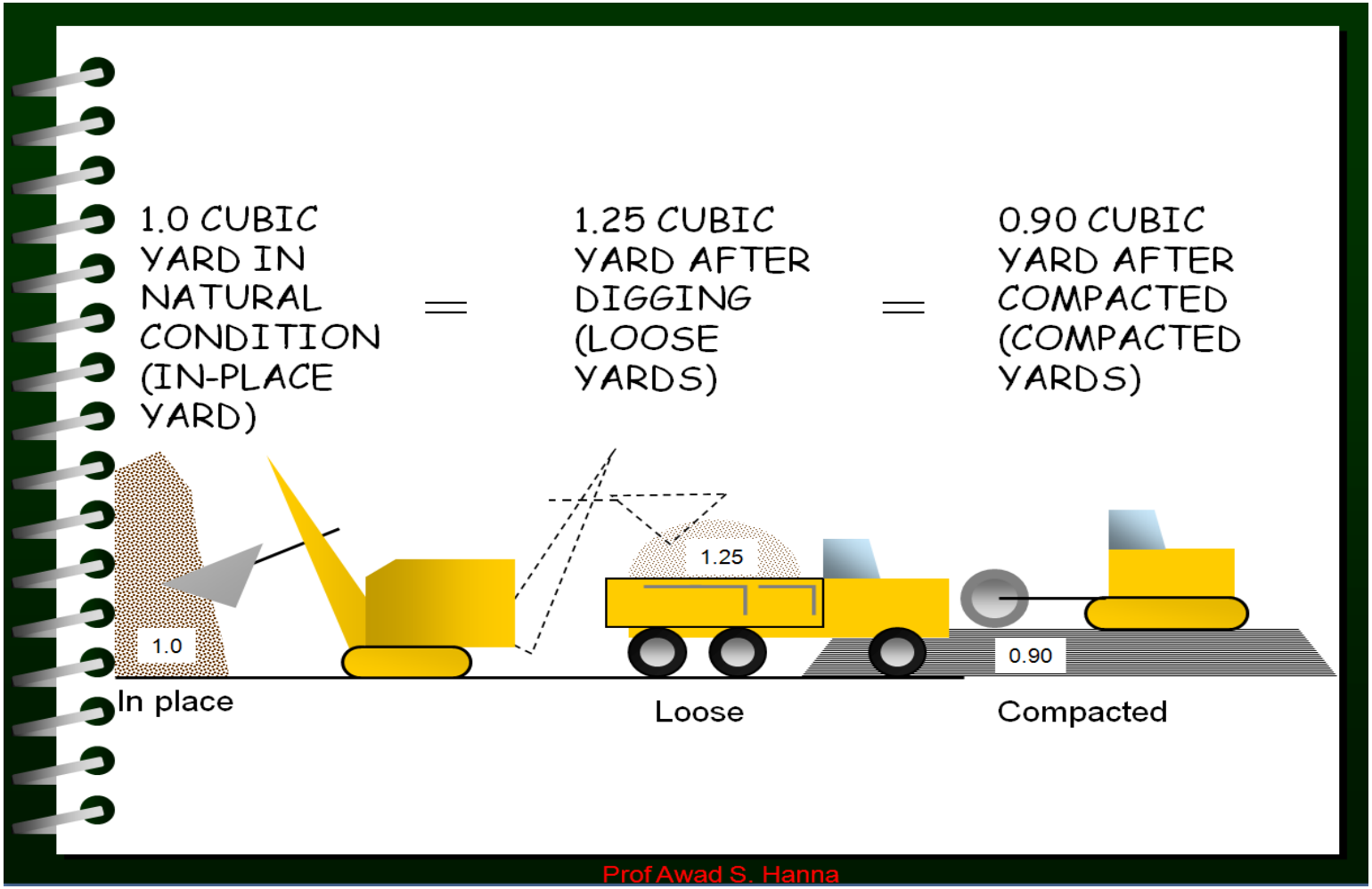
Shrinkage

- Shrinkage is the % additional volume added to the embankment quantity.

Three States of Material

1. Bank
2. Loose
3. Compacted

Earthwork


1.0 CUBIC YARD IN NATURAL CONDITION (IN-PLACE YARD)
=
1.25 CUBIC YARD AFTER DIGGING (LOOSE YARDS)
=
0.90 CUBIC YARD AFTER COMPACTED (COMPACTED YARDS)
1.0
1.25
0.90
In place
Loose
Compacted

Earthwork

Shrinkage

- In NDDOT plan sets, it will state that "XX% additional volume has been added to the embankment quantity to account for shrinkage".
- In other words, compacted cubic yards have been converted into bank cubic yards so you can compare "apples to apples".

Earthwork

			EARTHWORK				TOPSOIL		SEEDING
Pay Item Computation Variable			A	B	C	D	TS	TP	SD
LOCATION	STATION		Calculated Embankment Available* (Cut)	Calculated Embankment Required** (Fill)	Calculated Embankment: (+) Excess (-) Short	Trench Excavation	Topsoil Salvaged	Topsoil Proposed	Seeding Area
	Begin	End	CY	CY	CY	CY	CY	CY	ACRE
Highway 2	169+16	182+87	7,665	2,450	+5,215	0	1,965	1,599	2.97
55th Street South	94+77	98+50	1,127	132	+995	0	198	132	0.25
55th Street North	100+50	103+73	508	227	+281	0	124	58	0.11
Pipes Highway 2	169+98	169+98	225	0	+225	225	0	0	0
	176+75	176+75	518	0	+518	518	0	0	0
	182+00	182+00	201	0	+201	201	0	0	0
Pipes 55th Street	95+47	95+47	44	0	+44	44	0	0	0
	98+12	98+28	205	0	+205	205	0	0	0
	100+59	100+59	165	0	+165	165	0	0	0
		TOTALS	10,658	2,809	+7,849	1,358	2,287	1,789	3.33

Pay Item	Computation	Quantity (CY)
COMMON EXCAVATION-TYPE A	B	2,809
TOPSOIL	TS	2,287
COMMON EXCAVATION-WASTE	C - D	6,491
Pay Item	**Computation**	**Quantity (ACRE)**
SEEDING - TYPE B - Cl II	SD	3.33
SEEDING - HYDROMULCH	SD	3.33

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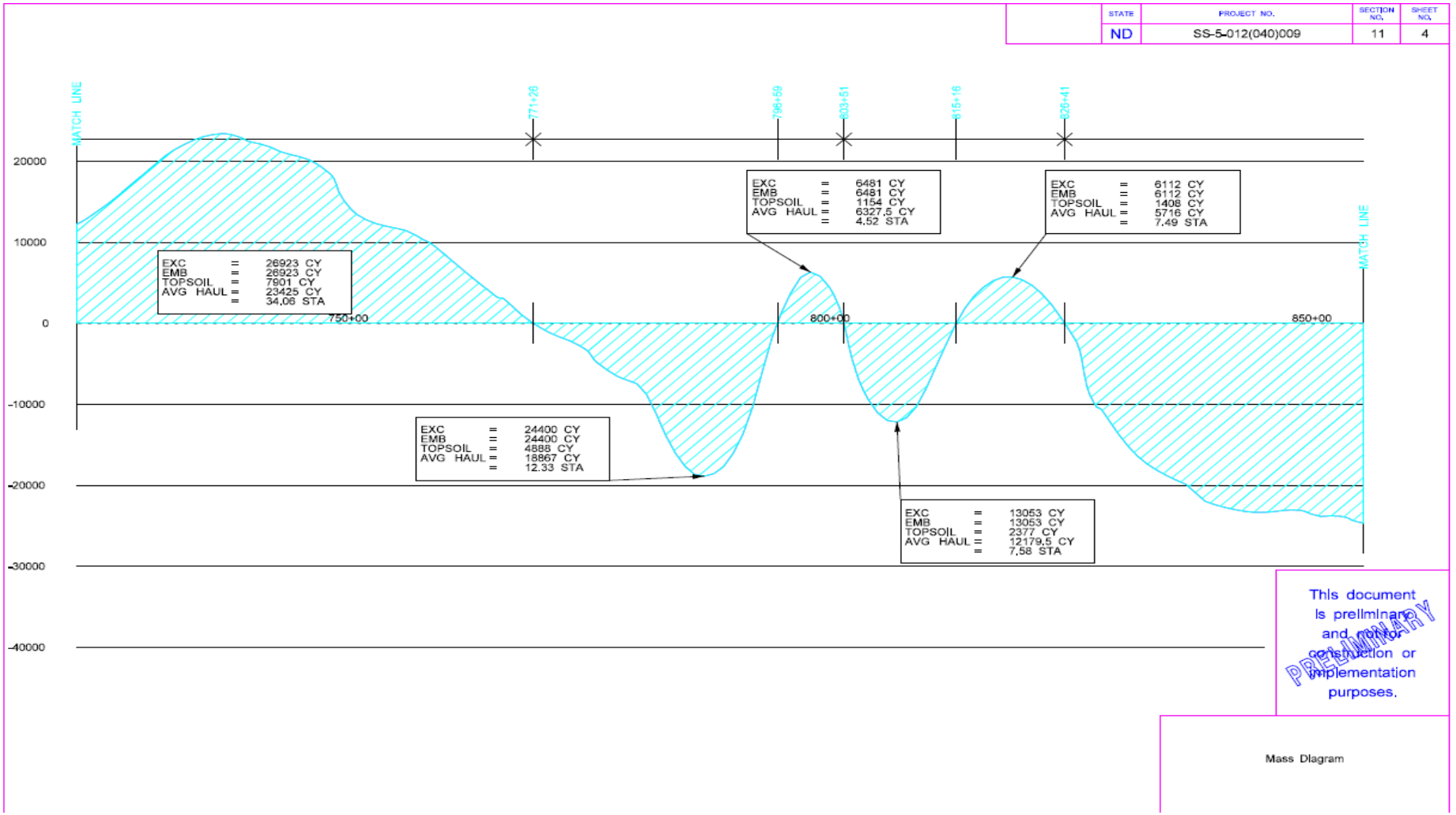
Mass Diagrams

Mass Diagrams

Mass Diagram Topics

- Basic Definitions
- Mass Ordinates
- Plot of Mass Ordinate

Mass Diagrams



Mass Diagrams

Basic Definitions

- Mass Diagram- A graphical representation of the cumulative amount of earthwork moved along the centerline and distances over which the earth and materials are to be transported.

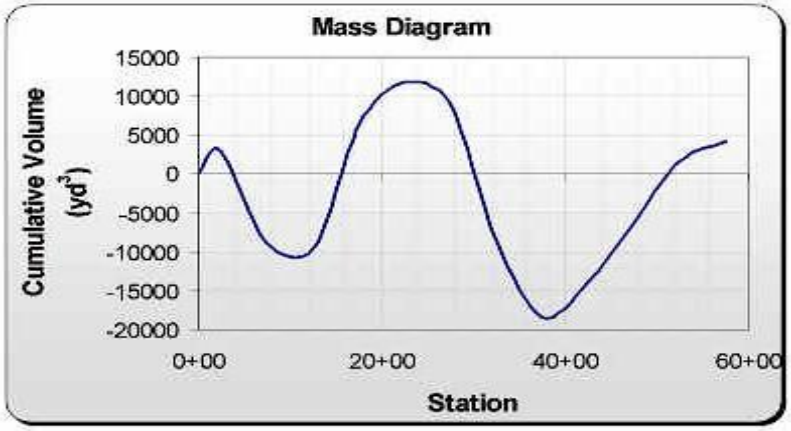
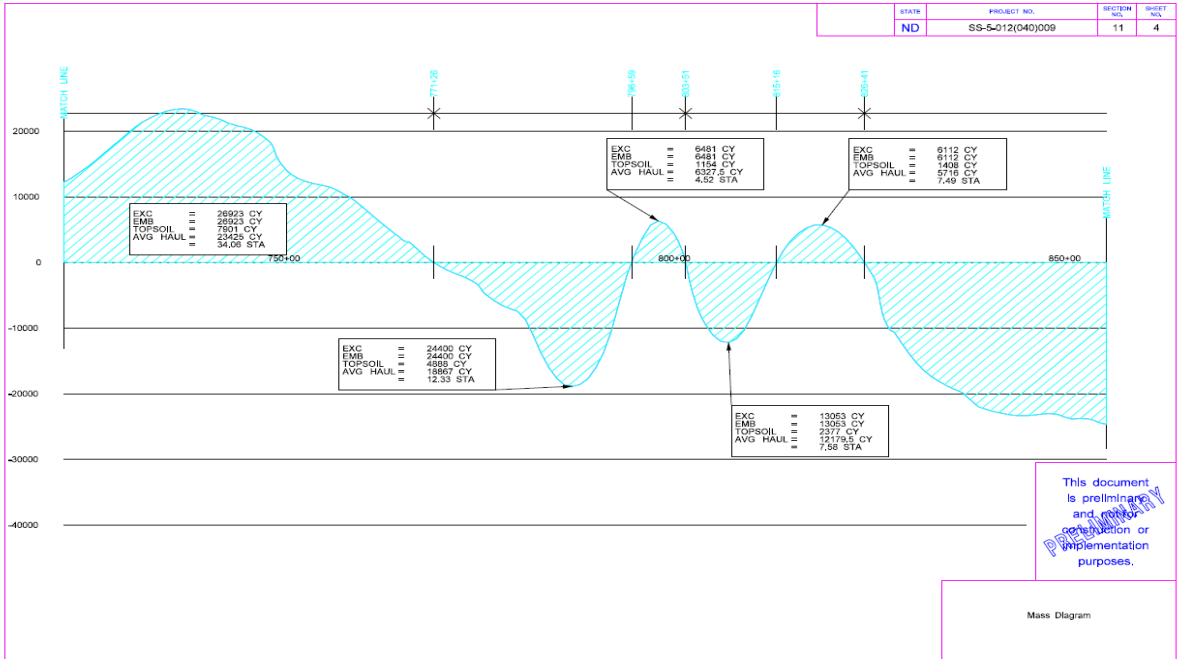


Photo from : http://www.webs1.uidaho.edu/niatt_labmanual/Chapters/roadwaydesign/theoryandconcepts/ImageFiles/EarthworkMassDiagram.jpg

Mass Diagrams

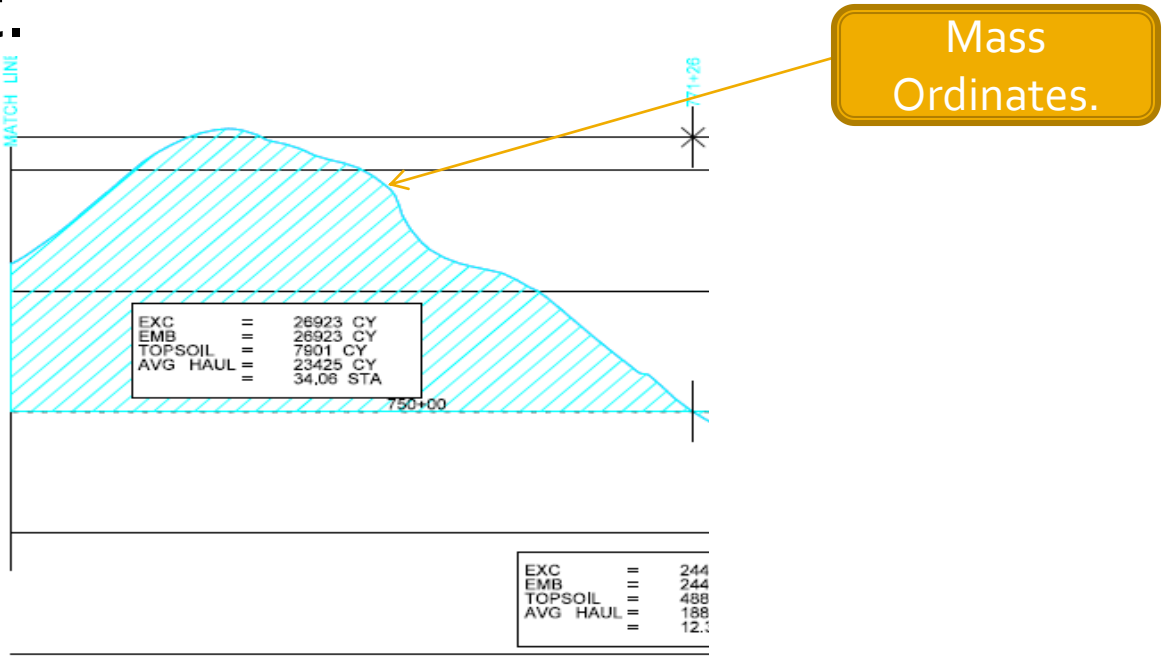
- Vertical Axis- Cubic Yards (excavation and embankment).
- Horizontal Axis- Stationing



Mass Diagrams

Mass Ordinates

- Mass ordinates are the cumulative total of the excavation and embankment on the project.

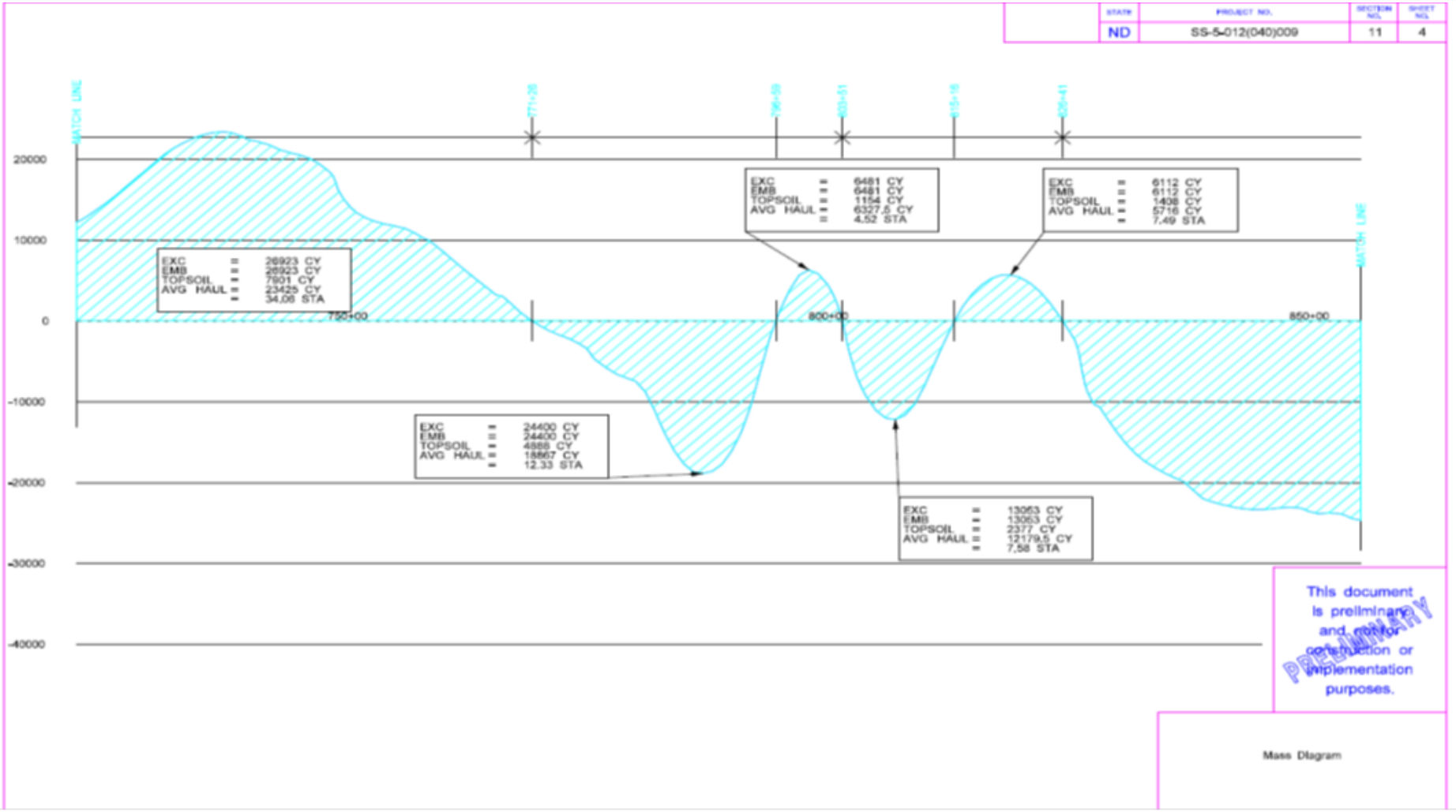


Mass Diagrams

Graph

- Uphill line indicates cut
- Downhill line indicates fill
- Flat line indicates cut and fill are equal
- Balance point is where the diagram intersects the baseline and indicates where the cut and fill have balanced out.

Mass Diagrams



Mass Diagrams

What do they tell us?

- Mass diagrams determine the average haul, free haul, and overhaul on a given segment of roadway.
- Mass diagrams tell the contractors and inspectors the quantity of material moved and how far it can be economically moved.

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How do we use this thing?

How a Mass Diagram is Used

Why do we need this in the first place?

How a Mass Diagram is Used

Topics

- Basic Definitions- Haul, Average Haul, Overhaul
- How to Calculate Average haul
- Borrow

How a Mass Diagram is Used

Definitions

- Haul- the transportation of excavated material from its original position to is final location in the work or other disposal area. This is also know as authorized haul.

How a Mass Diagram is Used

Definitions

- Average haul- determined from mass diagram. Average haul is the area of the mass diagram representing the number of cubic yard stations of haul between balance points divided by the ordinate of the mass which the yardage is hauled.

How a Mass Diagram is Used

- Mass Diagrams are used to calculate the average or free haul between two given balance points and also the average or free haul for the entire project area.
- They also tell the contractor which way the dirt is to be moved and the quantity of dirt to be moved.

How a Mass Diagram is Used

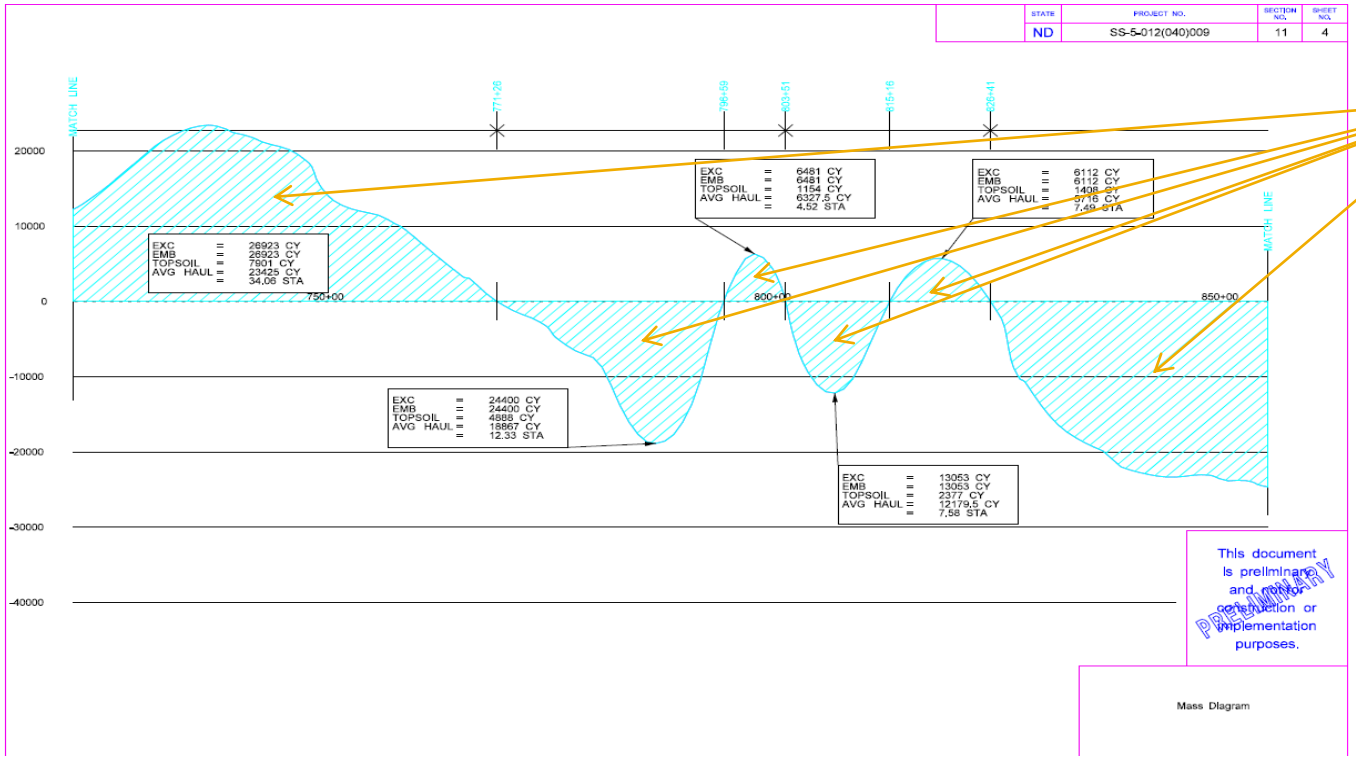
Calculation of Average or Free Haul

- The two values you need for the calculation of average or free haul are an area and a volume.
- These two values can be obtained from the mass diagram.
- The area you use is the area under the curve and the volume you use is the sum of the peaks and valleys on the diagram.

How a Mass Diagram is Used

Calculation of Average or Free Haul

Area- Shaded Portions



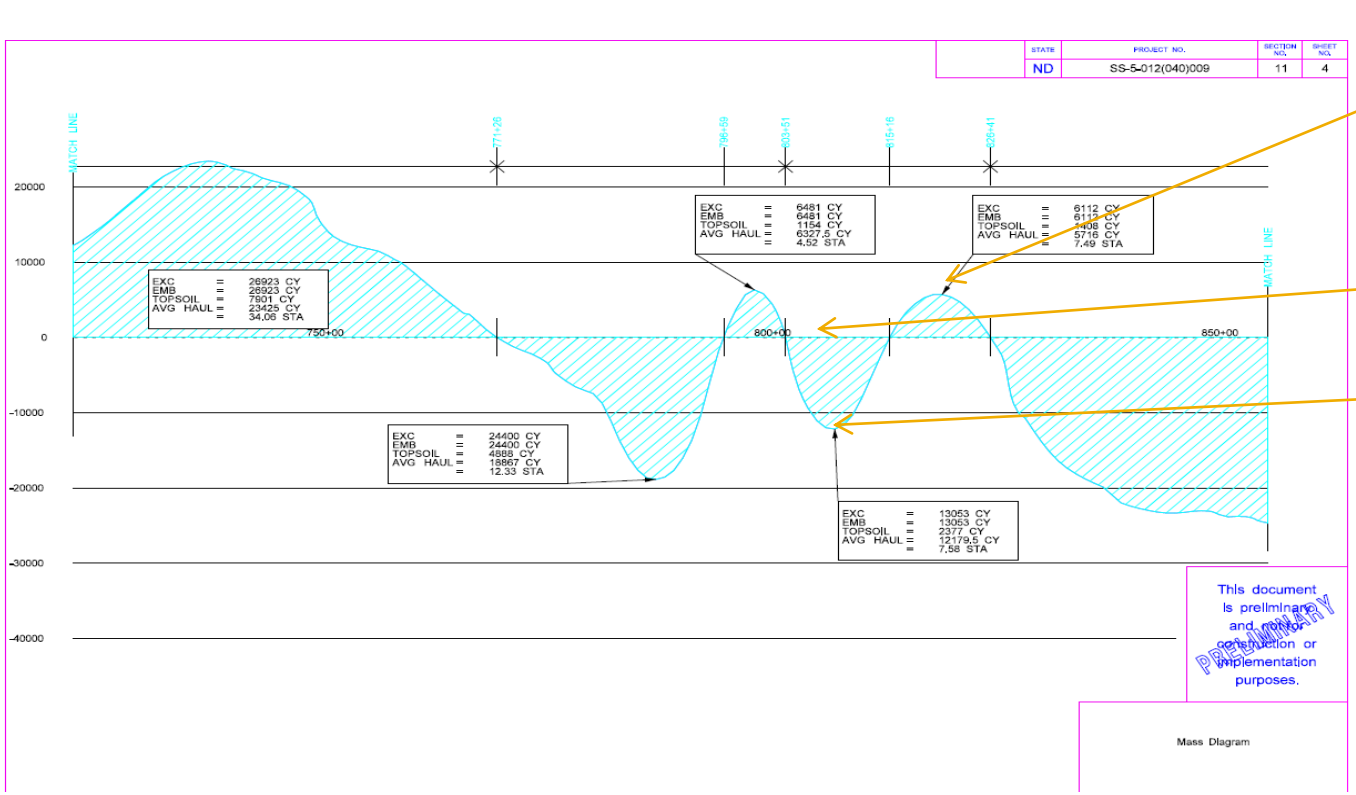
How a Mass Diagram is Used

Calculation of Average or Free Haul

Peaks and Valleys- Above balance line, add peaks and subtract valleys. Below balance line, add valleys and subtract peaks.

How a Mass Diagram is Used

- **Peaks and Valleys**



Peak

Balance Line

Valley

How a Mass Diagram is Used

Calculation of Average or Free Haul

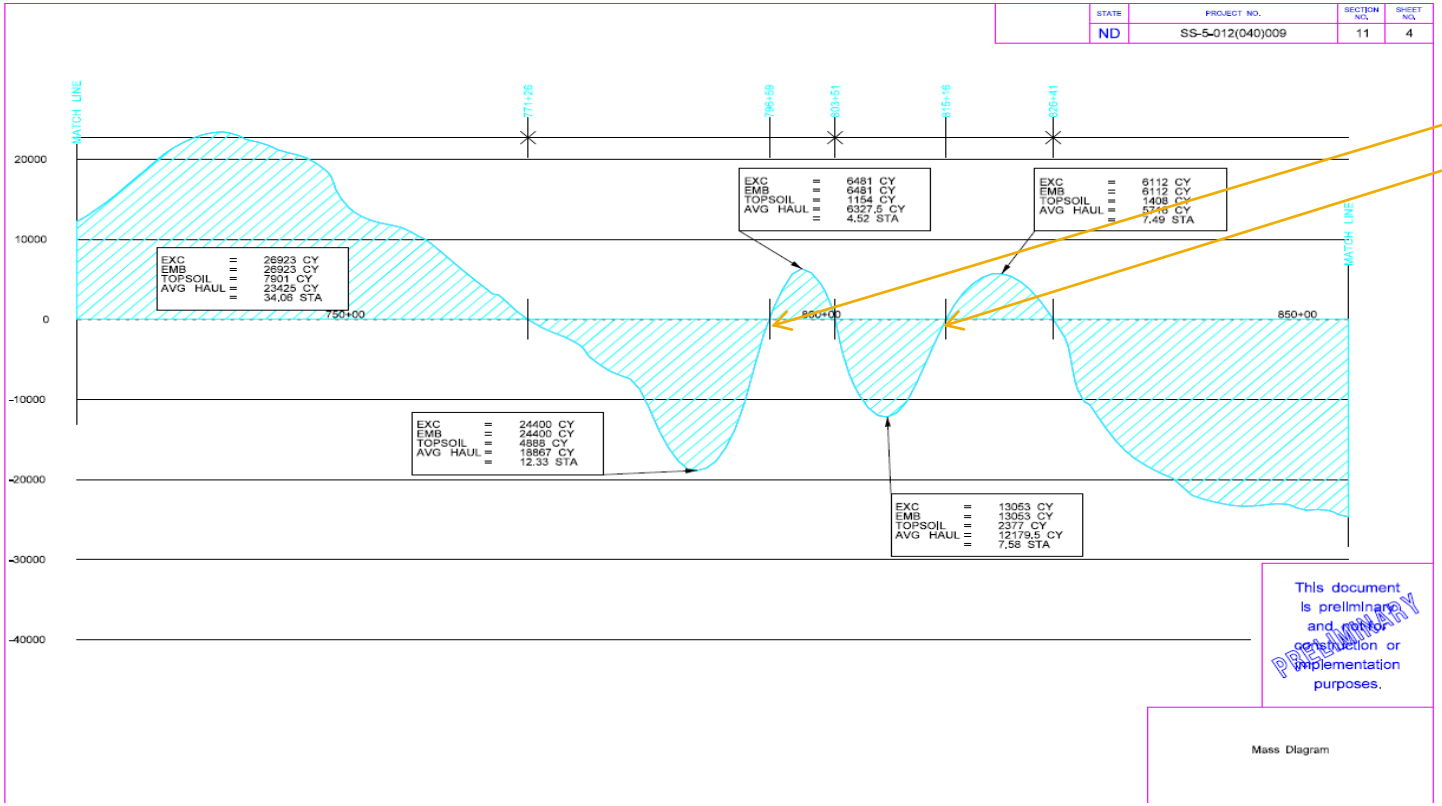
- The equation for average or free haul is as follows:

$$Average\ Haul = \frac{Area}{\sum Peaks/Valleys}$$

- Area= CY-sta.
- Peaks/Valleys= CY
- In order to get correct units, this value has to be divided by 1 Sta.
- The resulting number will be in Sta.

How a Mass Diagram is Used

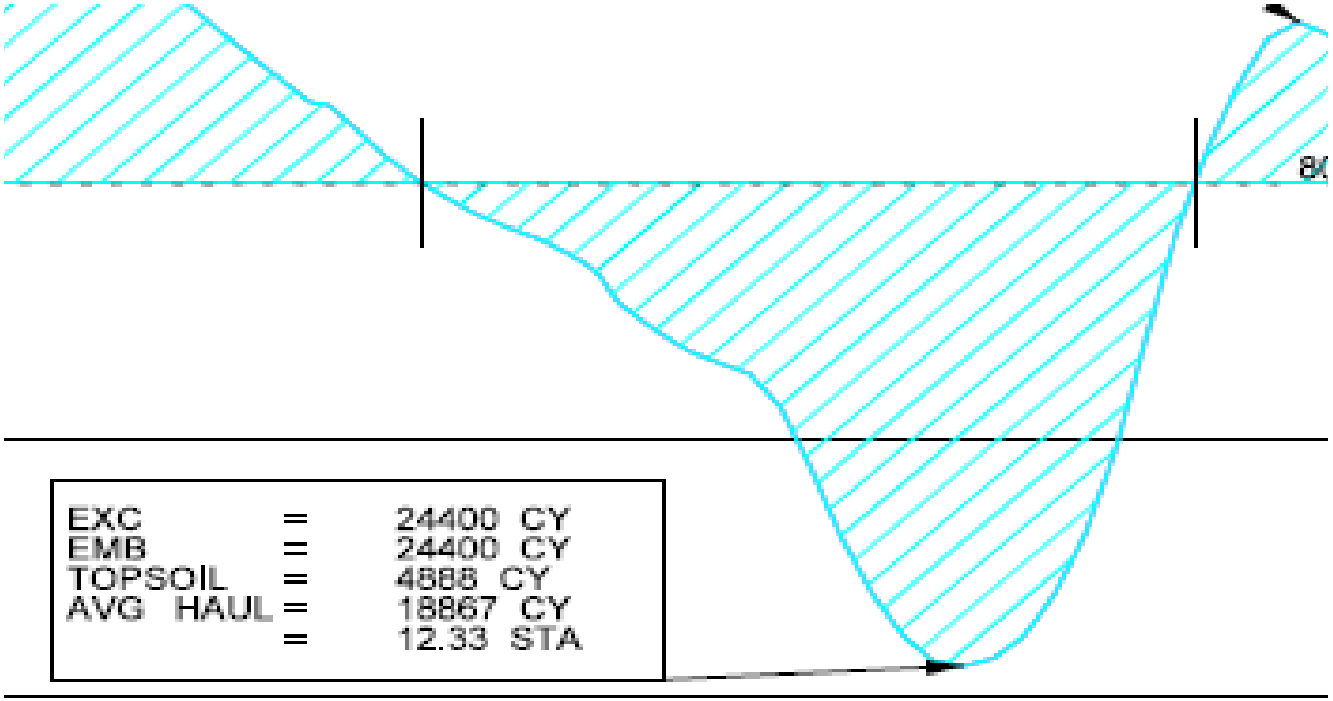
Calculation of Average or Free Haul



Balance Points

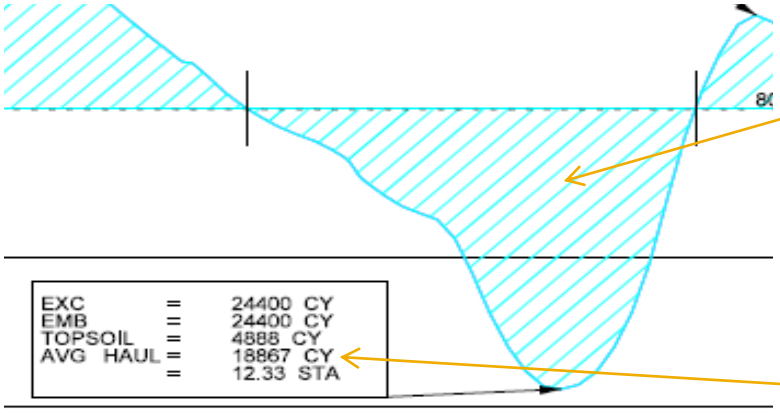
How a Mass Diagram is Used

- Example of Average Haul



How a Mass Diagram is Used

- Example of Average Haul



Area of Shaded Portion= 232,536 CY-Sta.

The Sum of the Peaks and Valleys= 18867 CY

Therefore: Average Haul= $\frac{232,536}{18867}$ = 12.33 Sta.

How a Mass Diagram is Used

Calculation of Average or Free Haul

- The equation for average or free haul for the entire project is as follows

$$Average\ Haul\ Project = \frac{\sum Areas}{\sum Peaks/Valleys}$$

- Areas= CY-Sta.
- Peaks/Valleys= CY
- The resulting number will be in Sta.

How a Mass Diagram is Used

Calculation of Average or Free Haul

- With the average haul value, you can determine when and where to pay for overhaul.
- When you exceed this average haul distance, you must begin paying for overhaul with a few exceptions.

How a Mass Diagram is Used

Definitions

- Overhaul- the authorized hauling of excavation beyond the specified free-haul distance.
- Free haul=Average haul for project

How a Mass Diagram is Used

Overhaul Exceptions

- Overhaul is paid for when you exceed the average or free haul distance.
- Overhaul is only paid if you are outside of the balance points.
- This means that if your average or free haul distance is exceeded within the balance point, you do NOT have to pay for overhaul.

How a Mass Diagram is Used

Borrow

- When using borrow, the dead haul is not included in calculations. The mass is entered into the diagram where it enters into the project.
- This is represented by a vertical line.

Conclusion

What We Covered

- Earthwork- cross sections, quantities, average end area method, topsoil, shrinkage.
- Mass Diagrams- mass ordinates, plot of mass diagram.
- How a Mass Diagram is Used- haul, average haul, how to calculate average haul, overhaul, borrow.

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Questions?