MONTANA
Department of Transportation

Earthworks Procedures

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Overview

This document contains the processes necessary for creating material lists, producing volume reports, adding earthwork values to cross sections, and plotting mass haul diagrams.

Process Provenance

- Date of development: 5/23/2025
- Revision date: *9/3/2025*
- Application/Tool(s): *AutoCAD Civil 3D*
- Version(s): *13.6.2020.0 Civil 3D 2024.4.3*
- Environment(s): *MDT Civil 3D State Kit r2024 v2.2.0*
- Author: *MDT Earthwork Workflow Subcommittee*

Statement of Need

This document is intended to provide guidance to MDT Autodesk users to calculate and incorporate earthwork quantities into plans for Civil 3D projects.

Acronyms/Definitions Used in This Document

ES – Existing Surface

Datum – The proposed subgrade surface used as the basis for earthwork calculations.

EMG - Excel Manager File

References

Creating Cross Sections

Road Design Manual – (MDT RDM)

Volume Calculation Methods

Define Gaps <Material List Name> Dialog Box

Apply Gaps <Material Name> Dialog Box

Process Description and Examples

Section I. Material Lists

Procedure – Creating Earthwork Material Lists

1. While in the desired file (e.g. XSF, EWK, MAS) select ***Compute Materials*** in the ***Analyze Tab***
    a. From the Compute Materials dialog, select the ***Alignment*** and ***Sample Line Group***

Note: Sample Lines must extend to or past the perimeter of the area being calculated. (e.g. construction limits)

    b. Pick a ***Quantity Takeoff Criteria*** style (e.g. "MDT-Quantity Takeoff").
    c. Use the dropdown menu to choose the proper ***Volume Calculation Method***
        - The ***Composite Volume*** (Surface to surface) method uses two surfaces to calculate the volumes, it utilizes the sample lines to slice the surface into polygons and connect them to form a three-dimensional shape. The software calculates the volume of the newly created prism.
            - Preferred method

        - The ***Average End Area*** method computes the volumes by adding the cross-sectional area of one cross section and the next and then divides the quantity by two. The value is then multiplied by the distance on the centerline between the two sections.
            - Curve correction tolerance toggle and value. (MDT Preferred method is toggle off)
            - Secondary method

        - The ***Prismoidal*** method begins by introducing an additional cross section in the middle of one cross section and the next. It then follows the same process stated in the ***Average End Area*** method.
            - For information only (not a preferred method)
            - Curve correction tolerance toggle and value. (MDT Preferred method is toggle off)

Note: For more information on volume calculations please refer to "Volume Calculation Methods" above in the References section.

    d. Assign Surfaces
    e. Assign Corridor Shapes (if applicable)

Note: Corridor Shapes aren't normally used for earthwork quantities and cannot be used with the Composite Volume calculation method.

f. Once the material list has been set up, close out of dialog box by clicking the ***OK*** button.

2. Reopen ***Compute Materials***

Note: Now that a material list exists for the Alignment and Sample Line Group, the Edit Material List window is displayed. From this window you can add new materials, add subcriteria to materials, define materials, edit materials, add gaps to material calculations, change the calculation method, and create additional material lists.

a. From the Compute Materials dialog, select the same ***Alignment*** and ***Sample Line Group*** as before***.***
b. Assign factors (if required)
    i. Cut Factor (Swell)
        1. Percent of cut material to be accounted for.
        2. Greater than or equal to zero

    ii. Fill Factor (Shrink)
        1. Percent of fill material to be accounted for.
        2. Greater than or equal to zero

    iii. Refill Factor
        1. Percent of accounted for cut material that is usable and that will be included in the mass ordinate.
        2. Greater than or equal to zero and less than or equal to one.

c. Additional materials can be added with the ***Add new material*** button. This can be used to include other quantities such as topsoil or other Add. Grading items.
d. Subcriteria
    i. Subcriteria offer the ability to set multiple conditions for a material. This could be used to include multiple surface comparisons under one material or have complex comparisons for exclusion/inclusion of multiple surfaces.
    ii. To add a Subcriteria
        1. The Volume Calculation Method must be one of the following:
            a. Average End Area
            b. Prismoidal

Note: Subcriteria is not available for use with a volume calculation method of “Composite Volume”.

        2. And the material must be:
            a. Empty (i.e. contains no surfaces or corridor shapes)
            b. A Quantity Type of one of the following:
                i. Cut
                ii. Fill

iii. Cut and Refill

Note: Subcriteria is not available for use with a material "Quantity Type" of "Earthworks" or "Structures".

iii. Select the material and click the ***Add a Subcriteria*** button to add a Subcriteria.

e. Gaps
   i. Gaps can be used to exclude volume calculations of a material for sections of the sample line group.

Note: Gaps are not available for use with the Composite Volume calculation method. For Composite Volume calculations the gap must be included in one of the surfaces.

ii. Gaps are added to the Material List by clicking the ellipses in the Gap column.
   1. Click ***Add a new gap.***
   2. Define station ranges.

iii. Gaps are then added to individual Materials by clicking the ellipses in the Gap column.
   1. Apply the gaps needed for each material by toggling the apply check box.
   2. Define runout distances.

Note: For more information on gaps please refer to "Define Gaps <Material List Name> Dialog Box" and "Apply Gaps <Material Name> Dialog Box" above in the References section.

f. If additional earthwork quantities are required, use the ***Import another criteria*** button to create another Material List.

3. Repeat the process above starting at step 2 "Reopen Compute Materials".

Note: All Materials Lists for a Sample Line Group use the same Volume Calculation Method.

a. Once all materials lists have been added, close out of the dialog box by clicking ***Apply*** then ***OK*** buttons.

Section II. Earthwork Quantities

Procedure – Creating Earthwork Volume Tables

Note: Volume tables are not necessary for this workflow, but they can be a useful tool in the design process for quick information about quantities.

1. Select **Total Volume Table** in the **Analyze Tab**
    a. Set a **Table Style** (e.g. "_MDT-Default").
    b. Assign **Alignment**, **Sample Line Group**, and **Material List**
    c. Assign "Split table" settings to user preferences.
        i. Assign "Tile tables" settings to user preferences.
    d. Assign Behavior settings to user preferences.
    e. Click **OK**
    f. Place in drawing space.

Procedure – Creating Volume Reports

1. Select **Volume Report** in the **Analyze Tab**
    a. Assign **Alignment**, **Sample Line Group**, and **Material List**
    b. Select a style sheet (e.g. "_MDT_Earthworks.xsl").
    c. Toggle **ON** "Display XML report"
    d. Click **OK**

Note: Once complete, a temporary ".html" file will be opened in your default web browser and a temporary ".xml" file will be opened in notepad. The ".html" file can be saved for documentation by right clicking and selecting "Save as" or pressing ctrl+s.

2. Save the ".html" (e.g. "12345000RDEWK001.html") and ".xml" (e.g. "12345000RDEWK001.xml") and upload them to PCMS

Procedure – EMG Summaries

Additional grading is currently unable to be included in the earthworks volume report. Therefore, additional grading will be added to the quantity from the earthworks volume report via EMG summaries. Additional grading will be subtotaled and included in the grading frame similar to how surfacing is quantified.

1. Grading Summary
    a. Grading line – cumulative excavation and embankment
    b. Additional grading line – subtotal from the Additional grading frame

Example:

GRADING				
STATION	cubic yards			REMARKS
	UNCL. EXC.	EXCESS EXC.	EMB.+	
2134+00.00				
	888,123		823,047	MAINLINE TEMPLATE
2488+00.00				
	27,220		51,920	ADDITIONAL GRADING
TOTAL	**915,343**	**◆ 40,376**	**◆ 874,967**	

◆ FOR INFORMATION ONLY

2. Additional Grading Summary
    a. All additional grading quantities (e.g. topsoil, approach grading, ditch blocks, etc.) to be subtotaled and included in the Grading Summary.

Example:

ADDITIONAL GRADING

STATION		cubic yards			REMARKS
		INCL. IN GRADING		ADD. UNCL. EXC.	
FROM	TO	UNCL. EXC.	EMB.+		
2134+00.00	2488+00.00	~	~		TOPSOIL REPLACEMENT ▼
2139+50.00		135	395		PRIVATE APP. LT. (JOINT USE)
2139+50.00		15	210		FARM FIELD APP. RT. (JOINT USE)
2171+05.00		700	230		FARM FIELD APP. LT.
2171+05.00		1,000	130		FARM FIELD APP. RT.
2185+72.00		290	115		FARM FIELD APP. RT.
2192+90.00		170	225		FARM FIELD APP. LT. (JOINT USE)
2220+90.00		70	175		FARM FIELD APP. LT.
2220+90.00		20	600		FARM FIELD APP. RT.
2240+90.00		75	195		FARM FIELD APP. LT.
2250+60.00		35	1,060		FARM FIELD APP. LT.
2250+60.00		20	6,580		FARM FIELD APP. RT.
2272+30.00			30		DITCH BLOCK - LT. (ELEV. 2669.80')
2285+03.00		805	310		FARM FIELD APP. LT.
2285+03.00		3,745	155		FARM FIELD APP. RT.
2290+00.00				120	INLET DITCH RT.
2290+00.00				30	OUTLET DITCH LT.
2298+15.00		40	17,705		PRIVATE APP. LT.
2298+15.00		70	4,040		PRIVATE APP. RT.
2308+71.00			5		DITCH BLOCK - RT. (ELEV. 2704.10')
2320+35.00		30	730		FARM FIELD APP. LT.
2320+35.00		40	225		FARM FIELD APP. RT.
2340+20.00		15	275		FARM FIELD APP. LT.
2348+12.00		1,340	240		FARM FIELD APP. RT.
2355+00.00		170	1,345		FARM FIELD APP. LT.
2355+00.00		280	755		FARM FIELD APP. RT.
2369+23.00		55	740		FARM FIELD APP. LT.
2379+10.00		55	280		FARM FIELD APP. LT.
2379+10.00		30	320		FARM FIELD APP. RT.
2401+50.00		300	305		FARM FIELD APP. LT.
2401+50.00		2,275	155		FARM FIELD APP. RT.
2424+75.00		165	260		FARM FIELD APP. LT.
2424+75.00		100	175		FARM FIELD APP. RT.
2442+24.00		1,415	315		FARM FIELD APP. LT.
2442+24.00		870	660		PRIVATE APP. RT.
2457+30.00		60	2,495		PUBLIC APP. LT. - LOGAN RD
2457+30.00		1,340	500		PUBLIC APP. RT. - CHALK BUTTE RD
2485+80.00		20	1,145		FARM FIELD APP. LT.
2485+80.00		40	335		FARM FIELD APP. RT.
2488+00.00	2501+60.00	11,430	8,505		CONNECTION
2488+00.00	2501+60.00	~	~		TOPSOIL REPLACEMENT (INCL. IN CONN.)
SUBTOTAL		**27,220**	**51,920**	**150**	
TOTAL		~	~	**150**	

▼ QUANTITY INCLUDED IN MAINLINE TEMPLATE

Note: If topsoil replacement is not included via the mainline template, include the adjusted volumes in the Additional Grading Frame.

Procedure – Balance Points

1. If a mass haul diagram is to be created, balance point locations and quantities will need to be calculated utilizing a volume report.
2. The volume report ".html" can be opened in excel and saved as an ".xlsx" or the data can be copied from the ".html" and pasted into an excel workbook.
3. Insert rows for additional grading locations and their volumes.
4. Recalculate the cumulative volumes to include the additional grading.
5. Interpolate the station and cumulative quantities of the balance point.
    a. Balance points are where the cumulative net volume is equal to zero. Which are between a positive and a negative cumulative net volume.
6. The volumes between balance points are the differences between the current point's cumulative volume and the prior point's cumulative volume.

Section III. Mass Haul Diagrams

Procedure – Creating Mass Haul Diagram

1. Overview
    a. Section 13.3.4 of the MDT RDM offers application guidelines to follow for understanding a mass diagram.
    b. The horizontal axis of the mass haul view represents the alignment stationing.
        i. The horizontal axis of the graph is not affected by scale. 1 graph unit = 1 drawing unit

    c. The vertical axis of the mass haul view represents the accumulative volume of the material list in cubic yards.
        i. 1 cubic yard = 27 feet in the drawing
        ii. The vertical axis can have an exaggeration applied.
            1. 4,000 cubic yards at a vertical exaggeration of 0.5 would be 54,000 feet in the drawing on the vertical axis.
                a. (4,000 x 27) x 0.5 = 54,000
    d. It is recommended to create the mass haul diagram in a standalone file. (e.g. EWK, MAS)
        i. A sample line group will need to be created or data shortcuted.

Note: For composite volume methods, sample line frequency only affects the plotting increments of the mass haul diagram.

        ii. A materials list will need to be created, see section 1

2. Mass Haul View
    a. Select **Mass Haul** in the **Analyze Tab**.
        i. General
            1. Select an alignment.
            2. Select a sample line group.
            3. Name the mass haul view.
            4. Select a style (e.g., “MDT-Mass Haul View”).
            5. Click Next.

        ii. Mass haul display options
            1. Material
                a. Select a material list.
                b. Choose a material to be displayed as the mass haul line (e.g. “Total Volume”).

            2. Mass haul line
                a. Name the mass haul line.
                b. Select a style (e.g. “MDT-Mass Haul Line”).
            3. Click Next.

iii. Balancing Options
1. Free haul distance – not used at MDT
2. Add/remove borrow pits and dump sites
    a. Overview
        i. This is where you can add additional grading quantities not represented by the Materials list. (e.g. topsoil, approach grading, ditch blocks, ect.)

    b. Table
        i. Type
            1. Borrow Pits (Additional Excavation)
                a. Adds material to the Mass Ordinate.
            2. Dump Sites (Additional Embankment)
                a. Removes material from the Mass Ordinate.
        ii. Station
            1. Duplicate stations are not accepted. If needed, place a small station gap between additional grading quantities splitting the embankment from excavation or use the net quantity for the location.
        iii. Capacity
            1. Must be greater than 0.

Note: Balancing options are not reflected in other objects, (i.e. volume report, volume tables, or cross section labels.) they only modify the mass haul line.

b. Select the “Create Diagram” button and place the graph in model space.

3. Dynamic Block
    a. Overview
        i. This block will aid in the scaling of the mass haul diagram for displaying and plotting purposes.
        ii. Parameters
            1. Project_Length
                a. Input
                b. Enter the length of the graph’s x axis.

            2. Max_Graph_Cut
                a. Input
                b. Enter the largest cut value on the graph’s y axis.

            3. Max_Graph_Fill
                a. Input

b. Enter the largest fill value on the graph's y axis.

4. Visibility_State
    a. Switch
    b. "Model Frame" Model space viewport boundary for the Mass Haul View to reside.
    c. "Layout Parameter" to gain access to additional parameters that affect the layout of the viewport size by paper units and buffer zones by paper units.

5. Buffer_Bottom
    a. Input
    b. Offsets, by paper units, the graph from the bottom of the viewport frame.

6. Buffer_Left
    a. Input
    b. Offsets, by paper units, the graph from the left of the viewport frame.

7. Buffer_Right
    a. Input
    b. Offsets, by paper units, the graph from the right of the viewport frame.

8. Buffer_Top
    a. Input
    b. Offsets, by paper units, the graph from the top of the viewport frame.

9. VP_Width
    a. Input
    b. The viewport's width in paper units.

10. VP_Height
    a. Input
    b. The viewport's height in paper units.

11. CU_YD_PER_INCH
    a. Output
    b. Calculates y axis per paper unit.

12. FEET_PER_INCH
    a. Output
    b. Calculates x axis per paper unit.

13. VERTICAL_EXAGGERATION
    a. Output ***(DO NOT CHANGE THIS VALUE)***
    b. Calculates the vertical exaggeration used in the mass haul view style.
    c. To update this value the block needs to be unselected and the drawing regenerated.
    d. If this value is ever changed by the user, it will no longer be updated from changes to the other properties and a new block will need to be placed.

iii. Origin point
    1. The origin point of the block will be placed at the bottom left of the graph.

b. With the command “INSERT” place the Dynamic Block “XSC_Mass_Haul_Layout_Aid” into the model space.
    i. Found under the “Libraries” tab and “RD-XS.dwg”

c. Select the block and input the following values via the properties window.
    i. Project_Length
        1. Total length of project or distance along the x-axis of the mass haul view.
    ii. Max_Graph_Cut
        1. Mass Haul View Minimum Volume. Largest positive tick on the y-axis of the mass haul view
    iii. Max_Graph_Fill
        1. Mass Haul View Maximum Volume. Largest negative tick on the y-axis of the mass haul view

d. If necessary, switch the visibility state to “Layout Parameter” to change the paper space size of the viewport width and height and the buffers around the graph. These values can be entered through the properties window or graphically with the block’s grips.
e. Clear selection and use the command “REGENALL”
f. Select the “MASS_HAUL_LAYOUT_AID” block and copy the value from the “VERTICAL_EXAGGERATION” property via the properties window.

Note: ***DO NOT MANUALLY CHANGE THIS VALUE***. To update this value the block needs to be unselected and the command “REGENALL” needs to be executed. This value will need to be updated for any change to any of the other values in this block. This value needs to be updated prior to using it in the mass haul view style. Repeat steps b through d if the “VERTICAL_EXAGGERATION” property was manually changed by the user.

g. Edit the mass haul view style and paste the value from the previous step into the “vertical exaggeration” field under the “Graph” tab. Save this as a new style so that it can continue to be changed by the user.

   h. The mass haul view should now be scaled to fit within the block.
   i. Place the block origin to the bottom left of the graph.

Note: The scale of the model space will not match the mass haul view and block. If the user desires the model space scale can be corrected by using the “FEET_PER_INCH” property value as a custom model space scale (this does not affect how paperspace displays).

4. Detail Sheet
   a. Create a detail sheet layout.
   b. Insert a viewport into the sheet and adjust to the size desired. (Normally a full sheet, if not, be sure to adjust the “MASS_HAUL_LAYOUT_AID” blocks layout properties.)
   c. Orient the viewports model space to the boundary of the “MASS_HAUL_LAOUT_AID” block. The command ALIGNSPACE or Zoom Window can aid in accurately aligning the viewport.,
   d. Refer to MDT RDM section 12.3.9.4 for information on what could be included in the Mass Diagram Detail Sheet.
      i. The dynamic blocks properties “CU_YD_PER_INCH” and “FEET_PER_INCH” can aid in acquiring the scale of the mass haul diagram.

Section IV. Cross Section Volume Labeling

Procedure – Creating Cross Section Earthwork Labels

Note: To complete this procedure a material list must be created, per Section 1, in the same file as the cross sections.

1. Click on a **Cross Section – Section View**
2. Select **View Group Properties** in the newly populated **Section View** tab
3. Select the **Ellipses** on the **Change Volume Tables** column.
4. Set **Type** to **Total Volume**
5. Set **Table Style** (e.g. “MDT-Total Volume”)
6. Click **Add**
7. Set **Material List**
8. Set **Section View Anchor** to **Bottom Center**
9. Set **Table Anchor** to **Middle Center**
10. Set **Table Layout** to **Horizontal**
11. Set **X and Y offset** to **0”**
12. Click **OK**
13. Click **OK**
14. Select **Update Group Layout** in the **Section View** tab

Note: Section View Tables can be added while creating multiple section views by using the same settings as steps 4 through 9 if a material list has been created prior to the creation of section views.

Section V. Volumes Dashboard

Procedure – How to Create Volumes Dashboard Surface

Note: The Volumes Dashboard can be utilized to observe cut and fill volumes in live time as changes occur. This tool can be advantageous when working in corridors to observe how slope modifications can affect the mass ordinate. However, cross section labels and Mass Hauls cannot be created using this tool, so follow the procedures above if you intend to create labels or a Mass Haul.

1. Select **Volumes Dashboard** in **Analyze Tab**
2. Select **Create new volume surface** ()
3. Set **Type** to **TIN volume surface.**
4. Assign **Name** and **Description** (if desired)
5. Set **Base Surface**
6. Set **Comparison Surface**
7. Assign **Factors** (if desired)
8. Click **OK**

Procedure – How to Add a Bounded Volume to a Surface

Note: This procedure assumes that the shape you want to measure with is already created.

1. Select **Volumes Dashboard** in **Analyze Tab**
2. Select **Add Bounded Volume** ()
3. Select the **Shape**