216 Earthwork

216.1 General

Earthwork is a generic term for all items of work, materials and operations required to construct the excavated areas and the embankments of a project.

In general, earthwork on a highway project consists of:

- **Embankment –** Compacted fill material needed to construct the roadway, excluding the base and pavement portions of the roadway and shoulders.
- **Regular Excavation –** Excavation necessary for the construction of the roadway, ditches, ponds, channel changes, or sidewalks.
- **Subsoil Excavation –** Excavation, removal and disposal of any material that is unsuitable in its original position and that is excavated below the finished grading template.

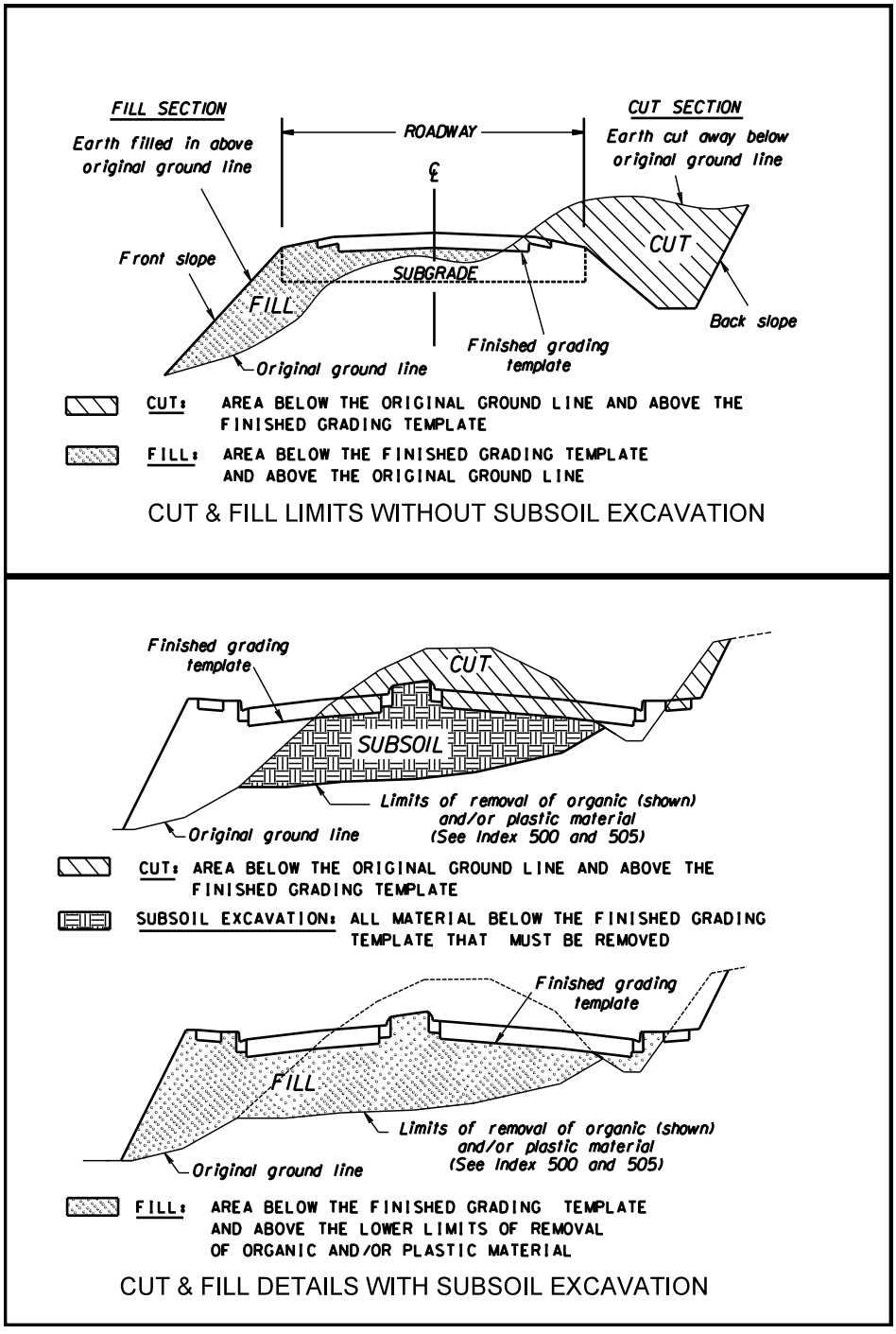
The most important roadway operation involving earthwork is constructing the roadbed. The roadbed is constructed by excavating soil from cut sections and placing soil as embankments in fill sections. In cut sections, the roadbed is built below the original ground - the original ground is excavated to the elevation of the proposed roadbed. In fill sections, the roadbed is built above the original ground - the earth fill is on an embankment.

The finished grading template is defined as the finished shoulder and slope lines and bottom of the completed base or rigid pavement for most pavements. The Department occasionally uses stabilized bases and sand bituminous road mixes. For these, consider the finished grading template as the top of the finished base, shoulders and slopes.

Figure 216.1.1 illustrates cut and fill limits and details. Additional criteria and earthwork details are found in the ***Standard Plans, Indexes 120-001, 120-002,*** and ***160-001***.

FDOT Specifications, Sections 120 and 125 define the terms, method of measure, basis of payment and pay items associated with earthwork.

Figure 216.1.1 Cut and Fill Limits (With and Without Subsoil Excavation)



216.2 Classification of Soils

The Department uses a system of soil classification that places materials into groups and subgroups based on soil fraction, liquid limit and plasticity index. This classification determines if and where the materials may be placed or left in their original position on a project. The soils survey, testing and classification of materials must be performed by a qualified geotechnical laboratory. The plans will include the information about the soil classification on the soil survey sheet and by showing the boring data soil boxes on the cross section sheets. If it is determined that an organic or plastic material must be removed below the finished grading template, the lower limits of removal of organic or plastic material will be shown to determine the area and volume of subsoil excavation.

216.3 Cross Sections

The details of cut and fill of earthwork are shown on the cross sections. The cross sections of the existing surface are usually obtained by location field survey or photogrammetry. The finished profile grades, typical section details, pavement design details, superelevation and horizontal alignments are used in combination to develop the finished template at each location where an existing cross section was obtained or generated. Sometimes it is advisable to develop and plot intermediate cross sections or half-sections to accurately determine quantities.

Cross sections cannot be finalized until late in the design process. However, preliminary cross section templates, developed early in the design process, can assist the designer in establishing many of the other design elements such as guardrail, shoulder gutter, inlets and special ditch grades. Preliminary cross sections are also used in performing the Soils Survey. Cross section templates should be plotted as soon as the alignment, profile grades and typical section details are established.

The interval selected for showing cross sections in the plans will vary according to project specific factors. For guidance see ***FDM 319.3***.

216.4 Earthwork Quantities

Earthwork quantities are calculated by the method of average end areas:

$$\textbf{CUBIC YARDS} = \frac{\textbf{EA1 + EA2}}{\textbf{2}} \textbf{ X LENGTH / 27}$$

Each set of end areas for the different types of earthwork (subsoil excavation, regular excavation and embankment) are calculated separately and shown in the appropriate column on the cross section sheets, as indicated in ***FDM 319***.

216.4.1 Earthwork Tabulation

Areas and volume for subsoil excavation, regular excavation and embankment are tabulated on the right hand side of the cross section sheet. To properly delineate and calculate earthwork quantities, the designer must be familiar with the control lines for earthwork operations .

Figure 216.4.1 Format for the Tabulation of Earthwork Quantities

(Show the appropriate tabulation on the right side of the sheet)

Projects With Limited or No Cross Sections
See Example in *FDM 216.6*

Projects With Cross Sections					
SUBSOIL EXC.		**REGULAR EXC.**		**EMBK.**	
A	**V**	**A**	**V**	**A**	**V**

216.4.2 Earthwork Accuracy

The calculation of earthwork volumes is not simple but, when performed with care and properly checked, many of the inaccuracies common in earthwork quantity calculations can be avoided. The primary causes for inaccurate earthwork quantities are found to be errors in calculating end areas and choosing inappropriate intervals between the cross sections. Correct methods and techniques for computing earthwork quantities will eliminate gross errors.

There are two methods of documenting the earthwork quantities for projects:

New construction and major reconstruction projects require the use of horizontal and vertical controlled cross sections. This is the most accurate and preferred method which involves the preparation of cross sections to define the quantities of earthwork involved.

(1) Calculate end areas and volumes by computer, when possible, and print the calculations for verification and future use by others.

(2) Plot cross section details at the largest scale the sheets will permit. Care should also be taken when plotting slopes that extend over long distances.

(3) If end areas are calculated from cross sections manually, show the breakdown of areas, etc. on the ***Design Backup*** worksheets in the ***Summary of Earthwork.xlsx*** file.

(4) When computing volumes, determine lengths between sets of end areas to compensate for volumes that do not run the entire lengths between the normal station lengths.

(5) Properly use match lines and turning lines to divide end areas when separate lengths should be used to calculate volumes.

(6) Reduce the interval between cross sections to 25 feet or less on ramps or sharp turning roadways, or determine and use the centroid of the section as the length for computing volumes.

(7) Exclude bridge spans, large culverts or other exceptions where earthwork is not required.

(8) Include quantities for fill slopes under bridges, at guardrail installations and at culvert extensions. Show extended shoulder slope on cross sections at guardrail locations (not steeper than 1:10 per the ***Standard Plans***, ***Index 536-001***).

(9) Make sure that the fill for all subsoil excavation is included in either the embankment or borrow excavation (truck measure) quantities.

RRR, intersection improvements, and minor widening projects may use working typical sections that are not horizontal and vertical controlled. These projects must meet the requirements for payment by Regular Excavation, Lump Sum (see ***FDM 216.5.1.2***).

(1) Include PDF files of working typical cross sections in the \calculations sub-directory under the proper directory for all locations where there is a change in either the existing or proposed templates.

(2) Working typicals should include the station limits of the typical, and the end areas of all cut and fill sections. Working typicals may be placed in the plans, but are not required.

(3) The thickness of the base box is calculated on the most probable base option. A plan note should also be shown in the plans stating which option was used for calculating the earthwork quantities.

(4) Extra fill material needed for the extended shoulder for guardrail placement should be documented on the ***Design Backup*** worksheets in the ***Summary of Earthwork.xlsx*** file with the final quantity being tabulated on the summary of earthwork. The quantity should be based on working typical sections showing the

extended shoulder slope on cross sections at guardrail locations (not steeper than 1:10 per the ***Standard Plans*, *Index 536-001***).

It is critical that the designer choose which method of documenting the earthwork quantities is best suited for their project with input from construction.

216.4.3 Variation in Quantities

When detailing and determining earthwork quantities, use the most probable base option within the optional base group. A plan note should also be shown in the plans stating which option was used for plotting the cross sections and calculating the earthwork quantities (see ***FDM 307.2.1***).

216.5 Earthwork Pay Items

Table 216.5.1 *provides g*uidelines for selecting the appropriate earthwork pay items.

Table 216.5.1 Guidelines for Selecting Earthwork Pay Items

Description		Control Lines	Recommended Pay Item	
			Projects with Cross Sections	Projects with Limited or No Cross Sections
Earthwork operations above the original ground line and below the finished grading template	Fill	from original ground to the finished grading template	Embankment (CY)	Borrow Excavation (Truck Measure) (CY)
Earthwork operations below the original ground line and above the finished grading template	Cut	from original ground to the finished grading template	Regular Excavation (CY)	Regular Excavation (3-R Projects) (LS)
Earthwork operations below the original ground line and below the finished grading template	Cut	from the finished grading template or original ground, whichever is lower, to the lower limits of removal of organic or plastic material	Subsoil Excavation (CY)	Subsoil Excavation (CY)
	Fill	from the lower limits of removal of organic or plastic material removed to the finished grading template	Embankment (CY)	Borrow Excavation (Truck Measure) (CY)
With significant quantities of lateral ditch or channel excavation the designer may select to pay for separately		from finished ground to the finished grading template	Lateral Ditch Exc. Channel Exc. (CY)	N/A

216.5.1 Regular Excavation

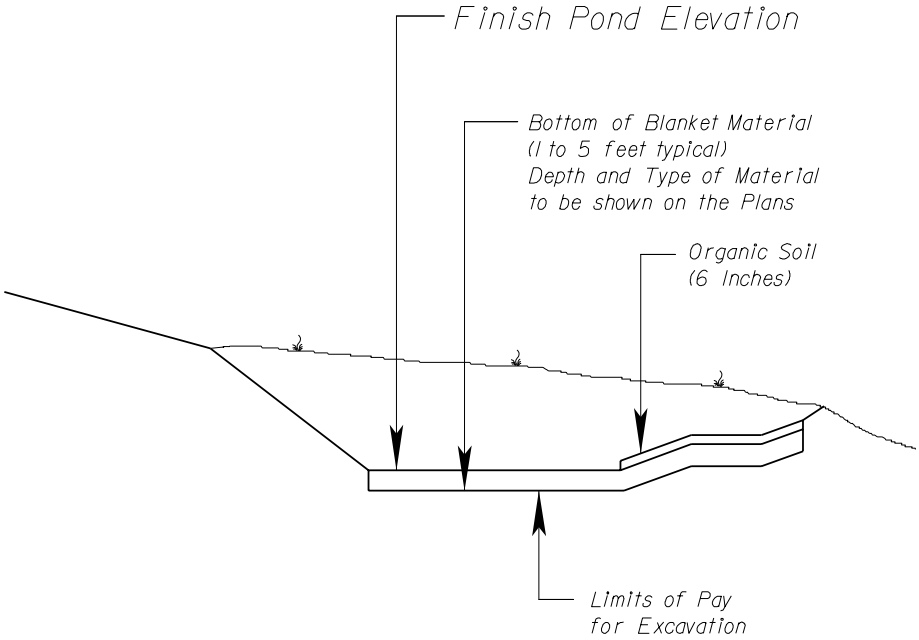
This is the most general classification of earthwork excavation. When Lateral Ditch or Channel excavation pay items are not called for in the plans, the total quantity of all excavation must be paid for as Regular Excavation. Regular Excavation may include roadway, pond and ditch excavation. Roadway Excavation consists of the net volume of material excavated between the original ground line and the finished grading template of the roadway.

216.5.1.1 Stormwater Treatment Ponds

Retention or detention areas that require considerable excavation should be summarized separately and added to the Regular Excavation. This is especially important if there is a large quantity and the area is removed from the project by some distance.

Some environmental permits now require that the plans call for excavating additional depth below the finish elevation of the bottom of a pond or ditch. They also require that the area of extra depth be replaced with “blanket material” that will either allow for percolation or not allow for percolation as required by the permit. The drawing below shows the limits of pay for excavation in this situation. The depth and type of fill material must be identified in the plans.

Figure 216.5.1 Pond Template



216.5.1.2 RRR Lump Sum Projects

The Pay Item for Regular Excavation (RRR Projects Only) - Lump Sum is used on resurfacing (RRR) projects that meet the following conditions:

(1) There are limited or no cross sections on the project.

(2) Existing typicals are reasonably consistent throughout the project.

(3) If utility adjustments are a consideration on the project, the designer will need to be sure that sufficient data is available to allow the utility to be relocated or adjusted.

(4) There are no right of way requirements on the project.

(5) There is no change in the existing horizontal or vertical alignment.

(6) There are no major special ditches on the project.

(7) There are no major intersection modifications.

(8) Show quantity of Excavation in Summary Box, but pay for as 1 Lump Sum.

Regular Excavation (RRR Projects Only) - Lump Sum may be used on intersection improvements and minor widening projects if they comply with the same listed above.

Earthwork will be paid for as Borrow Excavation (Truck Measure) and Regular Excavation (RRR Projects Only) – Lump Sum. The designer will calculate these quantities based on information obtained from the field and the proposed typical section. The designer must conduct a thorough field review to ensure existing field conditions are accurately reflected in earthwork estimates.

216.5.2 Embankment

This item includes placing material above the original ground line, or above the lower limits of removal of organic or plastic material to the finished grading template.

216.5.3 Subsoil Excavation

Subsoil Excavation consists of the excavation and disposal of any material that in its original position is excavated below the finished grading template or original ground, whichever is lower.

The soils investigation survey documents the organic or plastic material found on the project. Likewise, the cross sections and the earthwork calculations must use the lower

limits of removal of organic or plastic material in determining the quantities for Subsoil Excavation.

Where future widening of the roadway is anticipated, specify the limits of removal necessary to accommodate the future widening.

At some locations the complete removal of organic or soft soils may not be practical due to the depth. Review the subsoil excavation with the Geotechnical Engineer of Record and where constructability concerns exist, consult with the District Geotechnical Engineer to review design alternatives. If a geosynthetic reinforced design is selected, refer to ***FDM 263*** for plan content and design requirements. Additional information concerning geotechnical design can be found in the ***Soils and Foundations Handbook***.

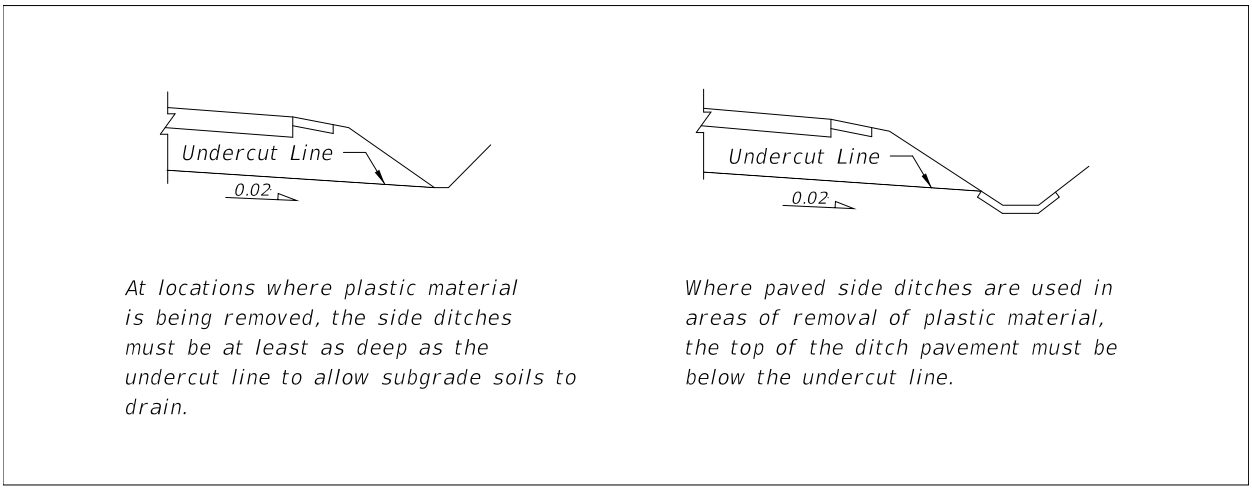
Where subsoil excavation is required due to plastic soils, ensure that adequate drainage of the pavement subgrade is provided. ***Figure 216.5.2*** illustrates the required excavation undercut line (i.e., grade and extent of excavation bottom) for flush shoulder roadways. To accommodate normal undercuts, the side ditches should be at least 3.5 feet below the shoulder break.

For curbed roadways, additional subsoil excavation may be needed beyond that shown in ***Figure 216.5.2*** or underdrains must be installed in accordance with ***Standard Plans***, ***Index 120-002***. Coordinate the removal of plastic materials with the Drainage Engineer of Record, as it may affect various drainage design elements including the profile grade of the ditch bottoms.

Tabulate subsoil excavation areas and volumes on the right side of the cross section sheets. The fill quantities (areas and volumes) must include areas and volumes required to fill the excavated areas created by subsoil removal. See example given in ***FDM 216.1***.

Do not include the payment for subsoil excavation in the pay quantities for other items no matter how small the subsoil quantity.

Figure 216.5.2 Undercut Detail of Plastic Material with Relation to Side Ditches



Embankment (fill) or Regular Excavation (cut) should be used in conjunction with the pay item Subsoil Excavation. Both Embankment and Regular Excavation are plan quantity items. The quantities are based on line and grades shown in the plans and would allow construction personnel to field verify the quantities of material used on a project. Subsoil Excavation is a field measure item, and the final pay quantity will be determined by cross section taken when the removal of the material is completed.

216.5.4 Lateral Ditch Excavation

Excavation required to construct inlet and outlet ditches at structures, changes in channels of streams and ditches parallel to the right of way, but separated from the roadway template, may be designated by the designer as Lateral Ditch Excavation.

On projects with very little of this type of excavation, this earthwork is usually included in the Regular or Roadway Excavation. If there is a significant amount of Lateral Ditch Excavation, it should be detailed, calculated and summarized on separate cross section sheets and shown separately in the Earthwork Summary.

Quantities for ***Excavation for Structures and Pipe*** must not be included in the quantities for Lateral Ditch or other excavation pay items.

216.5.5 Channel Excavation

The pay item for Channel Excavation consists of the excavation and satisfactory disposal of all material from the limits of the channel as shown in the plans. This work is generally called for by the plans and has lines, grades, typical sections and other details shown for excavating a channel change or a major modification to an existing channel or stream. This work may be significantly different from regular excavation or lateral ditch excavation, requiring draglines, barges or other special equipment. It is typically detailed, calculated and summarized separately.

216.5.6 Borrow Excavation (Truck Measure)

Borrow Excavation is the pay item used to indicate that the contractor is to furnish earthwork material from areas provided by him and generally outside the project limits. This could include material with a specific minimum bearing value for building up existing shoulders, when appropriate for the project.

Borrow material may be obtained from within the right of way of the project, if available. The proposed borrow areas must be reviewed and coordinated with the District Environmental Coordinator to minimize environmental disturbance and promote a future original appearance.

When the designer chooses the method of payment as Borrow Excavation (Truck Measure), a fill adjustment must be made to the net total fill material calculated from the plans to allow for handling. An additional adjustment (truck) is added to obtain a representative volume of material required. This is not a plan quantity item, but it is very important that a realistic determination of quantities be calculated by the designer.

216.6 Summary of Earthwork

A subtotal for each group or cross section (e.g., mainline, side street, pond) should be shown in the Summary of Earthwork box for each earthwork operation (subsoil excavation, regular excavation and embankment). This summary should be shown on the Summary of Quantities sheet. See ***FDM 307*** for information on Summary of Quantity sheets.

Figures 216.6.1 and ***216.6.2*** show examples of Summary of Earthwork boxes.

Figure 216.6.1 is an example of a Summary of Earthwork box for projects with cross sections. The summary should document all the groups' totals in one location.

Figure 216.6.1 Summary of Earthwork Box (Projects with Cross Sections)

SUMMARY OF EARTHWORK					
PAY ITEM NO.	PAY ITEM DESCRIPTION	CY		DESIGN NOTES	CONSTRUCTION REMARKS
		P	F		
0120 1	REGULAR EXCAVATION	10000.0		MAINLINE	
		800.0		SIDE STREET NAME	
		1005.0		POND NO. 1	
	TOTAL	11805			
0120 3	LATERAL DITCH EXCAVATION	5000.0			
0120 4	SUBSOIL EXCAVATION	2080.0		MAINLINE	
		1100.0		SIDE STREET NAME	
	TOTAL	3180			
0120 6	EMBANKMENT	20000.0		MAINLINE	
		7000.0		SIDE STREET NAME	
	TOTAL	27000			

Figure 216.6.2 is an example of a summary of earthwork box that should be used for projects with limited or no cross sections. The summary should show all quantities and adjustments. The adjustment percentages shown are for example only; contact District Materials or Construction Office for actual percentages to be used for each project.

Figure 216.6.2 Summary of Earthwork Box
(Projects with Limited or No Cross Sections)

SUMMARY OF EARTHWORK					
PAY ITEM NO.	PAY ITEM DESCRIPTION	CY		DESIGN NOTES	CONSTRUCTION REMARKS
		P	F		
0120 2 2	BORROW EXCAVATION				
	FILL	253.0			
	GUARDRAIL LOCATIONS	70.0			
	CROSS DRAINS	100.0			
	SUB TOTAL	423.0			
	FILL ADJUSTMENT (20%) (423 X 0.20)	85.0			
	SUB TOTAL	508.0			
	TRUCK ADJUSTMENT (25%) (508 X 0.25)	127.0			
	TOTAL BORROW EXCAVATION	635			
0120 71	REGULAR EXCAVATION (3R PROJECTS ONLY)	200		LS-QTY FOR REFERENCE ONLY	

The pay items used will be:

Regular Excavation (RRR Projects Only) 1 (LS)
Borrow Excavation (Truck Measure) 635 CY