MONTANA DEPARTMENT OF TRANSPORTATION

ROAD DESIGN MANUAL

Chapter 13

Quantity Summaries

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Chapter 13

Quantity Summaries

In addition to preparing clear and concise construction plans, as described in Chapter 12, the design team needs to compile an accurate estimate of the project construction quantities. This information leads directly to the Engineer's Estimate, which combines the computed quantities of work and the estimated unit bid prices. An accurate estimate of quantities is critical to prospective contractors interested in submitting a bid on the project. Chapter 13 presents detailed information on estimating quantities for highway construction projects.

13.1 GENERAL INFORMATION

13.1.1 Guidelines for Preparing Quantity Summaries

The design team should consider the following guidelines when preparing quantity summaries:

1. **Specifications.** Cross-check all items against the *Standard Specifications,* the *Supplemental Specifications* and Special Provisions to ensure that the appropriate pay items, methods of measurement, and basis of payment are used. Items that are not addressed in the *Standard Specifications* or *Supplemental Specifications*, or items that are intended to be measured differently than identified in the specifications, need to have a Special Provision or Note included in the plans.
2. **Computations.** For the summaries, prepare a separate computation sheet for each item used on the project. Include all computation sheets in the project work file.
3. **Rounding.** The quantity of any item provided in the summaries should match exactly with the figure provided on the computation sheets. Note any required rounding of raw estimates on the computation sheets. Unless stated

otherwise, do not round the calculations until the value is incorporated into the summary frames.

4. **Quantity Splits.** Some projects will require quantity splits for work conducted under various financing arrangements. The quantities for District-wide pavement marking projects do not need to be split. Determine the need to separate project quantities into funding categories during the Preliminary Field Review.

   Two types of project splits are utilized: a hard split, which is a detailed separation of quantities, and a soft split, which splits the quantities using a ratio based on the major cost items on a project.

   Hard splits are required when the following circumstances occur:

   a. A portion of the project is inside a Reservation boundary
   b. Different funding sources are utilized
   c. The project has local government involvement/funding
   d. The project is located in more than one Financial District
   e. Special funding considerations (e.g., items that are fully funded by either state or federal funds on projects that are otherwise dual funded)

   For projects requiring hard splits, organize the summary frames to readily identify each division subtotal and the total of all divisions. Show subtotals in the summaries for all hard splits.

   Soft splits are utilized when the following circumstances occur:

   a. Portions of the project are in different counties
   b. The project is inside and outside of a urbanized boundary
   c. The functional classification of the route changes within the project limits

   Quantity subtotals are not required for soft splits and no changes to the plans are necessary. A ratio for the soft split will be provided to the Contract Plans Bureau on the plans submittal form.

   To determine the ratio for a soft split, calculate the cost of major items on a project. These typically include surfacing (plant mix and base), grading (including unclassified borrow), major structures (bridges, retaining walls), lump sum items, mobilization and traffic control. The ratio is then determined based on the cost in each portion of the project.

   Show all splits if more than one split applies to a project.

5. **Preliminary Cost Estimate.** Use the total values from the summary frames to develop the Preliminary Cost Estimate. All items described in the plans that are to be included in the cost estimate must be shown in the summaries. The Preliminary Cost Estimate is used for planning purposes in developing MDT's 5-year Tentative Construction Plan, and to help ensure that projects remain within budget. A link to the additional cost estimating tools provided on the MDT Website is shown in Section 13.2.

13.1.2 Quantity Estimates

For most projects, use computer software to develop the quantity estimates to the extent possible. The design team should manually verify automated calculations, as needed. For small projects, it may be more efficient to manually calculate quantities.

13.1.3 Units of Measurement and Rounding Criteria

Report quantity estimates in summary frames for all contract bid items consistent with the terms and units of measurement presented in the *Standard Specifications (1)*. Unless stated elsewhere in this chapter, round quantities consistent with the summary frames rounding criteria tables presented in Appendix J. Appendix J also provides a list of quantity conversions (e.g., rates/factors) to establish a consistent approach developing quantities for MDT bid items.

13.1.4 Item Codes

Contact the Contract Plans Bureau or the Contractors System link on the MDT website to obtain a copy of the official item list.

Each item used for measurement and payment in construction is identified by a 9-digit item number with a description. These numbers are used by the MDT's Construction Management System for tracking the project through construction. Note that the first three digits of the item number are coordinated with the *Standard Specifications (1)*. For example, Item #606010030 "Guardrail - Steel" is referenced to Section 606 "Guardrail, Median Barrier Rail and Guide Post" of the *Standard Specifications*.

The Contract Plans Bureau is responsible for numbering and naming the various items used in construction. Contact the Contract Plans Bureau or the Contractors System link on the MDT web site to obtain a copy of the official item list. Submit all proposed changes or additions to this list to the Contract Plans Bureau. The list of item codes is provided at the following link on the MDT website:

MDT Item Codes (English)

13.2 PROJECT COST ESTIMATES

Project estimates are used by Fiscal Programming and the Districts to develop the 5-year Tentative Construction Plan (TCP or Red Book) to ensure that sufficient funds are available for construction. The TCP is MDT's best estimate of when projects will be let and what the costs will be. The Engineering Division uses the TCP to prioritize project design. If cost estimates are too low, there will not be enough funding to fund all of the designated projects. As a consequence, resources will be focused on projects that can't be let to contract until the next fiscal year. If cost estimates are too high, the TCP will under-estimate the number of projects designated for the fiscal year.

During project development, several cost estimates are prepared to determine and refine the expected project construction costs. Project cost estimates are

updated and included in all project milestone reports. MDT cost estimating tools and guidance is found at the following link on the MDT Website:

MDT Cost Estimating Information

The Engineer's Estimate is developed by using the final estimates from the various Sections and Bureaus involved with the project. The Contract Plans Bureau will be responsible for collecting and distributing the various units' final cost estimates to the Board of Review. The Board of Review includes representatives from the Construction Bureau, Road Design Section, Pavement Design Section and Contract Plans Bureau. The Board of Review will review and adjust the major bid item prices as deemed necessary. These items typically may include excavation, aggregate surfacing, plant mix surfacing, asphalt milling, erosion control, mobilization and miscellaneous work. The Contract Plans Bureau will review all other bid prices and prepare the Engineer's Estimate.

13.2.1 Estimating Procedures

When preparing a detailed cost estimate the design team should note the following:

1. **Funding Splits.** Some projects may have two or more funding sources. For example, where bridges comprise a substantial percentage of the total project, they may be funded separately under their own project coding. For these types of projects, separate cost estimates are required for each funding source based on the quantities within that particular funding source. The separation of quantities for funding splits will be determined during the project development.
2. **Quantities.** Show all estimated project quantities from the summary frames on the cost estimate. Some items may be shown as information purposes only. Do not include these items in the cost estimate. The totals from the appropriate summary frames are used in determining the cost estimate. Note that some summary frame totals are added to other frames (e.g., Additional Surfacing Frame totals are added to the Surfacing Frame). Therefore, the design team must be careful not to double count these quantities. Some items may have quantities shown in more than one frame. Combine these quantities when computing the cost estimate.
3. **Unit Prices.** For some items, particularly Traffic Control, Erosion Control, and other Lump Sum bid items, the estimating tools may not be appropriate for determining unit bid prices. Review of similar projects and input from the District Construction personnel should be used to aid in determining the unit prices.

13.3 EARTHWORK COMPUTATIONS

13.3.1 Computations

As stated in Section 13.1.2, most highway mainline earthwork computations are determined using the design software. Earthwork quantities for small projects, approaches, side roads, ditches and additional grading features may

need to be calculated manually. For either method, earthwork volumes are calculated using an average end-area method. The following are items typically needed for calculations:

1. horizontal and vertical roadway alignments;
2. typical sections;
3. terrain data;
4. shrink and swell factors (unclassified excavation projects);
5. cut and fill slope rates; and
6. identification of sections not to be included (e.g., bridge sections).

End-areas for each cross section of the mainline are used for mainline quantities. Examples of manual computations for end-area calculations are provided in Appendix K.

13.3.2 Shrink and Swell Factors

For projects using unclassified excavation as the grading bid items, adjust excavation and/or embankment quantities, calculated either manually or by the computer, by the appropriate shrink and/or swell factor(s). The use of more than one factor for a project is often necessary to describe the characteristics of the excavated material. However, do not apply both shrink and swell factors to the same material. The factors used in the calculations will depend on the soil type, quantity to be moved and historical data. The applicable shrink factors to be used in the calculations are provided by the District construction personnel, based on historic values for the project location and scope. Swell factors, when necessary, are determined by geotechnical review of the soil survey information. Typically, shrink factors range from 20 to 30 percent when adjusting embankments, and 20 percent is often the assumed value used for preliminary design in the absence of historical data. Swell factors generally range from 5 to 15 percent when applied to excavation of rock.

The unadjusted excavation quantities are still measured for payment.

For most MDT projects, the shrink factor is applied to proposed embankments, as this simplifies the calculation for unclassified borrow and more closely represents the amount of haul proposed. For projects with multiple shrink and swell factors, it is easier to track material volumes by making adjustments to the excavated materials. However, the unadjusted excavation quantities are still measured for payment.

13.3.3 Balancing

For most large projects, it is desirable to provide an earthwork balance for the project (i.e., excavation equals adjusted embankment quantities). However, due to the degree of accuracy of shrink/swell factors and the nature of grading work, do not make an extensive effort to produce an exact zero earthwork balance. Typically, a project is considered balanced if the borrow/excess quantity is within 3 percent of the total excavation quantity. If the earthwork is balanced within 3 percent, show the borrow or excess quantity with an asterisk (*) and a note stating “For informational purposes only” if excess, or a note stating “Include the cost of the borrow quantity in the cost of other grading items” if borrow is

required. A small amount of excess is preferred over a small amount of borrow on a project, because in most cases, a disposal site for a small excess quantity can be easily found. A small amount of borrow will likely be bid at an inflated price, if measured for payment. Unbalanced projects will require the contractor to haul extra material (e.g., borrow) or remove excess material (e.g., excavation) from the project, which will typically increase construction costs. Balancing within the project limits can be accomplished by revising the profile grade line, cut and fill slopes, ditch profiles, and by daylighting sections.

To determine if balancing is appropriate for a project, consider the following guidelines:

1. **New Construction/Reconstruction Projects**. For new construction, make every reasonable effort to balance the project. For reconstruction projects, balancing the project is desirable; however, its importance is secondary to the project purpose and need. Modernizing a facility generally results in greater width, improved sight distances, and flatter slopes which all contribute to the amount and location of grading required. Balancing earthwork should not be accomplished at the expense of the improved roadway geometrics. For some locations, balancing earthwork will not be cost effective or desirable, due to poor or saturated subgrade materials or physical constraints. It is often desirable to build over existing side borrow roadways to avoid the need for subexcavation and special borrow.
2. **Rehabilitation Projects.** Grading on rehabilitation projects is generally dictated by the project scope, with little room for adjustment. Determine the need for balancing the project on a project-by-project basis.
3. **Other Projects**. For urban projects, interchange projects and pavement preservation projects, it is generally impractical to provide a balanced grading design. Therefore, it will not be necessary to balance earthwork quantities on these project types.

It is generally not cost effective to balance a project over long distances. On long projects, provide several intermediate balance points. Preferably, the distance between balance points should not exceed 2 miles. Hauling material across bridges to achieve a balance is undesirable.

13.3.4 Mass Diagram

On projects where the grading is bid as unclassified excavation, prepare a mass diagram to illustrate how the grading will be accomplished. Do not include the mass diagram in the final plans package submitted to the Contract Plans Bureau.

To better understand the application of a mass diagram, consider the following guidelines:

1. **Curve.** The mass diagram curve illustrates a cumulative, algebraic summation of the adjusted excavation and embankment quantities, typically from the start of the project. A rising curve in the direction of summation indicates excavation exceeds embankment, and a falling curve indicates embankment exceeds excavation. Inflection points (e.g., curve crests and sags) represent points where the net earthwork changes from a

cut to a fill or vice versa. The horizontal distance on the mass diagram represents the horizontal distance on the ground in stations. The vertical distance represents the net accumulation of earthwork volume in cubic yards.

2. **Balance Line.** A balance line is any horizontal line which intersects the mass summary curve in at least two places. This indicates that the excavation and embankment quantities are balanced between the two intersecting points. These intersection points are called balance points. For most projects, the balance line is typically started at zero at the beginning of the project.
3. **Balance Points.** Once the grades have been finalized and the earthwork has been balanced, compute the balance points and the earthwork quantities for summarization. It is not always necessary to compute earthwork quantities for each balance point. Several small balance points may be combined if they are within distances of approximately 1,000 feet. Example computations are provided in Appendix K.
4. **Borrow/Excess.** If the grading curve does not end on the balance line, draw a vertical line from the curve to the balance line. Note the amount of borrow or excess next to the vertical line. The location of the borrow pit or waste disposal location will typically be determined by the contractor. As stated in Section 13.3.3, long distances between balance points or over bridges are generally not cost effective. To force balance a section, the balance line may need to be adjusted up or down within the limits of a project. Downward adjustments in the balance line indicate the need for borrow at the point of force balancing, and upward adjustments indicate excess material.
5. **Quantities**. Show the adjusted amounts of excavation and embankment on the mass diagram between each set of balance points.

13.3.5 Unclassified Excavation

The following presents the procedures for recording unclassified excavation quantities on the Grading and Additional Grading Frames:

1. **Roadway Quantities.** Typically, all the roadway grading quantities are shown on one line of the Grading Frame. If forced balancing within a project is required, represent each side of the forced balance point on a separate line. Include columns for each of the following as appropriate, based on how the earthwork was estimated:
    a. **Unclassified Excavation.** Always include the unadjusted volume of excavation, as this is measured for payment for all cases.
    b. **Adjusted Excavation.** Only shown when excavation is adjusted due to rock on the project. Indicate as “FOR INFORMATION ONLY”.
    c. **Emb.+.** This is the amount of adjusted embankment based on the project shrink factor, and is typical for most unclassified excavation projects. Indicate as “FOR INFORMATION ONLY”.
    d. **Unadjusted Embankment.** This represents the actual volume of embankment, and is only used when all excavation is adjusted for a project with rock excavation. Indicate as “FOR INFORMATION ONLY”.

e. **Excess Excavation/Unclassified Borrow.** Typically a project will result in either excess material or the need for borrow. This quantity is only shown in the Grading Frame total row based on all project volumes. Excess Excavation is shown "FOR INFORMATION ONLY". Unclassified Borrow is measured for payment unless it is 3 percent or less of the total Unclassified Excavation quantity.

2. **Additional Grading**. Additional grading is the excavation and embankment required for constructing the items of work in addition to the mainline roadway template required for the project. The Additional Grading Frame will include all the same columns used in the Grading Frame, except for Excess Excavation/Unclassified Borrow and may include an additional column labeled "ADD. UNCL. EXC." Embankment quantities should always be included in the roadway quantities. Excavation quantities fall into two categories as follows:

   a. **Suitable Material.** If the material is suitable, include the quantity in the mainline roadway quantities. Material is considered suitable if it consists of an acceptable soil type and the quantity is large enough to make handling practical. Examples include approaches, widening, and slope flattening.

   b. **Unsuitable Material.** If the material is unsuitable, designate the quantity as an "ADD. UNCL. EXC." item but do not include this item in the mainline roadway quantities. Material is considered unsuitable if:

      - It contains soil or organic matter unsuitable for foundation material, regardless of moisture content; or
      - It is too wet to be properly compacted and cannot be dried within a demonstrated reasonable time frame prior to incorporating into work. Excessive moisture alone is not sufficient cause for determining unsuitable material.

      Examples include material near inlet and outlet ditches, and existing ditches graded to drain.

   Do not use the additional excavation item ("ADD. UNCL. EXC.") as a catch-all for late entries. Items with significant volumes that are added late in the design phase require inclusion in both the mainline roadway quantities and the mass diagram to reflect the changes such quantities have on balances and volumes.

3. **Topsoil Replacement**. Topsoil replacement is the volume of embankment required to fill the void left after the topsoil has been removed. This quantity mathematically re-establishes the ground line to its original state prior to topsoil removal. Adjust topsoil replacement quantities by employing the same shrink factor used for mainline grading quantities in the area that the topsoil was removed. Include topsoil replacement in the roadway quantities for all projects. This results in representing topsoil replacement as an embankment or borrow quantity. Show the project total for topsoil replacement as an "EMB+" quantity in the "INCL. IN ROADWAY" column of the Additional Grading Frame. Although this quantity is shown once in

the summary frame, it should be split out every 30 stations for inclusion in the earthwork run and mass diagram to better represent its effect on earthwork balances.

4. **Subexcavation.** On reconstruction projects, subexcavation is generally a specified depth of excavation of unstable material below subgrade in existing fill or natural ground. Always specify subexcavation depth from the top of the subgrade elevation unless an unusual circumstance justifies another reference. Typically, this material can be excavated using the equipment and procedures normally used for unclassified excavation. If the material is unsuitable for embankment material, the subexcavation also includes the disposal of the material. Material is considered unstable if it contains saturated soils, mixtures of soils, and/or organic matter that is unsuitable for embankment material. Examples of unstable material include swelling clays or silty soils having low support value or subject to frost heaving.

   An unclassified excavation quantity is used to remove subexcavated material and either place it in embankments or dispose of it. If the material may be used for embankments, include the quantities in the earthwork run and denote the quantities shown in the Subexcavation Frame with an asterisk ("*") and a note stating "INCLUDED IN ROADWAY QUANTITIES." Record these same quantities in the "INCL. IN ROADWAY — UNCL. EXC." column of the Additional Grading Frame. If the material is to be disposed, record the quantity in the "UNCL. EXC." column of the Subexcavation Frame only. This quantity should not be included in the Additional Grading Frame or the earthwork run.

5. **Subexcavation Replacement.** If subexcavation is not replaced with special material, include the adjusted quantities in the earthwork run and show these quantities in the "INCL. IN ROADWAY – EMB+" column of the Additional Grading Frame. If special borrow is provided, show the actual quantity of special borrow in the Subexcavation Frame. The *MDT Sample Plans* provide additional information.

6. **Unclassified Borrow.** Unclassified borrow for embankment construction is contractor-furnished material excavated from outside the right-of-way or construction easement areas. Sources for this material must be approved by MDT and meet current environmental and cultural resource preservation regulations. Show the amount of unclassified borrow in the Grading Frame and mass diagram. It should be noted that the unclassified borrow is assumed to have the same shrink/swell factor and structural value as the unclassified excavation on the project.

13.3.6 Embankment-in-Place Projects

Use the embankment-in-place item on projects with embankment quantities less than 25,000 cubic yards where embankment exceeds the excavation quantity. In addition, embankment-in-place may be used when the embankment quantity exceeds the excavation quantity and the embankment quantity is between 25,000 and 75,000 cubic yards.

The use of embankment-in-place will be made on a case-by-case basis and should be discussed at the Alignment and Grade Review stage. Some of the

following factors should be considered in the decision to use embankment-in-place.

- The embankment greatly exceeds the excavation.
- The use of embankment-in-place is putting too much risk on the contractor – recognizing that embankment-in-place typically costs two to three times more per cubic yard than unclassified excavation.
- The project includes other types of materials such as special borrow in the top 2 feet of the subgrade that would require different methods of measurement, possibly from the same source.
- The mass diagram provides useful information regarding the movement of earthwork.

The use of embankment-in-place should not replace good design practices and the evaluation of in-situ soils and other grading considerations.

The following presents the procedures for recording the embankment-in-place quantities in the Grading and Additional Grading Frames:

1. **Shrink/Swell Factors**. Do not adjust the excavation or embankment quantities with shrink or swell factors.
2. **Additional Grading Frame**. Show both the embankment and excavation of suitable material quantities in the Additional Grading Frame. Suitable material is defined in Section 13.3.5, Item 2. Add the totals from the Additional Grading Frame to the Grading Frame.
3. **Minor Excavation.** Additional grading items consisting of small excavation quantities and/or excavation of unsuitable material will be paid as embankment-in-place. Unsuitable material is defined in Section 13.3.5, Item 2. Show these excavation quantities in the "ADD. EMB. IN PLACE" column of the Additional Grading Frame and total. This quantity is not used to determine the amount of borrow required for the project.
4. **Topsoil Replacement**. Show the project total for topsoil replacement as an "EMB. IN PLACE" quantity in the Grading Frame. However, it should not be adjusted for shrinkage.
5. **Subexcavation.** An embankment-in-place quantity reflects the removal of subexcavated material that is either placed in embankments or disposed of. Show the quantity as a line item in the Grading Frame. Denote the total of the Subexcavation Frame with an asterisk ("*") and a note stating "Included in the Grading Frame."
6. **Subexcavation Replacement.** If subexcavation is not replaced with special material, no subexcavation replacement quantity is needed, as the subexcavation is already measured as embankment-in-place. If a special material is required, show the actual quantity as a special borrow item in the Subexcavation Frame.
7. **Mass Diagram.** A mass diagram is not required for embankment-in-place projects.

13.3.7 Miscellaneous Considerations

In addition to the above, the following information provides additional considerations when determining earthwork quantities. Section 13.6.9 also provides considerations for grading with rock.

1. **Street Excavation.** Street excavation is typically used on urban projects and consists of the excavation of all material within the specified template. Street excavation should be utilized when the design team anticipates that material is present that is not normally encountered in typical unclassified excavation (e.g., abandoned pipe, old foundations, curbs and sidewalks). Street excavation is typically used instead of, not with, unclassified excavation. When both are used on a project, the location where each is measured must be specifically defined.
2. **Digout Excavation.** Digout excavation is used for removal of the existing roadway and unstable subgrade materials for projects that do not have other grading items. The District Office and the Geotechnical Section are responsible for determining the need for and location of digouts. The design team is responsible for incorporating their recommendations onto the plans. The excavation and disposal of existing surfacing and subgrade is measured and paid for by the cubic yard of "Digout Excavation." Special material is required for the subgrade portion of the digout replacement, and is measured and paid for as special borrow or as special backfill as determined by the Geotechnical Section and shown in the Digout Frame. Where digouts are required, include a detail showing all removal and replacement thicknesses in the plans.
3. **Muck Excavation.** Muck excavation is removing and disposing of unsuitable material in cut sections or below the natural ground line in embankment sections. Material defined as muck must be deemed unsuitable, as defined above, and is unable to be excavated using the same equipment and methods as for unclassified excavation. Muck excavation and muck excavation replacement material is called out in a similar fashion to subexcavation of unsuitable material, but in the Muck Excavation summary frame. Muck excavation is only used on projects with another grading bid item (e.g., unclassified excavation, street excavation, or embankment-in-place). For projects without grading, use digout excavation.
4. **Unclassified Channel Excavation.** Unclassified channel excavation is the excavation and disposal of all material for either the construction of new water courses and channels or the modification (e.g., widening, deepening, straightening) of existing channels. Unclassified channel excavation is typically specified when the excavated material is not used to construct roadway embankments.
5. **Special Borrow.** Special borrow for embankment construction is material that has a specific minimum R-value or soils-class designation. Typically, special borrow is contractor-furnished material excavated from a Department-approved source outside the right-of-way or construction easement areas. Use the following guidelines where special borrow is required:

R-value, also known as the resistance value, is the ability of the soil to resist lateral spreading due to an applied vertical load.

a. **Reducing Surfacing Section Thickness.** To reduce a surfacing section's depth and cost, its design may be based on a minimum R-value, for the top 2 feet of subgrade that is higher than that of readily available material. This practice frequently requires the use of special borrow. In this case, for the top 2 feet of subgrade, calculate the quantity of special borrow required from a MDT-approved source rather than relying on a special provision to specify the material's minimum R-value or soils-class designation. The use of a special provision, in this case, generally results in a cost increase and requires the contractor to selectively grade the project to meet the requirements. Without specific guidance, the contractor will estimate the quantity and source of the special borrow material, and any uncertainties will tend to produce overly conservative estimates and higher bid prices from the contractor. If special borrow is recommended to reduce the surfacing section thickness, the special borrow may be treated as either part of the surfacing section or included in the subgrade. Refer to Section 12.3.6 for guidance as to how the special borrow should be shown. Where special borrow that is used to reduce the surfacing section is included in the subgrade, it should not be shown in the profile view. For both methods of special borrow placement, ensure that the mass diagram and the grading quantities reflect roadway construction to the bottom of the special borrow.

b. **Unsuitable Material Replacement.** If special borrow is recommended to replace unsuitable material, do not consider it as part of the surfacing section. The subexcavation limits, depth and replacement material (i.e., special borrow) will be shown in a detail. The location and depth of special borrow will be designated by cross-hatched areas on the profile and cross sections. The roadway template shown on the cross sections will be at the bottom of the surfacing section. Ensure that the mass diagram and the grading quantities reflect roadway construction to the bottom of the surfacing section; however, do not include special borrow for subexcavation in the grading quantities or mass diagram. In addition, do not include subexcavation material in the grading quantities or mass diagram if disposed outside the roadway template.

   Where special borrow is specified, verify the material's availability and cost effectiveness. The required material may not be available in close proximity to the project or may be too costly or difficult to obtain from landowners. If an excessive price for special borrow is anticipated, it may be cost effective to redesign the roadway typical section. Discuss these issues during the Alignment and Grade Review meetings with District Construction, Materials, and Right-of-Way personnel. The design team should also discuss with District Construction how special borrow will be measured. Special borrow is typically measured in place and no shrink factor is applied. However, District personnel may elect to measure special borrow at the source (borrow site). A shrinkage factor needs to be

applied to the material when it will be measured at the pit, and it is represented as Excavation Special Borrow in the plans, special provisions and estimate.

6. **Approach Grading.** The approach grading will be paid the same as the mainline grading. Approach fills will utilize 6:1 slopes within the clear zone, regardless of fill height. This does not apply where the approach is shielded with guardrail. See the *MDT Detailed Drawings* for cut and fill slopes beyond the clear zone. The fill slopes on public approaches will at least match the existing slopes.

   More detailed earthwork calculations may be necessary for approaches involving a significant realignment (e.g., button hook approaches) or change in grade. Details that include a plan and profile should be provided for public approaches. For private or farm field approaches, show the horizontal alignment with the appropriate curve radii on the plan sheet. Also provide a profile of the approach on a detail sheet.

7. **Widening Behind Guardrail**. Additional embankment material and/or surfacing material is required for slope flattening behind guardrail. See the *MDT Detailed Drawings* for configuration of slope flattening. Use aggregate surfacing material for material placed above subgrade. Depending on the quantity involved, use either embankment or aggregate material for material placed below the subgrade. For projects without grading, widening behind guardrail end sections may be measured as each, without calculated volumes. This should only be used when the work can be accomplished within the existing right-of-way.

13.4 DRAINAGE COMPUTATIONS

Chapter 11 presents principles and criteria for the design and consideration of pipes, culverts, culvert ends, bedding material, riprap, irrigation facilities, storm drains and other drainage items. The design team should note the following for measuring and determining quantities of drainage items:

1. **Pipe Sizes**. Mainline culverts will be 24”diameter or greater. Approach pipes are typically 18” in diameter unless a hydraulic analysis indicates a larger size is needed. The culvert size indicated in the plans should match the bid item description.

2. **Optional Pipe.** On projects where optional material for mainline culverts is appropriate, specify all options for each culvert installation, as recommended by the Hydraulic Section. Indicate the size and thickness or class of each optional pipe option indicated, including the type of coating required. Irrigation or siphon should be noted, if applicable. Specify the standard corrugation sizes for steel and aluminum pipes and note any exceptions. For each option, compute and report separate quantities for bedding, foundation material, concrete, and geotextile material. Information on culvert size and any special requirements for thickness, class and/or corrugation size will be furnished by the Hydraulics Section for any culvert larger than 24 inches on the mainline and 18 inches on the approaches. Plastic options may be included for approach pipes. List the approach pipes in a separate summary.

3. **Alternate Culvert Material Bids.** All culverts that are greater than 10 feet in diameter, and where steel and concrete are considered appropriate materials, must be bid as alternates. Provide an alternate culvert frame for each material.
4. **End Sections**. List the appropriate end section only if a new one is required. If the end section is removed and relayed, leave the "End Section" column in the Culvert Summary blank. Include the length of the end section in both the remove culvert and relay culvert columns, and note the end section is to be relayed in the remarks column.
5. **Basic Bid.** When steel is an option, the basic bid culvert is always steel pipe. Therefore, the size, quantity, length, etc., for the culvert is the same as that for steel pipe, even though these characteristics may differ for pipe options (e.g., concrete pipe). If steel pipe is not an option, the basic bid item for culvert is the quantity of concrete pipe. If only one type of culvert is specified, the basic bid item is the quantity of that particular pipe.
6. **Culvert Recap Frame.** Summarize the basic bid items of the Culvert Summary Frame in the Culvert Recap Frame and present the total length of each pipe size and the total quantities for bedding material, concrete, foundation material, relay pipe, geotextile, remove pipe and riprap. List irrigation pipe and siphons separately from drainage pipe in the recap. Reference the pipe material, if only one culvert option is specified. The Culvert Recap Frame is only used when optional pipe material is used.
7. **Non-Optional Pipe**. On projects where optional culvert material is inappropriate (e.g., the type of material is specified), the Culvert Frame (No Option) should be used. Use this frame only if pipe options are not given on the project (e.g., an overlay and widening project where existing culverts are only being lengthened). If both optional and non-optional pipes exist in the project, use the Optional Culvert Frame.
8. **Storm Drains.** Storm drain designs will be prepared by the Hydraulics Section including trench and bedding details. Use the Storm Drain Frame to record quantities for storm drain culverts and appurtenant items. For most projects, the option bid provision will not apply to storm drain installations. Where options are proposed, the Hydraulics Section will provide the recommendations for storm drain installation. Include this information in the summaries and indicate the optional sizes and material types. Where optional materials are specified, the basic bid item is concrete. The design team will be responsible for calculating the quantity of trunk line, lateral lines, trench excavation, bedding, and length of removed storm drain. Record all quantities for the storm drain facility in the appropriate frames. Storm drain pipe bid lengths are measured from center to center of manholes and drop inlets. Trench excavation is calculated using the "bid" length of pipe. Bedding is calculated using the actual pipe length (length of pipe from inside wall to inside wall of manholes and drop inlets).
9. **Water Mains.** List water mains in a separate frame from storm drains because they are normally funded separately and include items not applicable to storm drains.

10. **Existing Culverts.** List the size, length and type of pipe for all culverts to be removed. Culvert removal will be paid by the linear foot of pipe removed regardless of pipe size. Relaying of culverts is measured and paid per length of culvert to be relayed regardless of pipe size. Lengthening existing culverts is measured and paid per length and size of new pipe. See Chapter 11 for criteria on culverts and extensions.

    Existing pipes that are plugged and abandoned will be paid per each. Existing pipes that are filled and abandoned will be paid based on the volume of material required to fill the existing pipes. The volume will be determined based on the nominal diameter and effective length of the pipe.

11. **Trench Excavation.** Trench excavation is not measured for payment. The quantity of trench excavation is shown for informational purposes. Trench excavation is typically specified where vertical trench walls are necessary and the trench width is provided (e.g., storm drain). Calculate the quantity of trench excavation by the volume bounded by the bottom and length of the pipe and by vertical planes 1.5 feet outside the pipes inside wall or to the width and depth of the bedding/foundation material, whichever is greater. The cost of trench excavation is included in the unit price bid per linear foot of new storm drain, and associated bedding/foundation material.

12. **Riprap.** The Hydraulics Section will specify both the use and dimensions of riprap for permanent erosion control in conjunction with pipe installations. Where excavation is required for riprap placement, the cost of excavation is included in the unit price bid for riprap. For riprap installations at bridges, the type, quantities, and design data are determined through coordination with the Hydraulics Section and the Bridge Bureau.

13. **Clean Culverts.** The Federal Highway Administration (FHWA) has determined that there will be no federal participation for cleaning culverts less than or equal to 48". Federal participation for culverts greater than (>) 48" will be determined on a case-by-case basis. This also applies to off-system projects, even though MDT is not responsible for maintenance.

    Consequently, do not include culvert cleaning on projects unless FHWA has determined that participation is appropriate or unless MDT has agreed to use state funds for culvert cleaning.

14. **Pipe Length.** Draw cross drains to scale at the proper flowline on the nearest template cross section. See Chapter 11 and the *MDT Detailed Drawings* for end section criteria and dimensions. If the installation is perpendicular or skewed less than 5 degrees, then the pipe length may be scaled directly from the cross sections. Also consider the following:

    a. Do not bid FETS (Flared End Terminal Section) and RACETS (Road Approach Culvert End Treatment Section) separately. Include them in the length of pipe.

    b. Where beveled ends are used, measure the pipe length along the pipe flowline.

    If the pipe is skewed more than 5 degrees, scale its length along the skewed line.

No additional pipe length is required where skewed beveled end sections are provided on a skewed pipe. However, if end sections are perpendicular to the centerline of the skewed pipe, additional pipe length is required.

15. **End Treatments**. Quantities for cutoff walls, concrete edge protection and riprap for each pipe size are presented in the *MDT Detailed Drawings*. Adjust end treatment quantities for skewed beveled end sections as follows:

Equation 13.4-1

$$T = \frac{Q}{\cos\theta}$$

Where:

T = adjusted quantity, cubic yard
Q = quantity from the *MDT Detailed Drawings*
θ = angle of skew, degrees

16. **Bedding and Foundation Material**. For culverts less than or equal to 48 inches in diameter, bedding is paid for with the cost of the culvert and does not need to be shown in the Culvert Summary. For culverts greater than 48 inches in diameter, bedding must be quantified and paid for separately and specified in the Culvert Summary in accordance with the *MDT Detailed Drawings*. Where foundation material is specified, it is quantified and measured for payment in all cases.
17. **Stockpasses and Vehicular Underpasses.** Stockpass and vehicular underpass lengths are measured along the invert of the structure. The quantities for vehicular underpasses should be recorded in a separate summary frame.

13.5 ROADWAY COMPUTATIONS

The Pavement Analysis Section is responsible for determining the type of finished surface, pavement material type and various course thicknesses. The design team is responsible for recording this information on the construction plans and calculating the roadway quantities. Use the criteria and procedures presented in this Section to prepare the typical sections and quantities. The basis for roadway quantities is presented on the Notes Sheet.

13.5.1 Typical Section Geometrics

The following sections present recommended procedures for determining the horizontal dimensions of various surface courses. These horizontal dimensions are used for developing the surfacing quantities and for field construction staking. Surfacing thicknesses are typically identified on the typical sections in 0.05-foot increments; however, depths may be specified to 0.01-foot increments for some applications The precision is used to identify thicknesses of existing materials is also 0.01–foot, when applicable.

13.5.1.1 Symmetrical Sections

The most commonly used typical section is the two-lane highway on a tangent alignment with normal cross slopes. In this typical section, the dimensions of the subgrade width and intermediate surfacing courses are symmetrical about the centerline. The finished roadway width will be determined according to the criteria in the *MDT Geometric Design Standards* or as determined during the Preliminary Field Review *(2)*. Example calculations are provided in Appendix K.

13.5.1.2 Unsymmetrical Sections

Where sections are not symmetrical about the centerline, compute and record the widths to the left and right of centerline separately. Unsymmetrical sections exist with each superelevated section and with divided highways where inside and outside shoulders have different widths. The widths of unsymmetrical section are determined through the following and example calculations are provided in Appendix K:

a. Superelevated sections
b. Divided highways
c. Intermediate (high side)
d. Intermediate (low side)

13.5.2 Typical Section Quantities

In most cases, the quantities required to build the tangent sections are used to approximate the total quantities for the project. Where superelevated typical sections account for the majority of the project length, or when a superelevated section does not have a tangent typical of the same top width, provide typical quantities for those sections as well. For each typical section where quantities are shown, determine the quantities per station for each type of surfacing material. These quantities will be used to compute the total mainline surfacing quantities for the project. Use the procedures indicated below and in Appendix K, along with the basis of plan quantities to calculate typical section quantities. The descriptions and examples provided in this manual cover the most commonly used surfacing materials. For instances when new or less common materials are used, or items are measured differently than indicated (e.g., tons instead of gallons), the design team should use the process that most closely matches the material application and method of measurement to determine and show typical quantities.

Exhibits 13-1 and 13-2 provide quantities frame rounding criteria for typical sections.

Exhibit 13-1 Quantities Frame Rounding Criteria (Typical Sections)

Quantities								
	Aggregate				Bituminous Material			
Units	Cover	Plant Mix	Crushed Agg. Course**	Units	Asphalt Cement	Seal	Tack	Agg. Treatment
Area ft²	—	0.01	0.01	yd³/Sta.	—	1	1	1
yd³/Sta.	—	0.1	0.1	ton/Sta.	0.01	0.01	—	—
ton/Sta.	—	0.1	*0.1	Gal/Sta.	—	—	1	—
yd²/Sta.	1	—	—	—	—	—	—	—

*The basis of payment for these items is typically paid for at the unit price bid per cubic yard.
** Crushed Base Course or Crushed Top Surfacing may be specified for gravel roads.

Exhibit 13-2 Quantities Frame Rounding Criteria Cement Treated Base (Typical Sections)

Quantities													
	Aggregate						Bituminous Material				Cement		
Units	Cover	Plant Mix	Cr. Agg. Course	Cement Treated Base	Blotter	Units	Asphalt Cement	Seal	Tack	Curing Seal	Portland Cement **	Fly Ash **	Agg. Treat.
Area (ft²)	—	0.01	0.01	0.01	—	yd²/Sta.	—	1	1	1	—	—	1
yd³/Sta.	—	0.1	0.1	0.1		ton/Sta.	0.01	0.01	—	0.01	0.01	0.01	—
ton/Sta.	—	0.1	0.1*	0.1	—	Gal/Sta.	—	—	1	—	—	—	—
yd²/Sta.	1	—	—	—	1	—	—	—	—	—		—	—

*The basis of payment for these items is typically paid for at the unit price bid per cubic yard.
** Portland Cement and Fly Ash may not be measured separately depending on application or current MDT practice. Show only if measured for payment.

13.5.2.1 Aggregate Quantities

The left side of the Typical Section Quantities Frame is used to show the quantities per station for all aggregate type materials included in the project surfacing section. Example calculations are provided in Appendix K.

1. **Aggregate Cover Material.** For projects with Seal and Cover, calculate the square yards per station and record this value in the "COVER" column of the Typical Section Quantities Frame.
2. **Plant Mix Quantities.** The total aggregate quantity of the Plant Mix Surfacing is shown in the Typical Section Quantities Frame. Include the cross sectional area, cubic yards per station, and tons per station for each type of Plant Mix Surfacing specified.
3. **Leveling & Isolation Lifts.** Leveling quantities should not exceed 25 percent of the mainline quantity for a planned overlay. If more than 25 percent is required, the project is probably not a good candidate for a single-lift overlay.

   When a plant mix overlay is placed on a surface that has been crack sealed, the heat from the plant mix overlay causes the sealant to expand resulting in a bump in the riding surface. MDT has determined that placing an extremely thin lift of plant mix prior to placing the primary overlay will reduce the effects of the sealant expansion on the riding surface. This application is called an isolation lift.

   The decision to use an isolation lift will be made at the Preliminary Field Review. The use of isolation lifts generally applies to pavement preservation projects, although they could be used on designed overlay projects with plant mix thicknesses less than 0.30 feet. Isolation lifts are not needed on projects that include milling of the travel lanes. MDT recommends that milling be considered as an option for treating surfaces that have extensive crack sealing.

   To ensure that adequate surfacing is provided in the plans, a minimum 0.22 feet overlay thickness will be required whenever an isolation lift is needed. The isolation lift is placed with a paver or other approved method to a minimum thickness of 0.07 feet. Leveling used to correct distortion in the road's surface may be placed in conjunction with the isolation lift, but this will depend on the project specific characteristics of the road surface.

   The quantity for the isolation lift is included in the overall lift thickness (e.g., a 0.22-foot overlay will be shown in the typical section even though the 0.07 feet isolation layer will be placed in a separate operation than the 0.15-foot overlay). Leveling used to correct distortion in the road's surface will continue to be shown as a separate quantity in the Additional Surfacing summary and not called out on the Typical Section Quantities Frame.
4. **Crushed Aggregate Quantities.** When crushed aggregate surfacing is included on the typical section, the cross sectional area and cubic yards per station are shown in the Typical Section Quantities Frame. If the crushed aggregate is to be measured by the ton, also include the tons per station. Include a separate column for each different type of crushed aggregate

material specified (e.g., Crushed Aggregate Course and Crushed Top Surfacing).

5. **Cement-Treated Surfacing**. Use the following guidelines to estimate cement-treated surfacing quantities:

   - **Cement-Treated Base (CTB).** Cement is added to the CTB to increase the structural strength of the surfacing. The greater strength allows the use of thinner aggregate sections. The minimum thickness for CTB is 0.65 feet. CTB typically extends 1.0 feet beyond the outside edges of the travel lanes and then downward on a 1:1 slope to the top of the subgrade. Crushed Aggregate Course of equal depth is used for the remaining gravel section. Calculate and show the cross sectional area and cubic yards per station of the CTB shown on the Typical Section. For cases where the cement is measured separately, that quantity is based on a percentage of the overall weight and therefore, the tons per station for the CTB must also be shown for information only.

   - **Cement-Treated Pulverized Base.** A cement-treated pulverized base also increases the strength of the surfacing. The existing paved surface is pulverized and mixed with the existing base aggregate prior to application of the cement. The cement is then added and mixed through a second pulverization. Calculate the square yards of Cement-Treated Pulverized Base and record the total in the "CEMENT TREATED PULVERIZED BASE" column of the Typical Section Quantities Frame. The depth of pulverization and the percentage of cement will be provided by the Materials Bureau. Record the computed quantity in the "CEMENT" column of the Typical Section Quantities Frame using the information provided in Exhibits 13-1 and 13-2.

     The Surfacing Design Section will determine the need for cement-treated and cement-stabilized bases. However, a CTB alternate may be considered when the depth of the crushed aggregate course exceeds 1.30 feet, a thinner surfacing section is desired to reduce impacts, or when gravel sources are an issue.

6. **Blotter.** On projects with cement-treated base, use blotter material to cover the curing seal. Calculate the area of the Cement-Treated Base (CTB) surface in square yards per station.

13.5.2.2 Bituminous Material Quantities

The right side of the Typical Section Quantities Frame is used to show the quantities per station for all non-aggregate materials that are measured for payment in the project surfacing section. Example calculations are provided in Appendix K:

1. **Performance Graded Asphalt Cement**. All grades of asphalt cement will be referred to as Performance Graded Asphalt Binders (PGAB). The PGAB will be followed by two numbers (e.g., PG 64-28). The first number is an indicator

of rut resistance and the second number is an indicator of its resistance to thermal cracking at temperature extremes.

Separate columns should be provided where more than one PGAB is used on a project.

Asphalt contents (by percent weight) vary from region to region, and statewide averages may not accurately predict the asphalt content on some projects. Specifying project-specific asphalt contents will increase the accuracy of project cost estimates and reduce the possibility of unbalanced construction bids. Project-specific asphalt contents should be used on projects where Grade S volumetric PMS is specified.

The tons per station of asphalt cement quantity is calculated by multiplying the project specific asphalt content by the tons per station of plant mix. Record this value in the bituminous material "ASPHALT CEMENT" column of the Typical Section Quantities Frame using the rounding criteria illustrated in Exhibits 13-1 and 13-2. When the asphalt cement is included in the cost of Plant Mix Surfacing (e.g., Commercial Plant Mix bid items), do not show a value in the Typical Section Quantities Frame.

2. **Seal Oil.** Record both the surface area and the number of tons per station in the bituminous material "SEAL" column of the Typical Section Quantities Frame using the rounding criteria illustrated in Exhibits 13-1 and 13-2. Seal and cover is typically applied to mainline travel lanes, turn lanes and shoulders only. Discuss the need to apply seal and cover to approaches, and turnouts during the Plan-In-Hand.

3. **Tack.** Tack is slow-setting emulsified asphalt, used to help separate lifts of plant mix bond to each other, and to help bond plant mix overlays to underlying material. When tack is measured separately for payment, include quantities for the total surface area per station where tack will be applied, as well as the bid item quantity per station in the Typical Section Quantities Frame. Tack quantities are generally presented in gallons, measured by the amount of undiluted emulsion applied. For projects with aggregate treatment, include an application of tack on top of the treated aggregate, as well as between subsequent lifts of plant mix. It is acceptable to use the area at the bottom of the plant mix to estimate tack oil quantities for all lifts. Record the quantities in the bituminous material "TACK" column of the Typical Section Quantities Frame using the rounding criteria illustrated in Exhibits 13-1 and 13-2. See Appendix K for application rates and sample quantity calculations.

4. **Fog Seal**. A fog seal may be applied to the top of a seal and cover operation or to new or disturbed plant mix surfaces to improve durability. Materially, a fog seal is the same or very similar to tack, however the purpose and application rate(s) are different. When fog seal is measured separately for payment, include quantities for the total surface area per station where the fog seal will be applied, as well as the bid item quantity per station in the Typical Section Quantities Frame. Fog seal quantities are generally presented in gallons, measured by the amount of undiluted emulsion applied. Record the quantities in the bituminous material “FOG SEAL” column of the Typical Section Quantities Frame using the rounding criteria for tack illustrated in Exhibits 13-

1 and 13-2. See Appendix K for application rates and sample quantity calculations.

5. **Double Bituminous Surface Treatment (Double Shot)**. Application rates for this material are provided in Appendix K.
6. **Curing Seal.** A curing seal is typically placed on top of the CTB. CRS-2 oil is typically used for the curing seal. Record both the surface area and the number of tons per station in the "CURING SEAL" column of the Typical Section Quantities Frame. Curing seal is applied to the top of the Cement-Treated Pulverized Base at the same rate as it is applied to CTB.

13.5.2.3 Other Material Quantities

Materials that are neither bituminous nor aggregate in nature are generally included on the right side of the Typical Section Quantities Frame, as their method of measurement and calculations are similar to those of bituminous materials. Example calculations are provided in Appendix K.

1. **Aggregate Treatment.** Aggregate Treatment is applied to the top of otherwise untreated Crushed Aggregate. Record the surface area in square yards per station in the "AGGREGATE TREATMENT" column of the Typical Section Quantities Frame using the rounding criteria illustrated in Exhibits 13-1 and 13-2.
2. **Portland Cement.** For projects with Cement Treated Pulverized Base, the cement used is generally measured separately for payment. The Surfacing Design Section will provide the estimated cement content (by percent weight) used to calculate the tons per station. Current practice is to allow the contractor to substitute some amount of the Portland Cement with fly ash. In a case such as this, when the substitution is optional but the bid item remains Portland Cement, only show a quantity of Portland Cement assuming no substitution. If a fly ash content is specified and measured for payment, calculate the tons per station based on the specified fly ash content, and record that quantity in a separate column.

13.5.2.1 Portland Cement Concrete Pavement (PCCP)

Quantities

PCCP is measured by the square yard and rounded to the nearest 0.1 square yard. Fillets for widened sections or at drainage structures and similar locations placed monolithic with the pavement are measured as pavement. Areas constructed other than as pavement are deducted from the pavement area (e.g., gutter pan). Do not make any deductions for any fixtures located within the pavement limits that have a surface area of 1.0 square yard or less.

Where PCCP is specified, include the necessary details in the plans for the various types of joints and joint locations or patterns. Additional information is provided in the Joint Details discussion.

PCCP Types

The following are the two basic categories of PCCP:

1. **Plain-Jointed Pavement.** This PCCP has transverse joints without dowel bars. Load transfer across the joint is developed by aggregate interlock. Aggregate interlock relies on the interaction between aggregate particles at the irregular crack face that forms below the saw cut. MDT does not recommend the use of plain-jointed pavement for new construction, and has retrofitted existing plain-jointed pavements with dowel bars in some cases. Plain-jointed concrete may be approved for use on urban facilities with very low truck volumes, and for PCCP pavements less than 8 inches thick.
2. **Reinforced-Jointed Pavement.** This PCCP has transverse joints with dowel bars. Dowel bars are round, smooth steel bars placed across transverse joints to transfer loads without restricting horizontal joint movement due to thermal and moisture contractions and expansions. Dowel bars also keep slabs in horizontal and vertical alignment and reduce deflections and stresses due to traffic loads. Tie bars, made of deformed reinforcing steel, are used to tie slabs across longitudinal joints.

   Reinforced-jointed PCCP is applicable for new construction when PCCP is at least 8 inches or thick. Typical dowel and tie-bar size and spacing can be found in the *MDT Detailed Drawings*.

Joint Details

There are four general classifications of joints for PCCP. Joint types and their functions are briefly discussed below, while details are provided in the *MDT Detailed Drawings*:

1. **Transverse Joints**. Transverse joints are placed perpendicular to the roadway's centerline. These joints primarily control the natural transverse cracking due to contraction in the PCCP. Proper transverse joint design for both plain and reinforced pavements will specify the joint interval that will control cracks and provide adequate load transfer across joints.
2. **Construction Joints.** These joints are placed at planned interruptions (e.g., at the end of each day's paving, at intersections, where unplanned interruptions suspend operations for an extended period of time). Wherever practical, install the joints shown in the *MDT Detailed Drawings* at the location of a planned joint. These are butt-type joints that need dowels because there is no aggregate interlock to provide load transfer. Dowel size and spacing are the same as shown in the *MDT Detailed Drawings*. To perform properly, the dowel ends extending through the butt joint must include a bond breaker. If an unplanned construction joint occurs in the middle two-thirds of the normal joint interval, use a keyed joint as shown in the *MDT Detailed Drawings* with tie-bars instead of dowels.
3. **Longitudinal Joints.** Longitudinal joints are placed parallel to the roadway's centerline. These joints primarily control longitudinal cracking developed from the combined effects of load and restrained warping after pavements are subjected to traffic. On two-lane and multilane roadway pavements, a

spacing of 10 feet to 13 feet serves the dual purpose of crack control and lane delineation.

The longitudinal construction joint shown in the *MDT Detailed Drawings* is typically used for one lane-at-a-time construction. This includes adjacent lanes, shoulders, and curb and gutters. This joint may or may not be keyed depending on the slab thickness, lateral restraint and traffic volumes. The longitudinal contraction joint shown in the *MDT Detailed Drawings* is used where two or more lanes are paved at a time. With slip-form paving, two-, three- or four-lane pavements can be placed in one pass. These joints depend on the tie-bar to maintain aggregate interlock, structural capacity and serviceability.

4. **Isolation Joints**. Isolation joints are placed around in-pavement structures (e.g., drainage inlets, manholes, lighting structures). These joints primarily lessen compressive stresses that develop between the pavement and a structure or between two pavement sections. See the *MDT Detailed Drawings* for a typical isolation joint.

   Isolation joints used at structures (e.g., bridges) should have dowels to provide load transfer and increase pavement performance. See the *MDT Detailed Drawings* for detail of doweled isolation joints.

Jointing Layout

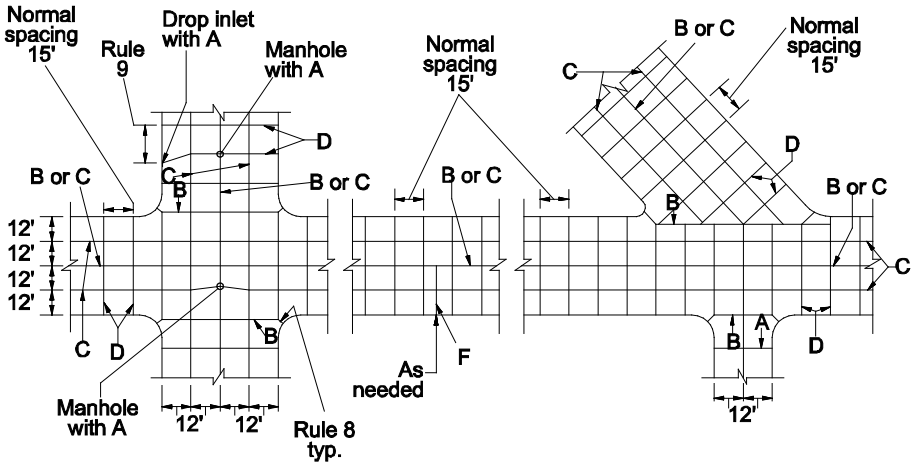
A well-designed jointing layout can eliminate unsightly random cracking, can enhance the appearance of the pavement and can provide years of low maintenance service. The following recommendations will help in the design of a proper jointing system.

1. Avoid odd-shaped slabs, including triangles and narrow rectangular sections. Avoid joint intersection angles less than 60 degrees.
2. Maximum transverse joint spacing should either be 24 times the slab thickness or 15 feet, whichever is less.
3. Longitudinal joint spacing should not exceed 12.5 feet. Locate longitudinal joints at or near the edge of the lane when possible.
4. Keep slabs as square as practical. Long narrow slabs tend to crack more than square ones. Limit the slab length to width ratio to 1.5 or less if practical.
5. All transverse contraction joints must be continuous through the curb and have a depth equal to 25 percent to 33 percent of the pavement thickness depending on the subbase type.
6. In isolation joints, the filler must be full depth and extend through the curb.
7. Tie longitudinal joints with deformed tie-bars.
8. Offsets at radius points should be at least 1.5 feet wide. One method is to widen or vary the width of the gutter pan, so that adjacent slabs can remain square.
9. Minor adjustments in joint location made by shifting or skewing to meet inlets and manholes will improve pavement performance.

10. Where the pavement area has drainage structures, place the joints to meet these structures, if practical.

A typical joint layout detail is shown in Exhibit 13-3.

Exhibit 13-3
Pavement Joint Details



A, Isolation joints
B. Longitudinal construction joints
C. Longitudinal contraction joints
D. Transverse contraction joints
E. Planned transverse construction joint
F. Emergency transverse construction joint

13.5.3 Surfacing Quantities (Summary Sheet)

When calculating the quantities for the Surfacing and Additional Surfacing Frame on the Summary Sheets, consider the following guidelines:

1. **Typical Section Quantities.** For each typical section that has a Typical Section Quantities Frame, multiply the quantities by the net number of stations and record the values in the Surfacing Frame. Do not include bridge lengths, as measured from the bridge end bents' centerline-of-bearing to centerline-of-bearing, in the net length. Provide a separate line in the Surfacing Frame each time the typical section used to calculate quantities changes. Quantities between the transition of two typical sections should also be recorded on a separate line. Estimate transition quantities by multiplying the transition length, in stations (Sta.), by the average quantity of surfacing in the two typical sections.
2. **Bridges.** Any surfacing of bridges must be approved by the Bridge Bureau. The thickness of plant mix material allowed on bridge decks is based on the structural capacity of the bridge.
3. **Hydrated Lime**. Typically, hydrated lime is used to treat plant mix surfacing materials, including RAP. Estimate the quantity of hydrated lime at 1.4 percent of the mass of plant mix and record the total in the Surfacing Frame on the Summary Sheets. Hydrated Lime is not calculated for projects that are utilizing commercial plant mix.

4. **Additional Surfacing Frame.** Use the Additional Surfacing Frame to record the surfacing quantities for approaches, connections to present travel way (PTW), leveling, and other surfacing quantities not represented in the quantity frames of the typical sections. The quantity totals from the Additional Surfacing Frame are recorded on the bottom of the Surfacing Frame and added to the Surfacing Frame totals.
5. **Approach Surfacing Quantities**. Chapter 6 presents MDT's criteria for approaches. In addition, Appendix K provides additional information and examples. In addition, the design team should consider the following guidelines:
    a. **New Construction or Reconstruction Projects.** Pave public and private approaches to the right-of-way line. Farm field approaches will be surfaced with gravel to the right-of-way line and will receive a 12 feet plant mix strip adjacent to the roadway. The decision whether to seal and cover approaches will be determined at the Plan-in-Hand.
    b. **Overlay and Overlay/Widening Projects.** All public approaches will be overlaid to the radius returns or the right-of-way line. On all paved private approaches and all farm field approaches having a paved width of 12 feet, provide a 3 feet plant mix strip. This strip serves as a transition and reduces the edge-breaking potential of the new pavement.
    c. **High-Volume Approaches.** Approaches with high volumes of traffic, particularly truck traffic, may require special designs. The surfacing design and layout should be discussed with the Surfacing Design Section and the Geometric Design Section during the development of the project.
    d. **Frame Listing.** Total the surfacing required for all of the approaches for each type of approach and record each total on a separate row in the Additional Surfacing Frame. Approaches that require a lengthy or different surfacing section also should be recorded separately in the Additional Surfacing Frame.

13.5.4 Miscellaneous Roadway Quantities

This section provides guidance for miscellaneous roadway quantities.

13.5.4.1 Pavement Markings

The Traffic and Safety Bureau is responsible for determining both interim and final pavement marking quantities. The design team is responsible for recording each in the Pavement Marking Frame on the Summary Sheet. When a Seal and Cover operation is included with the project, a quantity for Final Sweeping and Brooming is shown in the Pavement Marking Summary. The quantity for Final Sweeping and Brooming is measured by the two-lane course mile, and is prorated for auxiliary lanes.

The design team is responsible for determining the quantities required for temporary pavement markings. Estimate the quantities for each of the following paving operations:

1. Each lift of pavement – for estimating purposes lift thicknesses are between 0.15 feet and 0.20 feet inclusive
2. A milled surface
3. Isolations lifts

An additional quantity of temporary pavement markings may also be required for the existing pavement. The need for additional quantities will be determined by District Construction personnel. Temporary pavement markings are not needed for normal leveling. Compute the quantities for temporary pavement markings for each two-lane mile of the project.

13.5.4.2 Guardrail

Chapter 9 presents MDT's criteria for guardrail placement. Station limits for guardrail will include the terminal sections and bridge approach sections. Guardrail is measured from center-to-center of the end posts of each section along the guardrail's actual location and quantity calculations should reflect the following information:

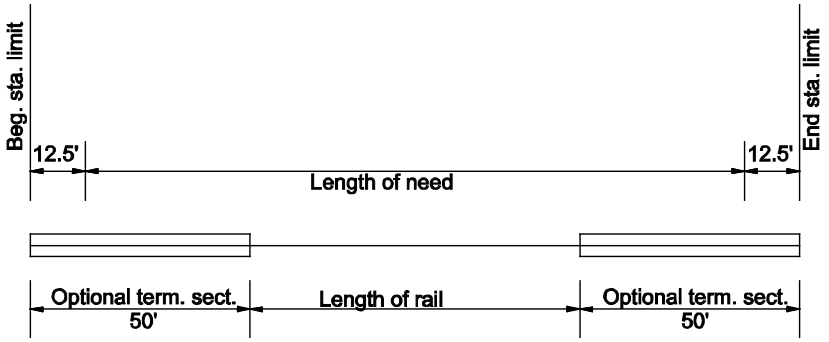
1. **W-Beam Guardrail Quantities**. Due to manufacturing criteria, compute the length of need and round up to the next highest multiple of 12.5 feet. If room is available, multiples of 25 feet are preferred.
2. **Low-Tension Cable Guardrail Quantities**. Compute the length of need and round up to the next highest multiple post spacing. Post spacing on tangents and curves with radii greater than 720 feet is 16 feet. Post spacing on curves with radii less than 720 feet and greater than or equal to 440 feet is 12 feet. Do not install cable guardrail on the outside of curves with radii less than 440 feet or on the inside of any curve.
3. **Box Beam Guardrail Quantities**. Due to manufacturing criteria, compute the length of need and round up to the next highest multiple of 18.0 feet.
4. **Concrete Barrier Rail.** Due to manufacturing criteria, compute the length of need and round up to the next highest multiple of 10 feet. Concrete barrier rail is paid at the unit price bid for each 10 feet increment.
5. **Raise Guardrail.** Use the pay item "Raise Guardrail" only when the existing rail has a predrilled hole in the post for that reason. See the Detailed Drawings for criteria on the height for when raising guardrail is appropriate. If the existing rail cannot be raised, it should be removed and replaced by new, or reset.
6. **Remove Guardrail**. Compute actual quantity of guardrail to be removed.
7. **Reset Guardrail.** Reset Guardrail is used to adjust guardrail that is too low, but is otherwise in good condition, to the proper height when it cannot be raised as described above. Terminal sections that are reset are bid separately per each. The remaining run is measured up to the nearest 12.5 feet. Guardrail that does not meet current requirements cannot be reset (e.g., concrete posts).

8. **Bridge Approaches.** Bridge approach sections are included in the station limits, but are bid as a separate unit. Therefore, they are not included in the length of rail. Ensure the type of bridge approach section specified matches the bridge rail. See the *MDT Detailed Drawings* for the application of each type of bridge approach section. Box beam guardrail can only be connected to Wyoming Bridge Rail. The design team should contact the Bridge Bureau for the type of bridge rail in place or to be installed.

9. **Terminal Sections**:

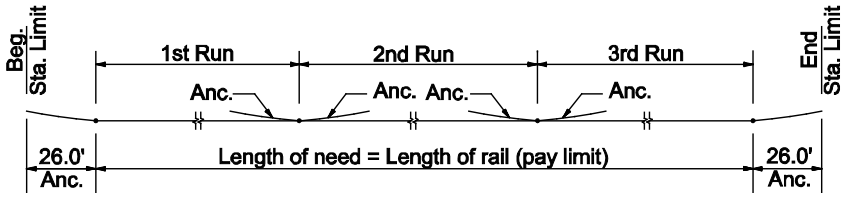
   a. W-Beam Guardrail. The optional terminal sections and one-way departure terminal sections are included in the station limits but are separate bid items; therefore, it is not included in the length of rail. See Exhibit 13-4 for computing guardrail lengths with Optional Terminal Sections.

Exhibit 13-4
Optional Terminal Section



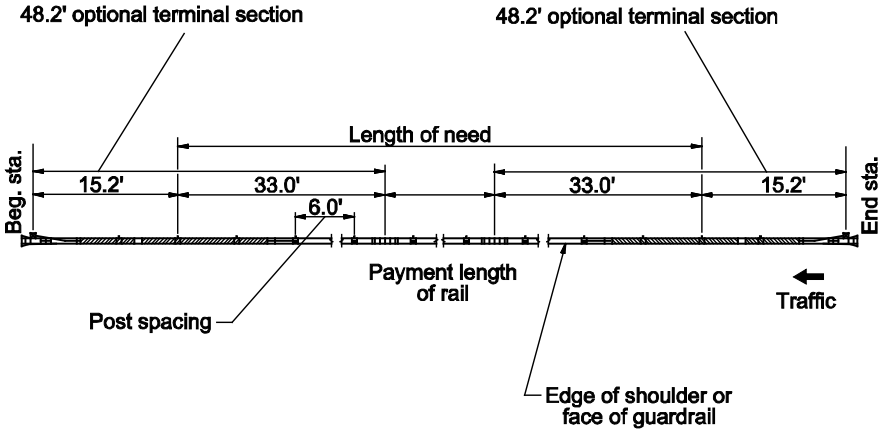
   b. Cable Guardrail. Note that the maximum run of low tension cable guardrail is 2,000 feet (excluding terminal sections); see the *MDT Detailed Drawings*. Therefore, with a long run of cable guardrail, there may be several terminal sections. See Exhibit 13-5 for computing the length of cable guardrail.

Exhibit 13-5
Cable Guardrail



   c. Box Beam Guardrail. The box beam optional terminal sections and one-way departure terminal sections are included in the station limits but are separate bid items; therefore, they are not included in the length of rail. See Exhibit 13-6 for computing length of box beam guardrail.

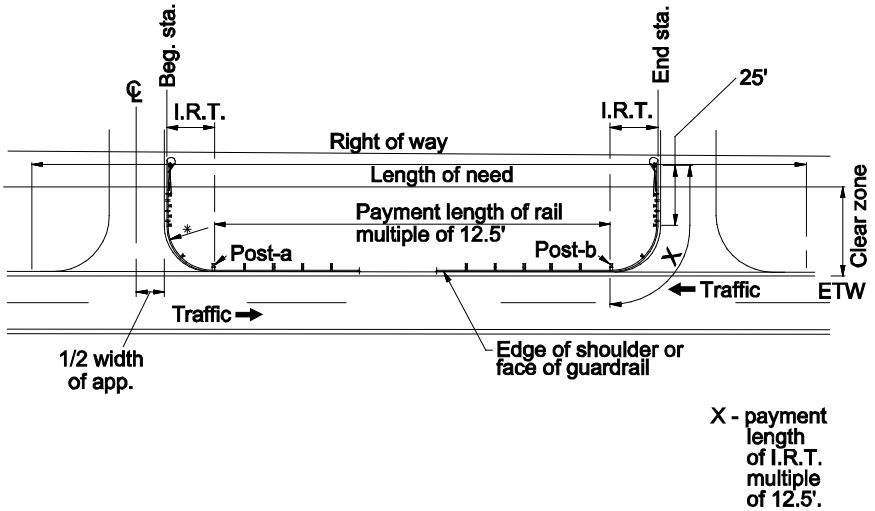
Exhibit 13-6
Box Beam Guardrail



10. **End Anchors**. End anchors are not bid separately, but are included in the cost of the terminal section.

11. **Intersecting Roadway Terminal Section**. For intersecting roadway terminal (IRT) sections, the length of the IRT rail is bid separately from the rest of the guardrail. The station limits of the IRT should extend from the guardrail connection to the end of the IRT. Because the IRT is installed on a radius, the station limits do not reflect the length of the IRT rail. See the *MDT Detailed Drawings* for the selection of radii that will result in 12.5 feet increments of rail. Do not use intersecting roadway terminal sections with box beam rail. Exhibit 13-7 provides additional details on intersecting roadway terminal sections.

Exhibit 13-7
Intersecting Roadway Terminal Sections



12. **Impact Attenuators**. Using the manufacturer's guidelines, determine the number of bays required based on the design speed at the site. Impact attenuators are included in the station limits of the guardrail, but are a separate bid item. The entire impact attenuator system is bid as a unit (i.e., each).

13. **Stiffened Guardrail Sections.** Stiffened guardrail sections are used to shield an obstacle where dynamic deflection must be limited. See the *MDT Detailed Drawings* for configuration on one-way and two-way roadways, as well as required length and pay limits of stiffened guardrail.

13.5.4.3 Curb and Gutter

Chapter 5, Section 5.2.8 provides MDT criteria for curb and gutter sections. Show the curb and gutter station limits in the Curb Frame from the beginning of one curb return to the beginning of the next curb return (BCR to BCR). Chapter 6, Exhibit 6-3 illustrates the location of the BCR. In addition to the length of the curb and gutter between BCRs, the distance of the curb and gutter around the radius to the end of the curb return must also be included in the summary quantities. Radii dimensions are to the back of curb; however, the length is measured to the face of curb.

13.5.4.4 Sidewalks

Chapter 5, Section 5.2.9 provides MDT criteria for sidewalks. Sidewalk stations are recorded in the same manner as curb and gutter. For each depth of sidewalk in the project, compute the sidewalk area in square yards and round to the nearest 0.1 square yard. Report the results in the Sidewalk Frame. The cost for the aggregate base is incorporated in the unit cost per square yard of sidewalk. For sidewalk sections under vehicular traffic (e.g., intersections with approaches and alleys), use a 6-inch sidewalk depth. For all other locations, use a 4-inch sidewalk depth. Curb ramps are included in the 4-inch sidewalk quantities and are not a separate bid item. For areas where detectable warning devices (DWD) are used, the sidewalk under the DWD is included in the sidewalk quantity. The curbing around the curb ramp is paid for as curb and gutter and is typically included in the curb radii of curb and gutter; see Section 13.5.4.3.

13.5.4.5 Detectable Warning Devices

Detectable warning devices are a standardized detectable warning surface for sight-impaired pedestrians. The detectable warning devices are installed in the sidewalk ramp adjacent to the roadway and provide a cue that the pedestrian is moving from a pedestrian area to a vehicular area. Projects are required to install detectable warning devices on all new curb ramps and any project involving alterations to existing ramps.

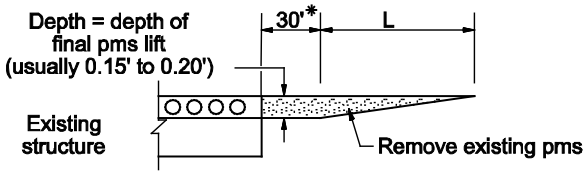
The detectable warning devices are two feet wide, and are located at the bottom of the curb ramp and extend the width of the ramp. Detectable warning devices will be measured and paid by the square yard. Show the quantities for detectable warning devices in a separate column in the Sidewalk Summary. Refer to the *MDT Detailed Drawings* for more complete information.

13.5.4.6 Cold Milling

Cold milling is used to remove a specified depth of pavement. Where the pavement has deteriorated, the removal of all pavement above the plane of failure may be necessary prior to placing a new overlay. For these cases, the

depth of milling will be determined by the Surfacing Design Section. A tapered depth cold milling connection is also used in conjunction with overlays to match the new surfacing elevations to existing bridge decks, railroad crossings, cattle guards and connections to existing pavement. Exhibit 13-8 provides an example of cold milling taper.

Exhibit 13-8
Cold Milling Taper Example



*Add the following note to the Detail Sheet in the contract plans: "Actual removal distances to be determined during construction by the Engineer."

See Appendix K for additional information and to determine the extent of milling beyond the bridge ends. If taper milling has been used to tie a previous overlay to the bridge end, L must be calculated for both overlay thicknesses. For cattle guards, the pavement is typically milled for 65 feet (15′ of full depth milling and 50′ of taper milling) on either side of the structure. Review the application of this criterion during the Plan-In-Hand field review. Standard milling widths are 6.25 feet, 12.5 feet and 14.0 feet. Use the bottom width of the milled surface to compute the cold milling area and round to the nearest square yard. Where milling depth tapers are needed, use the maximum width (e.g., width at the bottom of the milled surface) to calculate the cold milling area. Record the results in the Cold Milling Frame.

13.5.4.7 Pavement Pulverization

Pavement pulverization is used to produce a uniform material for the total subgrade width by mixing the existing bituminous pavement with aggregate. Specify the depth of pavement pulverization based on Surfacing Design recommendation. The depth of the pulverization is the average depth of the existing bituminous pavement (the maximum depth is typically 0.66 feet). Use the bottom width of the pulverized surface base at the specified depth to compute the quantity of pavement pulverization. Calculate the area in square yards. Record the results in the Pulverization Frame.

Achieving a blend of pulverized plant mix and untreated aggregate surfacing is important. Pulverized plant mix should comprise 60 percent of the mix, while the remainder should be underlying base gravel, new aggregate blended during pulverization, or a combination of the two. Aggregate added to the pulverized material for leveling is measured by the ton. Record the results in the Surfacing Frame. Provide a design profile grade where pavement pulverization is specified. The design profile grade should be adjusted as necessary to account for leveling and swell of pulverized material.

13.5.4.8 Finish Grade Control

Record finish grade control staking quantities in the Finish Grade Control Frame on the Summary Sheets. Also consider the following:

1. Each course foot of finish grade control staking is based on a 2-lane roadway, including shoulders and ditches.
2. Each traffic lane, ramp, climbing lane, etc., is one-half of a course foot for measurement. Do not measure parking lanes, turning lanes, median lanes and chain-up areas separately from the adjacent roadway.
3. Four-lane facilities require separate measurements for each direction of the roadway.
4. Measure the subgrade and each base course of aggregate requiring finish grade control staking separately, by the course foot, for each roadway, ramp, intersecting roadway, PTW connection, temporary detour and frontage road.
5. For facilities with aggregate surfaces, finish grade control is only provided for the subgrade if the aggregate is paid for by the ton. However, finish grade control is provided for both subgrade and aggregate surfacing if the aggregate is paid for by the cubic yard. A separate course of finish grade control staking will be required where special borrow is used.
6. Take measurements along the centerline of each roadway and round to the nearest 50 feet.

13.5.4.9 Traffic Gravel

Traffic gravel is used as temporary surfacing to carry traffic on stages of unfinished grading (e.g., cuts or fills). For the areas where the traffic cannot be maintained on the PTW or finished subgrade, determine the number of stages the cut or fill will be constructed. Compute the quantity of traffic gravel based on the following criteria:

1. 24-foot minimum travel width,
2. 0.20 feet depth of traffic gravel, and
3. the length of temporary surfacing.

Verify traffic gravel quantities with District construction personnel. Traffic gravel is measured and paid by the cubic yard or ton. Round the calculated quantity to the nearest cubic yard or ton and record the quantity in the "TRAFFIC GRAVEL" column of the Surfacing Frame.

13.5.4.10 Rumble Strips

Rumble strips should be installed in accordance with *MDT Rumble Strip Guidance* and in conjunction with the *MDT Detailed Drawings* or project plan details. When calculating rumble strip quantities, consider the following guidelines:

1. Each individual line of rumble strips is measured separately for payment.
2. Deduct gaps for bridges, ramps, and approaches from the length quantity for rumble strips.

3. Discontinue rumble strips on shoulders less than 6 feet wide if guardrail exists or is proposed. For other locations to discontinue rumble strips, the design team should refer to the *MDT Rumble Strip Policy*
4. Take measurements along the centerline of the roadway and round to the nearest 0.1 miles.
5. Record the rounded quantity in the Rumble Strips Frame.
6. On all projects that have shoulder rumble strips, calculate a quantity of fog seal to be applied to the rumble strips. Use SS-1, applied to a width of 2 feet at an undiluted application rate of 0.05 gal/yd^2. Show this quantity for informational purposes. The cost of the fog seal is included in the cost of the rumble strips.
7. The *MDT Detail Drawings* show a Centerline Rumble Strips (CLRS) detail and should be used in all locations where CLRS are specified, unless documented in the Scope of Work Report for use of a different design.

13.6 MISCELLANEOUS COMPUTATIONS

13.6.1 Lump Sum Items

Use lump sum bid items where the scope of work for the item is clearly defined and the amount of work has a minimal chance of changing during construction. Lump sum should also be considered where the end result is defined, but there are various methods of achieving the desired results. Including an item of work in another item should only be done where the scope of work for each item is clearly defined and the chance of the quantity of either item changing is minimal. Where practical, list separately the quantities that comprise the lump sum item of work. The list should note that the "quantities are for estimating purposes only." Provide a clear definition of work for each item whether it is bid by the unit, included in the cost of other items, or bid lump sum. Where there is a significant chance of quantity change, the work should be bid by the unit. Where lump sum items are used, the total quantity for the project should always equal one. If more than one item or location is included in the lump sum, show the decimal proportion of the work of each location. For example, for a project which includes the removal of three structures being 30 feet, 30 feet, and 60 feet long, the proportion would be 0.25, 0.25, and 0.50, respectively.

13.6.2 Clearing and Grubbing

Clearing and grubbing is typically included in the construction plans and, generally, will not require a separate set of plan sheets. Decisions related to the payment method (e.g., lump sum, absorbed in other bid items, by the acres) should be made during the Plan-in-Hand field review. Payments based on the number of acres involved require the quantities to be presented on the Clearing and Grubbing Frame. Where clearing and grubbing will be included in the grading bid item, include an appropriate note in the Notes Sheet. Clearing and grubbing may be bid either as separate bid items with different bases for payment or as a single item. If the clearing and grubbing has separate phases, the

quantities for each should be shown separately in the summary and the special provisions should describe the measurement and payment for each phase. The decision on the disposition and areas of selective cutting will be made at the Plan-in-Hand field review. The disposition of merchantable timber should be determined during right-of-way negotiations.

13.6.3 Topsoil

In general, topsoil will be required on most projects. The design team should review the following relative to the placement of topsoil:

1. **Topsoiled Areas**. Provide topsoil according to the following guidelines:
    a. Topsoil will be required on all projects where the existing topsoil is disturbed. Where topsoil is impractical to salvage or is unsuitable (e.g., rock cut), eliminate the area from the topsoil salvage quantity. Also provide a special provision describing the special slope treatment to be used.
    b. Provide topsoil on all 2:1 or flatter slopes.
    c. Place topsoil on the gravel surfacing inslope to the edge of the plant mix for all projects that involve disturbance of the inslope as per the *MDT Detail Drawings*.
2. **Topsoil.** Assume that the existing topsoil will be salvaged and stockpiled unless otherwise noted.
3. **Placement.** Where required, provide topsoil to a loose depth of 4 inches from the bottom edge of the plant mix to the catch point.
4. **Quantities.** Use the following procedure to compute topsoil quantities and record them on the summary sheets:
    a. Topsoil quantities should be based on a 4-inch depth over the area of the constructed slopes requiring topsoil placement.
    b. Show topsoil quantities, in cubic yards, in 3,000 feet increments in the Topsoil and Seeding Frame.
    c. Topsoil quantities can be obtained using computer-generated data or manually calculated computation sheets.

13.6.4 Seeding

Where seeding is provided on a project, consider the following guidelines:

1. **Seeded Areas.** Provide seeding on all slopes extending from the edge of plant mix to the new right-of-way limit, except on slopes steeper than 1.5:1, areas that are predominantly rock, and other locations that are difficult to grow grass.
2. **Determining Quantities.** The Environmental Services Bureau is responsible for determining the seed type, seeding rate, amount of fertilizer and mulch used per acre. Generally, different seeding rates will be specified for:
    a. The total area to be seeded inside the new right-of-way having 3:1 or flatter slopes (Area 1) minus the areas described below,

b. Constructed slopes steeper than 3:1 (Area 2),

c. A strip extending from a point from the edge of the plant mix to a distance of 15 feet or to the edge of the surfacing inslope, whichever is greater (Area 3), and

d. Other specified areas.

The design team will be responsible for determining the size of the area to be seeded at each rate using computer generated data or manually calculated computation sheets. The number of acres in Area 1 that require seeding are calculated as follows:

Area 1 = Right-of-Way - Area 2 - Area 3 - Surface Area

Where:

Right-of-Way = The total area inside the new right-of-way

Surface Area = (Finished top width) x (length of project)

No fertilizer is required for Area 3.

3. **Recording Quantities**. Record the seeding areas in the Topsoil and Seeding Frame. The seeding areas should be recorded as follows:

   a. Present the number of separate acres for areas on slopes of 3:1 or flatter, areas on slopes steeper than 3:1, the 15 feet wide strip adjacent to the edge of pavement and for other areas defined in the seeding recommendations.

   b. For Area 1 and Area 3 seeding conditions, provide areas of seed bed conditioning in acres. Mulch, in acres, is generally provided for Area 2 conditions.

13.6.5 Fencing

The *MDT Detailed Drawings* present MDT criteria for the design and placement of fencing. For quantity estimating, consider the following guidelines:

1. **Fence Types.** Refer to the Right-of-Way agreements to determine the type of fence required. Fencing is typically measured to the nearest foot. The length of fence does not include cattle guards, gates or other openings. These items are paid for separately.
2. **Temporary Fencing.** The length around the construction permit areas should be used to determine the quantity of temporary fence.
3. **Panels.** See the *MDT Detailed Drawings* to determine the type and number of fence panels that should be used with a run of fencing.
4. **Deadmen.** For estimating purposes, include the following number of deadmen per mile of fence based on the type of terrain:
   a. Flat terrain — 2 deadmen per mile of fence
   b. Rolling terrain — 5 deadmen per mile of fence
   c. Rough terrain — 8 deadmen per mile of fence
5. **Gates.** Most gates used by MDT should be measured in 2 feet increments.

6. **Recording.** Include all fencing quantities in the Fencing Frame. List the fence lengths for the left side of the roadway from the beginning station to ending station, and then for the right side from beginning to ending station. Terminate the stationing at each parcel (per the Right-of-Way agreements), change in fence or post type, gates, cattle guards, or other openings. Also include the following information in the fencing summary:
    a. The "FENCE TYPE" column heading should include the post designation (e.g., F4M, F4W) where:
        M = metal posts
        W = wood posts
    b. Call out the gates by station at each end of the gate and list them according to type.
    c. Show totals only for temporary fence and deadmen.
7. **Fencing Plans.** If requested by the District, prepare fencing plans on a set of white prints of the right-of-way plans. The *MDT Detailed Drawings* show how the fencing plans should be prepared. Do not include the fencing plans in the contract package, but transmit them to the District at the time of the project letting.

13.6.6 Cattle Guards

The *MDT Detailed Drawings* present MDT criteria for the design and placement of cattle guards. For quantity measurements, note that cattle guards are available in two standard sizes: 10′ by 8′ and 12′ by 8′. For most roadways, two 12′ by 8′ cattle guards will provide an adequate design. In all cases, extend the cattle guard fully across the finished surface width, including finished shoulders. Itemize the number of cattle guards in the Cattle Guard Frame.

13.6.7 Concrete Slope Protection

Design concrete slope protection, used for bridge end slopes, as shown in the *MDT Detailed Drawings*. Estimate quantities of concrete slope protection in square yards of concrete rounded to the nearest 0.1 square yard.

13.6.8 Detours

During the construction of a project, a detour often is constructed, maintained and removed. Provide sufficient details for all detours on a project. The details include the plan and profile of the detour, the typical section of the detour, the design speed of the detour and a list of the components and quantities necessary to construct the detour. The quantities are for informational purposes only. The construction, maintenance and removal of the detour will be paid either per each or as a lump sum bid item. Chapter 10 provides additional information on detour details. Include the detour typical section with the project typical sections.

Waterway openings for detours will consist of recommendations from the Hydraulics Section for a specific drainage structure (e.g., pipes, bridge), or a statement in the special provisions that the contractor will provide an adequate

waterway opening for the detour. Include the cost of any required drainage structures in the lump sum or per each bid for "Construct, Maintain and Remove Detour."

13.6.9 Considerations for Grading with Rock

Material requiring ripping or production blasting is included in the regular excavation quantities for the project, and no separate or additional method of measurement is used. When formation material is encountered at the design subgrade, a six inch depth of subexcavation, called “excavation below grade”, is required and measured for payment. Unclassified soil is used to backfill areas of excavation below grade, and the quantities are typically identified in the Additional Grading Frame with equal volumes of cut and fill.

Rock slope stabilization projects and projects with rock excavation may require quantities for trim blasting, rock scaling, rock bolting, or rock slope mesh to reduce or mitigate the potential for rock fall reaching the roadway. The need and quantities for these items will be determined by the Geotechnical Section.

13.6.9.1 Pre-Splitting Rock Slopes

Pre-splitting rock cuts is used to produce a continuous or semi-continuous fracture between drill holes and a stable rock cut, and to eliminate overbreak in the backslope during primary blasting. Pre-splitting rock cut to a smooth plane is achieved by detonating evenly spaced holes prior to detonation of the production holes. Pre-splitting rock cuts will be recommended by the Geotechnical Section, if needed.

Drill pre-splitting holes are measured by the foot for each hole. The measurement is made from the rock surface to the roadway grade or to a predetermined bench elevation. A 30-inch interval is used to estimate the number of drilling pre-splitting holes. Record the computed length of holes in the Drill Pre-Splitting Holes Frame.

13.7 COORDINATION

The design team should refer to current MDT specifications, supplemental provisions, and design memos, to ensure the project quantities they include in the plans meet the current state of the practice for measurement and payment.

13.8 REFERENCES

1. Montana Department of Transportation (MDT). *Standard Specifications.* MDT, Helena, MT, 2014.
2. MDT. *Geometric Design Standards.* MDT, Helena, MT, 2016.