

APPENDIX N

SURFACE MATERIAL REMOVAL AND TEMPLATE SUBCUT

This Appendix discusses the surface material removal and template subcut processes. The two processes are discussed in the same fashion, surface material removal first, followed by template subcut.

SURFACE MATERIAL REMOVAL PROCESS

The surface material removal process enables the user to specify by roadway the location (station to station), removal limits and configurations for surface material removal. The process is useful for topsoil removal and stockpiling, as shown in Figure N-1a. It is also useful for unsuitable material removal and wastage, as shown in Figure N-1b. Since the process can be sensitive to material classification, unsuitable materials can be removed and wasted, while suitable material can be removed and stored for later embankment use, as shown in Figure N-1c. Also, multiple removal limits specifications can be defined over a station range. Figure N-1d shows a typical example of multiple removal limits specifications.

Removal Limits

An unlimited number of removal limits specifications can be defined for each design roadway between catch points for a station range. For each specification, the left and right removal limits are defined independently. There are five methods for defining the removal limits specifications:

- Distance from Catch Point - This option signifies that the removal limit (left or right) is specified as a distance from the left or right catch point, as shown in Figure N-2a. Note: Distances outside of catch points are not permitted.
- Distance from Center Line - This option signifies that the removal limit is specified as a distance from the centerline, as shown in Figure N-2b.
- Slope from Shoulder Point - This option signifies that the removal limit is specified as a slope from the left or right shoulder point to an intersection with the terrain, as shown in Figure N-2c.
- Distance from Shoulder Point - This option signifies that the removal limit is specified as a distance from the left or right shoulder point, as shown in Figure N-2d.
- Geometric Element - This option signifies that the removal limit is specified as a geometry element, as shown in Figure N-2e.

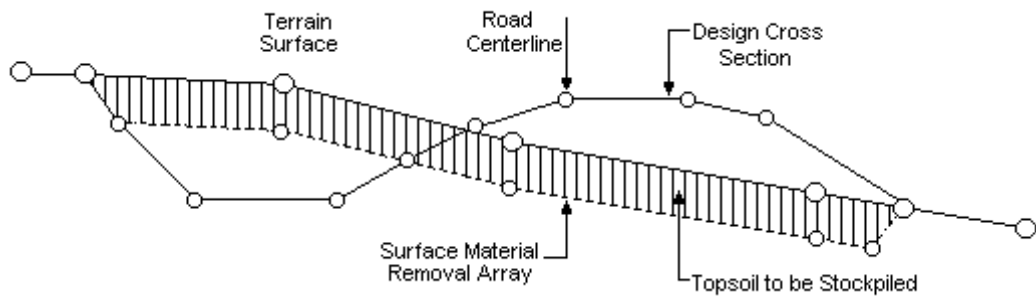


Figure N-1a

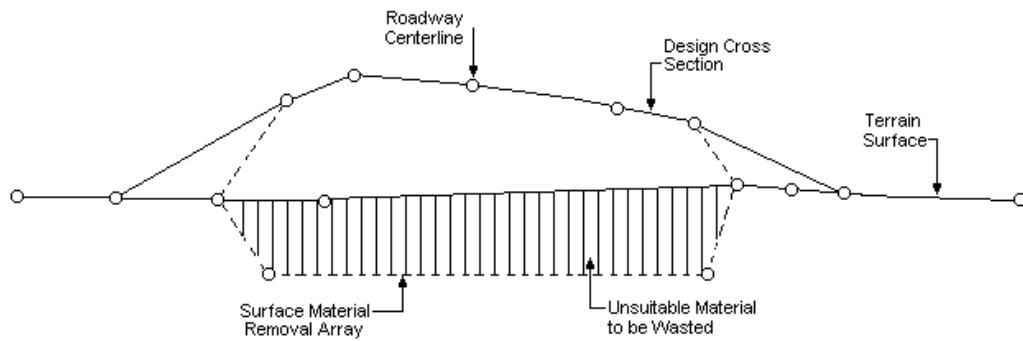


Figure N-1b

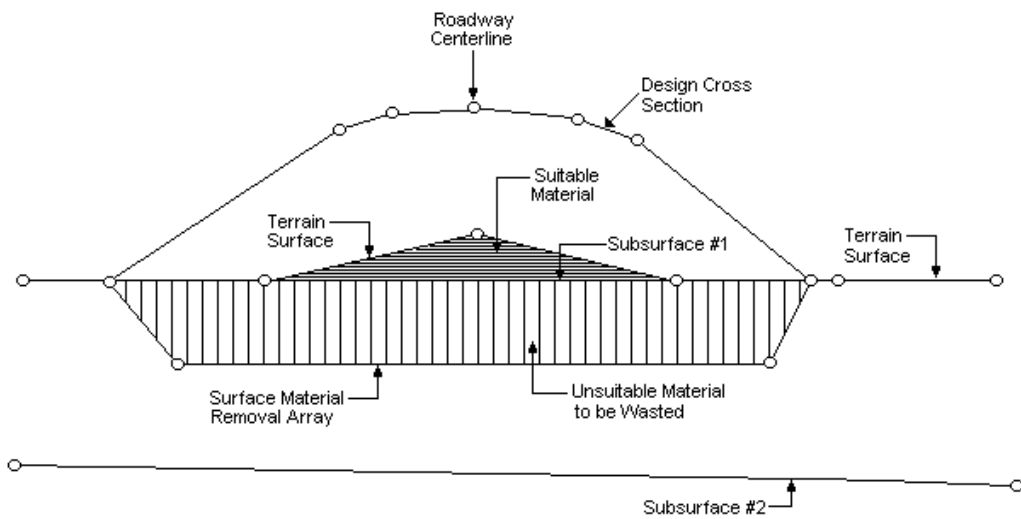


Figure N-1c

Surface Material Removal Process

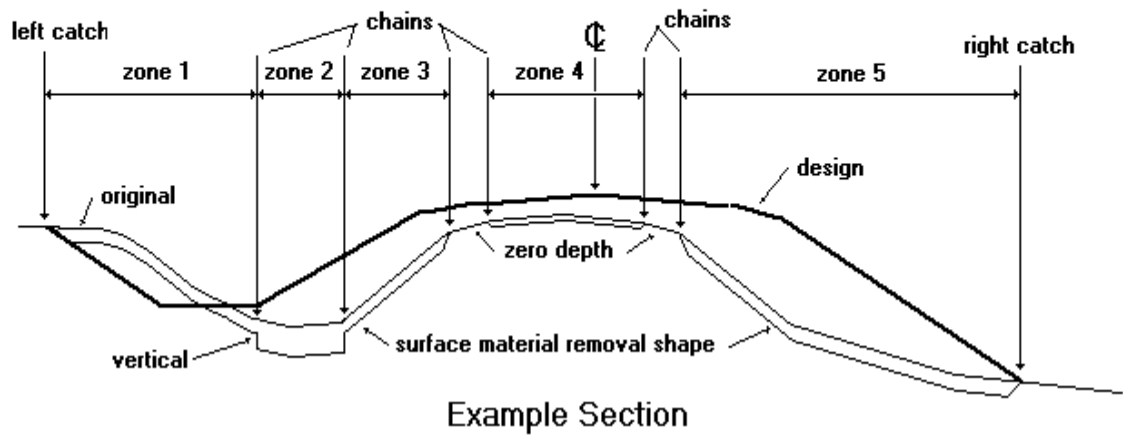
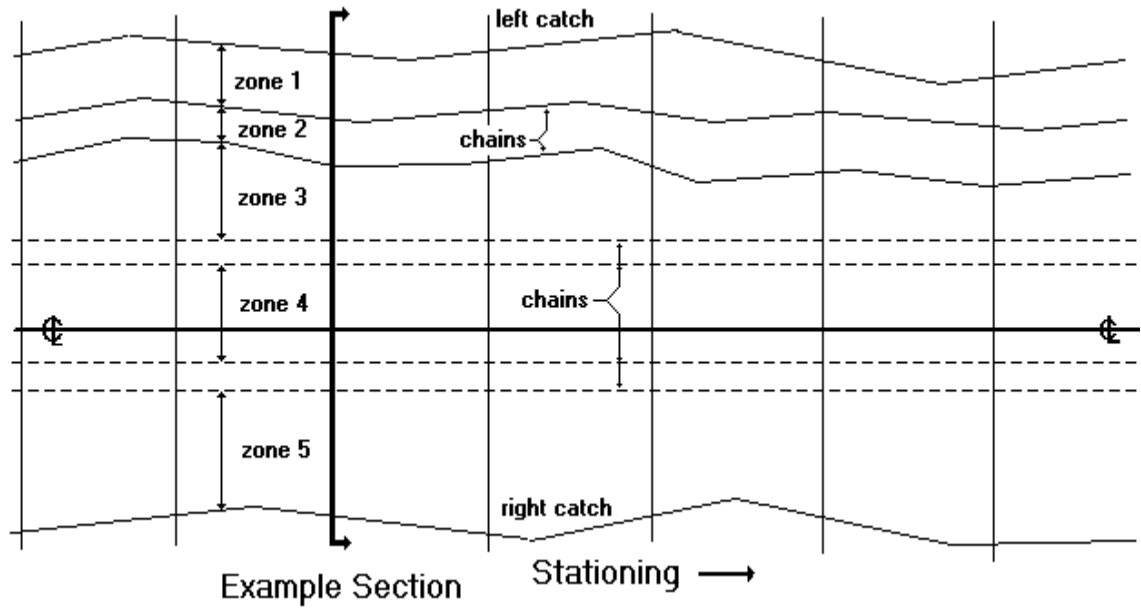


Figure N-1d - Multiple Zone Surface Material Removal Processing

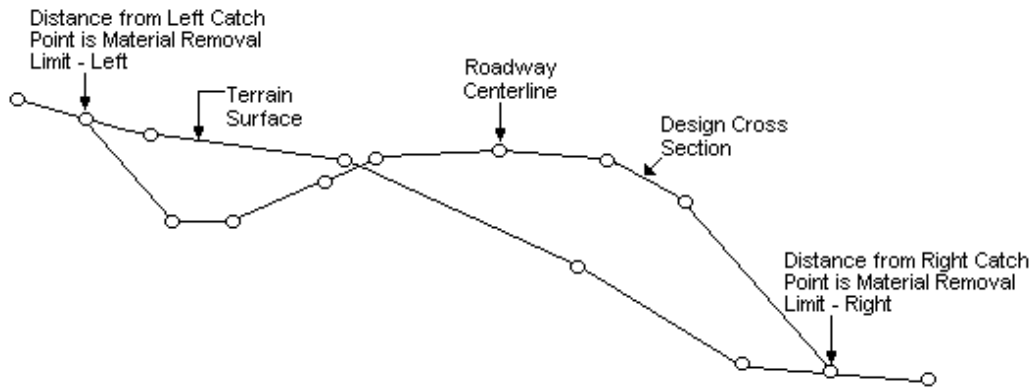


Figure N-2a - Distance from Left or Right Catch Point
 (Note: If a median is built, the median point is the catch point.)

Figure N-2b - Distance from Centerline

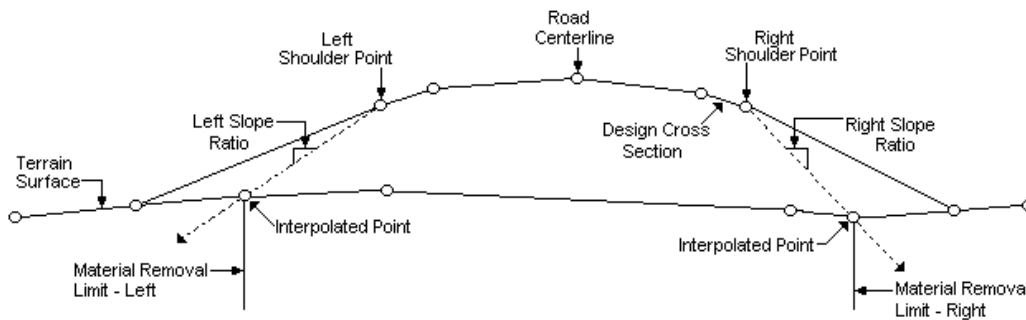
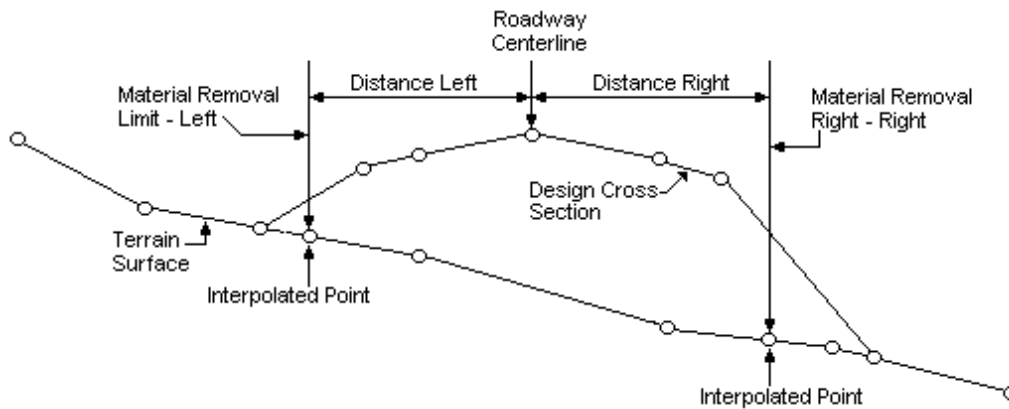


Figure N-2c - Slope from Left or Right Shoulder Point

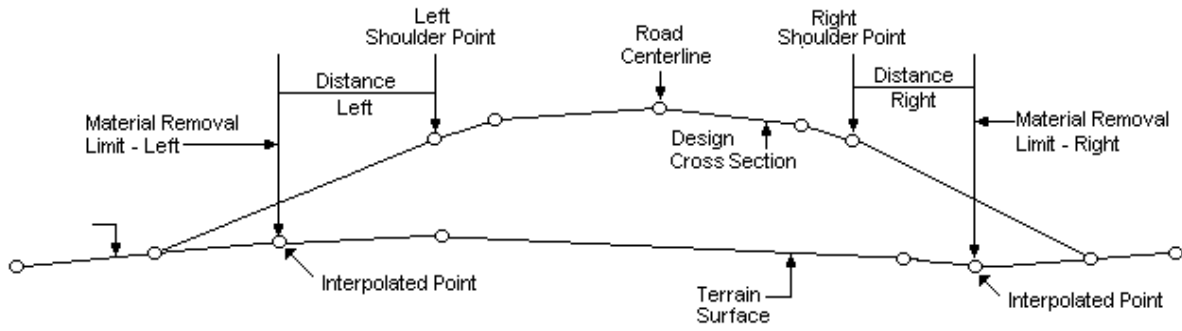


Figure N-2d - Distance from Left or Right Shoulder Point

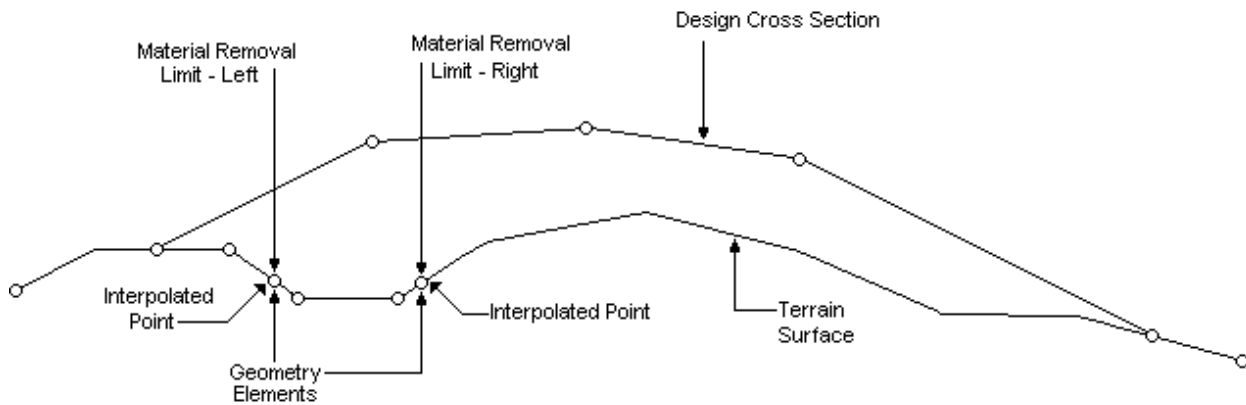
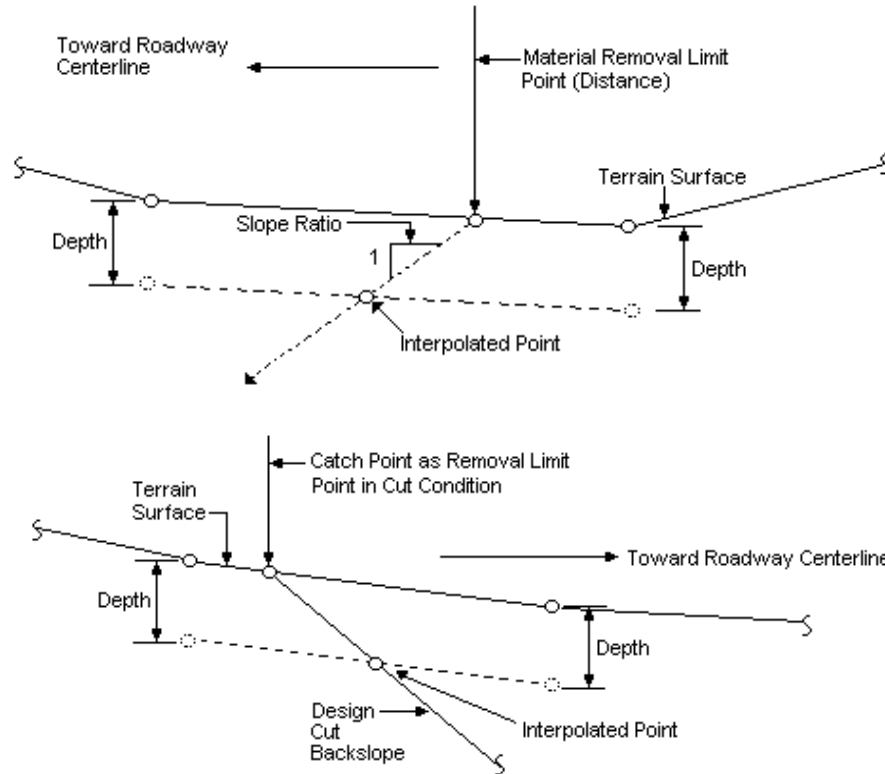


Figure N-2e - Geometry Element as Removal Limit

Cut Slope

The cut slope ratio is applied at the material removal limit distance, or point, to the depth of surface material removal. In instances where the catch point defines the limit of material removal in cut conditions, the design cut slope ratio is used in lieu of the given cut slope ratio. A positive cut slope ratio forms a line going down and toward the roadway centerline. See the illustration below.



Removal Shape

There are two options for defining the actual removal shape - follow terrain or straight line.

Follow terrain is the default option. This implies that the surface material removal process will follow the terrain at the specified depth. Straight line indicates that the process will follow a straight line between the end points. See Figure N-3 for an example of each type.

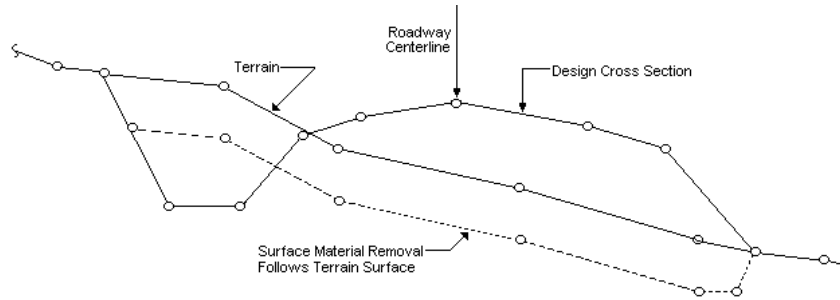


Figure N-3a - Surface Material Removal Shapes - Follow Terrain

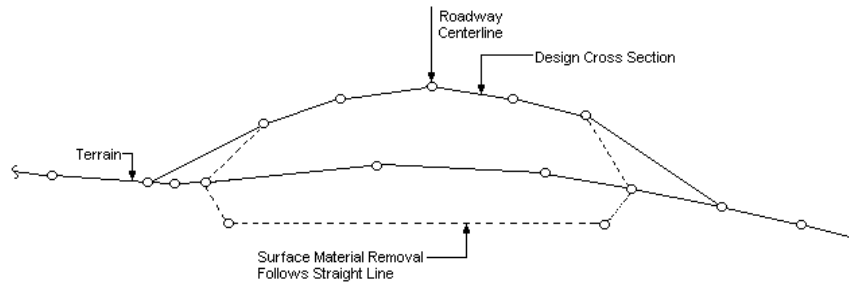
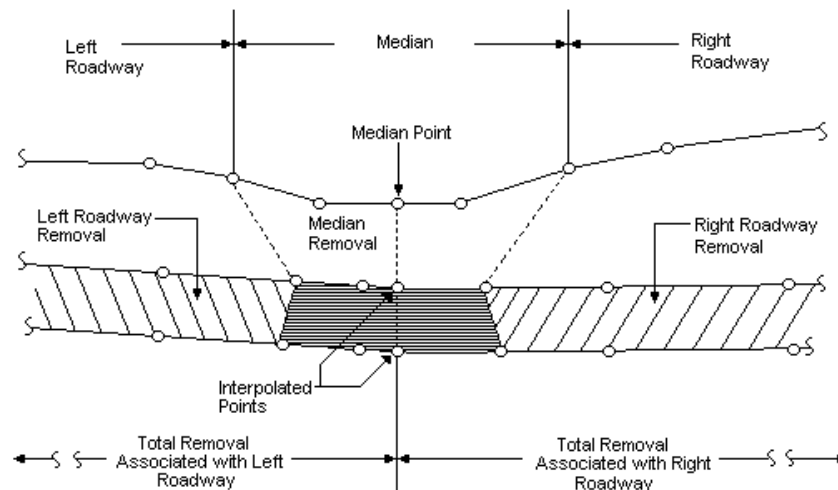


Figure N-3b - Surface Material Removal Shapes - Straight Line

Median Removal

It may be desirable to remove surface material from median areas. The user has the option of removing material in medians, if desired. A median occurs when the catch points of the adjacent roadways are coincident. Median removal will not be performed if no median is formed. Similarly, median removal will not be performed if surface material removal is not to be performed for one of the adjacent roadways. Typical median removal is shown in the illustration below. Median removal can also be accomplished by defining removal limits to the catch points (median point) for each roadway.



Material Sensitivity

If desired, the surface material removal process can be sensitive to subsurface materials. If the material sensitive toggle is set to No, then the final visible shape of the surface material removal section is always the same as the preliminary section. Figures N-4a, b, and c provide a graphic depiction of several examples in which the material sensitivity toggle is set to Yes. In these cases, the preliminary surface material section, created from the previous input descriptions, is compared with the various subsurface layers. The example in Figure N-4a shows the condition in which the preliminary surface material section is totally contained within a material designated as removal. In this case, the visible shape of the final surface material removal section is identical to the preliminary section. Figure N-4b shows the condition in which the preliminary section intercepts with, and is generally below, a subsurface boundary. The material above the boundary is removable, the material below is not. In this case, the final removal section is visible in the removable material and invisible in the non-removal materials, as shown. Figure N-4c shows a similar condition in which multiple subsurfaces "day light" with the terrain surface. In this case, the final surface material removal section is also visible in the removable materials and invisible in the non-removable materials, as shown.

Process Methodology

The surface material removal process is performed in conjunction with and after the template, median, and sideslope processes have been performed, and prior to the template subcut process. The process is triggered by the design cross section computation flag. The surface material removal process is performed for a design roadway only if there is data stored in the surface material removal structure for that roadway. There must be at least one entry. The process is performed for the same baseline station range as defined for design cross section computations, taking station equations and design exceptions into account. The following subsections discuss the surface material removal process in a step-by-step fashion.

Baseline Station Processing

For each baseline station in the station range defined above, the process is performed, in design roadway order, not in left to right order. Each design roadway is compared with the entries in the roadway surface material removal structure to determine whether the roadway should be processed. If the roadway has parameter data stored at this station, the data is retrieved from the structure; otherwise, the next roadway is checked.

Preliminary Surface Material Removal Section

The preliminary surface material removal section for the roadway is then created in the following manner:

- First, for each removal limit zone, the beginning and ending points in the zone are created at the material removal limits (Figure N-2)

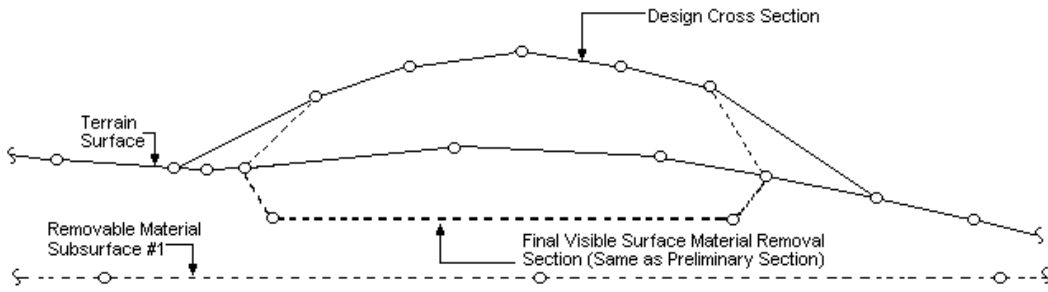


Figure N-4a

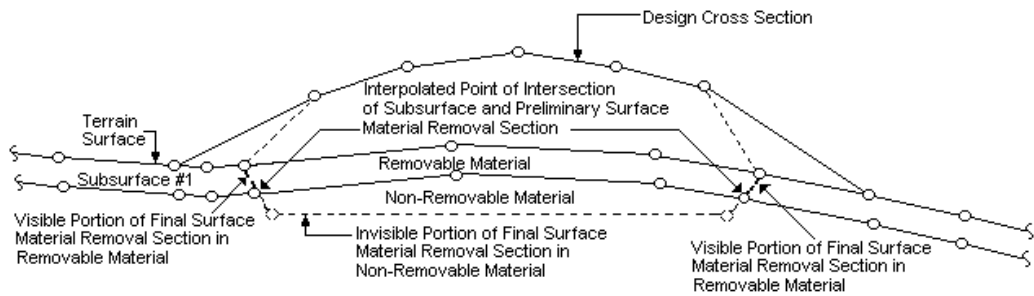


Figure N-4b

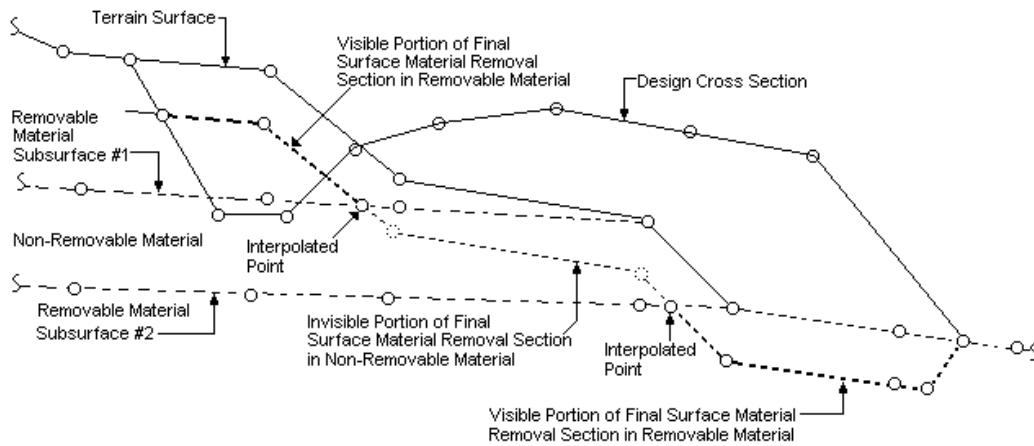


Figure N-4c

Surface Removal - Material Sensitive Conditions

- Then, using the removal depth and cut slope ratio, the first and last “lowered” points are created for the zone.
- Next, the intervening points of the removal zone, if any are required, are created by either following the terrain (follow terrain option) at the specified depth, or by constructing a straight line between the first and last "lowered" points (straight line option).
- Finally, when all of the removal zones are calculated, they are concatenated into the preliminary surface removal section.

Typical preliminary surface material removal sections are shown in Figure N-3.

Final Surface Material Removal Section

The final surface material removal section for the roadway is then created in the following manner:

- If the material sensitive toggle is set to No, then the final section is identical to the preliminary section, and all points and segments within the section are set to be visible.
- If the material sensitive toggle is set to Yes, then the creation of the final section will take multiple subsurfaces into account. The visible shape of the final surface material removal section may be affected by subsurface materials.
- Proceeding in left to right order, the preliminary section is compared with the various subsurfaces.
- A point is interpolated at each intersection with a subsurface (i.e., material boundary) and inserted in the preliminary section.
- All points within the preliminary section are then transferred to the final section.
- Then, using data stored in the material criteria table regarding whether materials are removable, the visibility of all points within the final surface material removal section are determined. Points and segments within removable materials are set to be visible for displaying and plotting. Points and segments within materials designated not removable are set to be invisible for displays and plotting.
- Finally, the final surface material removal section for the roadway is stored and the process is continued with the next roadway.

Typical final surface material removal sections are shown in Figures N-4a, b, and c.

Median Removal

When all roadways for a station have been processed, the median removal flag is checked. If the median removal flag is set to No, the process continues with the next station. If the flag is set to Yes, then the median removal subprocess is performed. The median removal subprocess is performed in left to right roadway order. A check is performed to determine whether a median exists, and, if so, whether surface material removal has been performed for both roadways. If either of these conditions is not true, the next median is checked. If both conditions are met, the preliminary median removal section is created, as follows:

- The last lowered point of the left roadway final removal section becomes the beginning point, and the first lowered point of the right roadway final removal section becomes the ending point.
- Then, the intervening points of the median removal preliminary section, if any are required, are created by either following the terrain surface (follow terrain option) at the specified depth, or by constructing a straight line between the beginning and ending points (straight line option).
- Finally, a lowered median point is interpolated on both the terrain surface and the preliminary median removal section at the median point baseline offset distance.

The final median removal section is created in the same fashion as the final surface material removal sections for the roadways.

Points within a median removal section to the left of the median point are added to the final surface material removal section for the left roadway; likewise, points to the right are added to the right roadway. The ending point of the left roadway and beginning point of the right roadway final surface material removal sections are both replaced with the interpolated point on the terrain surface at the median point offset distance. See the Figure on page N-7.

When all the medians have been processed, the surface material removal process continues with the next baseline station. End area calculations are performed after the template subcut process is executed.

Output

Output from the surface material removal process is in the form of final surface material removal sections which are stored in an output data structure for use in the template subcut process, the end area calculation process and the earthwork volume and mass ordinate calculations. These sections are also available for interactive displays, hard copy plots and reports.

TEMPLATE SUBCUT PROCESS

Template subcut is the removal of material below subgrade in excavation sections. The process enables the user to specify, by design roadway, the location (station to station) template subcut limits, type of subcut section and configuration. The template subcut process is sensitive to material classification, if so desired. The process is useful for moisture and density control. Material is removed, then replaced and compacted to provide better transition from cut to fill sections. See Figure N-5a for an example.

The process is also useful for removal and wastage of unsuitable materials below subgrade, as shown in Figure N-5b. Since the process can be sensitive to material classification, suitable materials can be ignored, or cut, replaced and recompacted, as shown in Figure N-5c.

Subcut Type

There are two subcut type options - rural or urban. The default is rural.

The shape of the subcut section is the primary difference between the two options. When the rural option is in effect and the cut slope ratio is blank, then the section is completed by extending the lowered segment adjacent to the shoulder point until this segment intersects the front slope of the ditch. If the slope ratio is not blank, then the given slope ratio is applied from the lowered shoulder point, until intersection occurs. The distance left and right, discussed later, are the maximum intercept distances. If no intercept has occurred before the maximum distance, then an intersection is forced at that distance.

When the urban option is in effect, the section is completed by first determining the subcut limits using reference points and distances, discussed later, and then applying the slope ratio to the subcut depth and lowering the intervening point. Typically the urban option is used for curb and gutter sections requiring subcut, and the rural option is used for open ditch sections. Examples of each type are shown in Figure N-6.

Subcut Limits

The left and right template subcut limits are defined independently. There are three elements within each subcut limit group that must be defined - the reference point, the distance from the reference point and the cut slope. Each element is shown graphically and discussed below.

Reference Point

There are two reference point choices - distance from shoulder point and distance from centerline point. Distance from shoulder point is the default.

Distances are measured from one of these two reference points. Subgrade template points, not finish grade, are used in the computations.

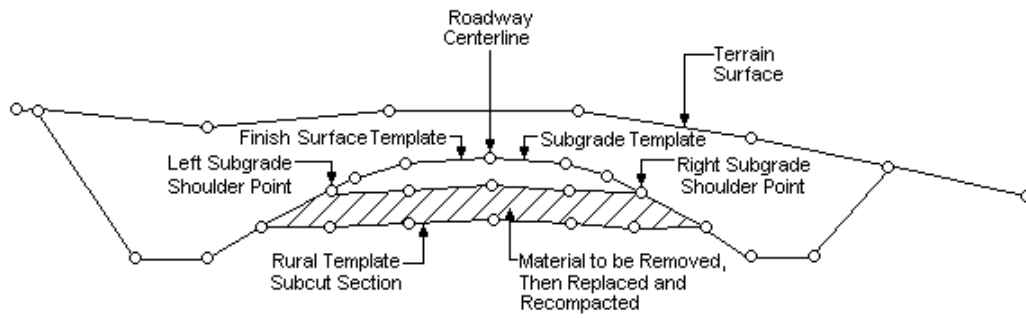


Figure N-5a
Typical Rural Subcut for Moisture and Density Control

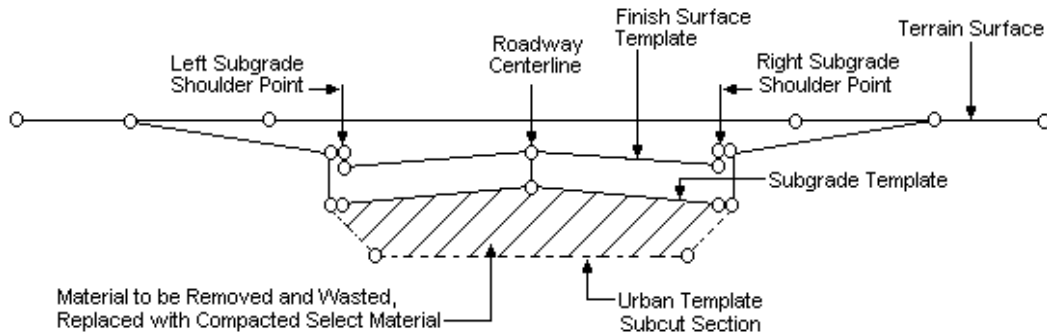


Figure N-5b
Typical Urban Subcut for Unsuitable Material Removal

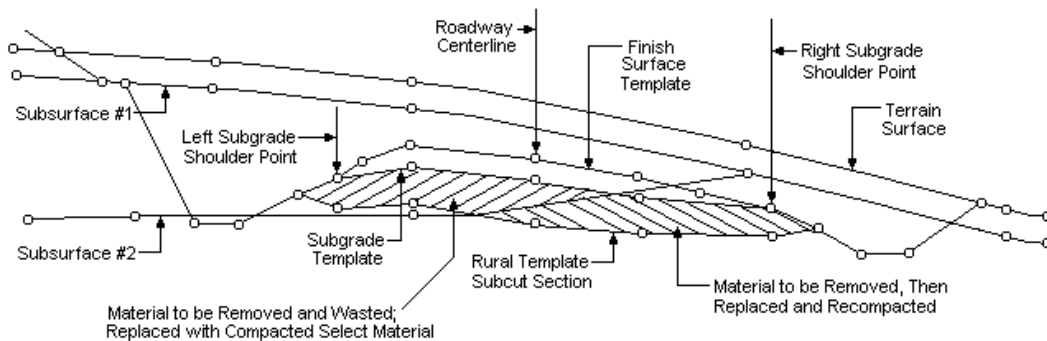
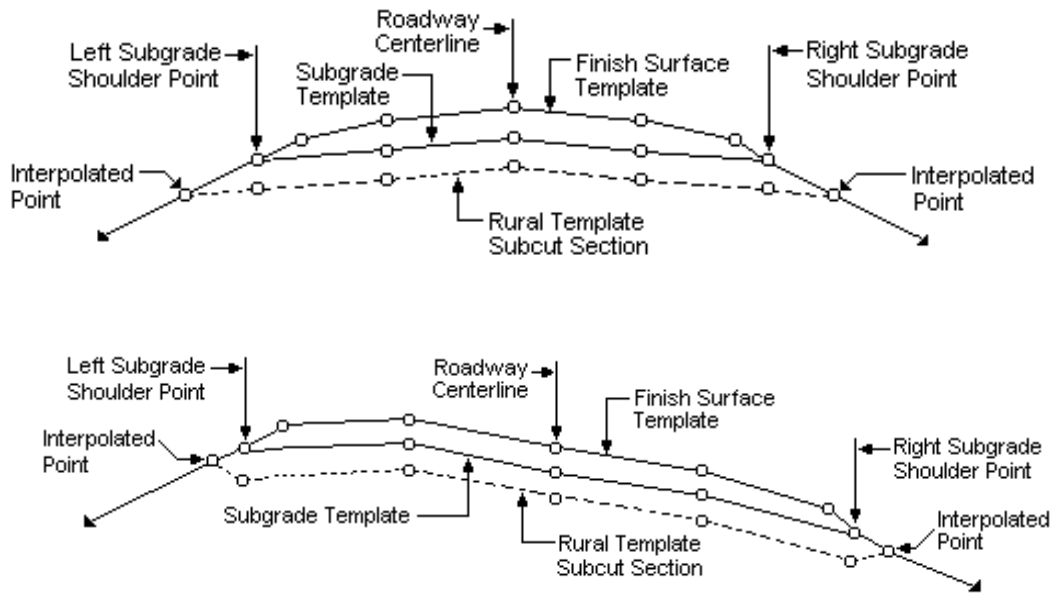
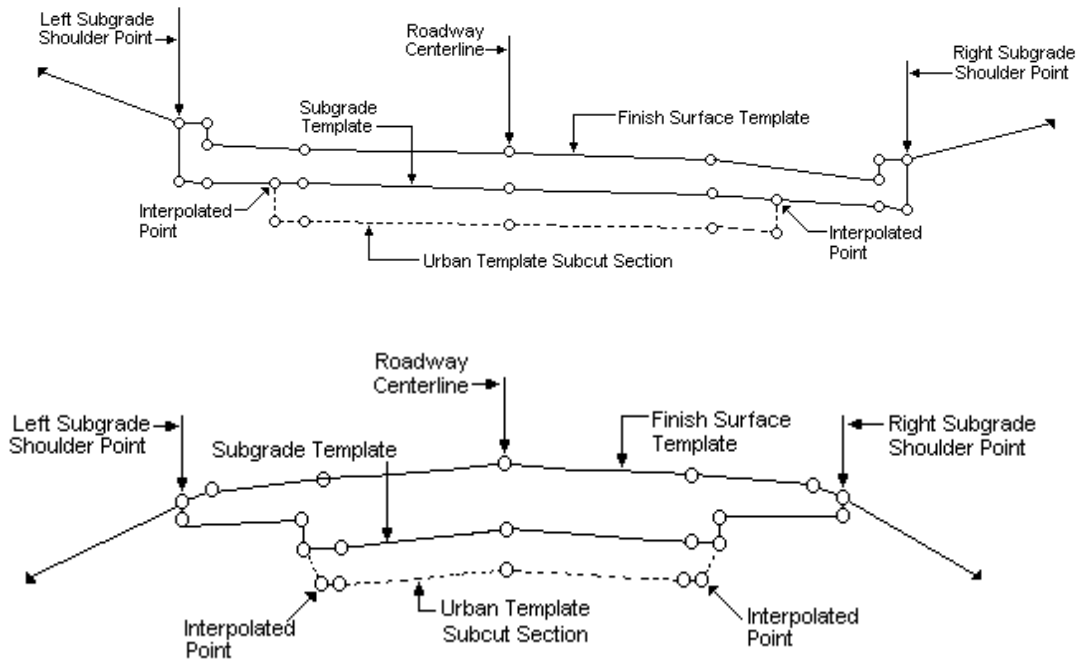


Figure N-5c
Template Subcut Material Sensitivity



Typical Rural Template Subcut Sections



Typical Urban Template Subcut Sections

Figure N-6

Distance from Reference Point

The meaning of the distances from the reference point vary according to the subcut type - rural or urban. In all cases, the distance is measured from the designated reference point. Positive distances indicate a distance to the right; negative distances to the left.

If the subcut type is set to rural, then the distance indicates the maximum intercept distance. If no intercept has occurred before this distance, then an intercept is forced at this distance. If the centerline is the reference point, then the distance must be equal to or greater than the distance to the shoulder point.

If the subcut type is set to urban, then the distance given indicates the distance to the beginning point of the subcut section. Urban subcut sections must be totally contained between the subgrade shoulder points of the template. See Figure N-7 for examples of distances for both rural and urban sections.

Cut Slope

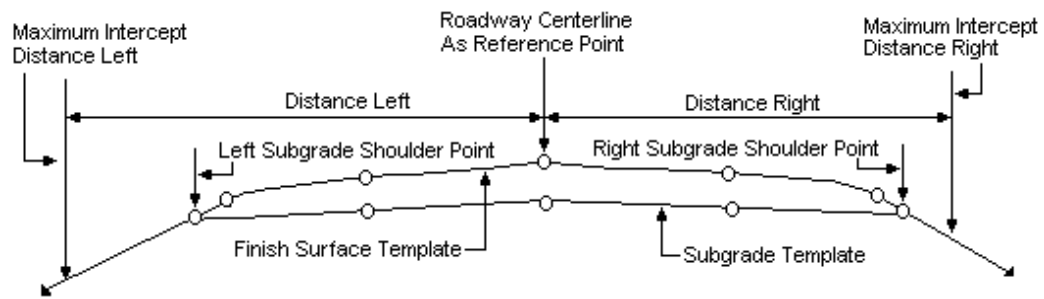
The meaning of the cut slope values vary according to the subcut type - rural or urban.

If the subcut type is rural and the cut slope data is blank, then the lowered segment adjacent to the shoulder point is extended until this segment intersects the front slope of the ditch forming the beginning (left side) or ending (right side) point of the rural subcut section. If a value is entered for cut slope, then a line is constructed using this slope ratio from the lowered shoulder point until this line intersects the front slope of the ditch. Positive slope ratios are up and away from the shoulder point; negative slope ratios are down and away from the shoulder point.

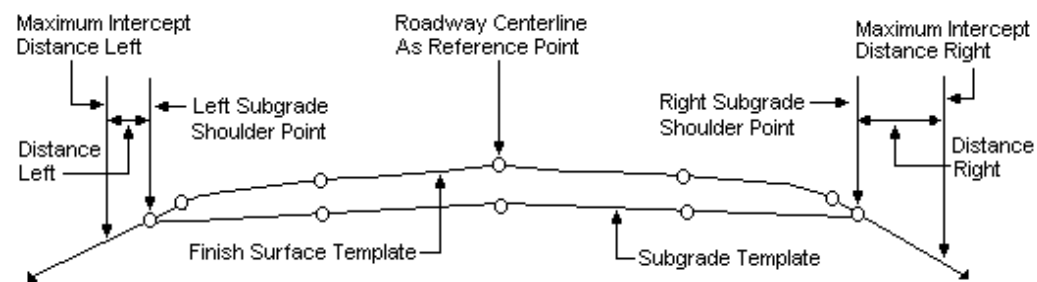
If the subcut type is urban and the cut slope data is blank, then a vertical slope is built from the reference point (modified by distance) to the specified depth. If a value is entered for the cut slope, then a line is constructed using this slope ratio from the reference point, modified by distance, to the specified depth. Positive slope ratios are down and toward the centerline; negative slope ratios are down and away from the centerline. See Figure N-8 for examples of both rural and urban conditions.

Subcut Depth

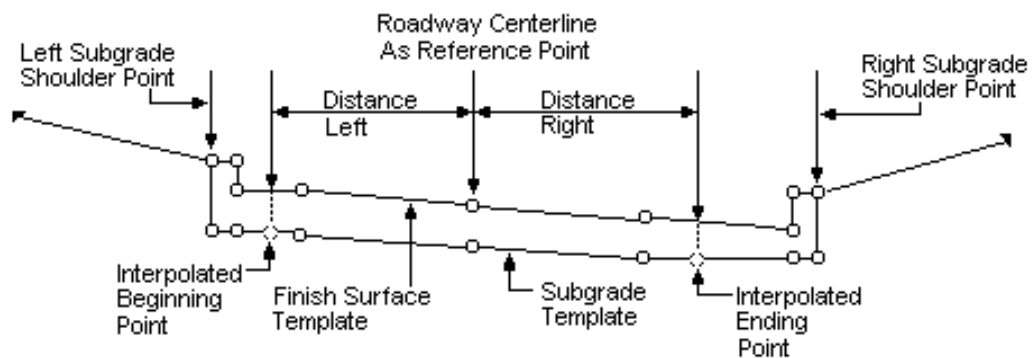
Subcut depth is measured vertically from the subgrade template. For rural sections, this depth is applied at the shoulder point. For urban sections, it is applied at the reference point modified by the distances left or right. See Figure N-8 for examples of cut slope and subcut depth calculations for both rural and urban sections.



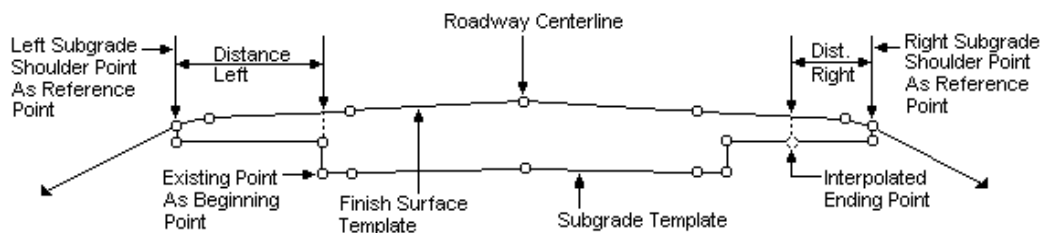
Rural Option



Rural Option

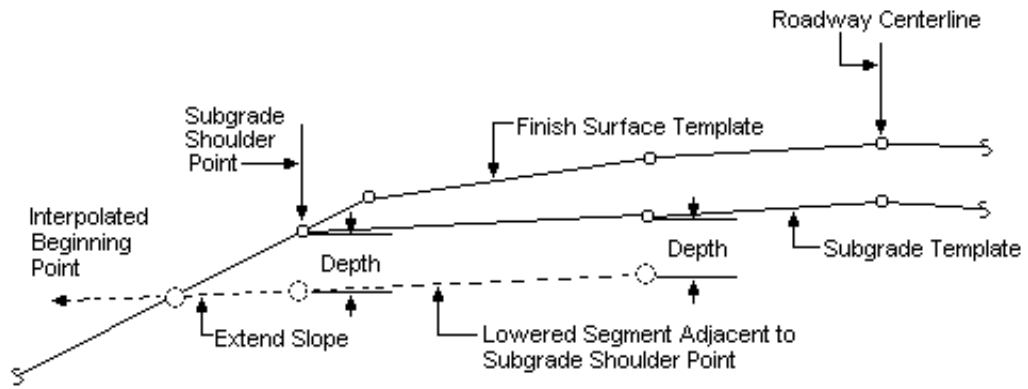


Urban Option

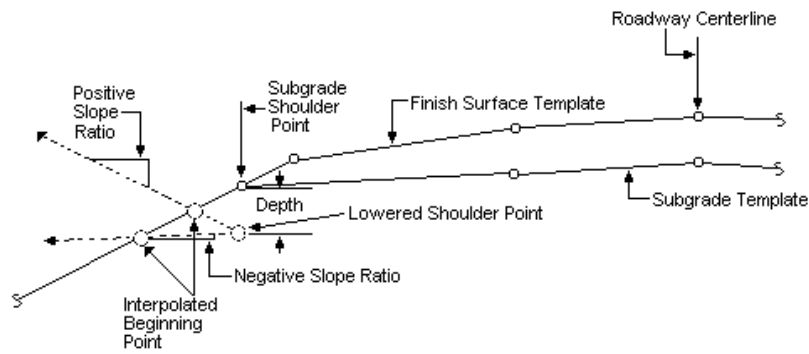


Urban Option

Figure N-7 - Reference Distances



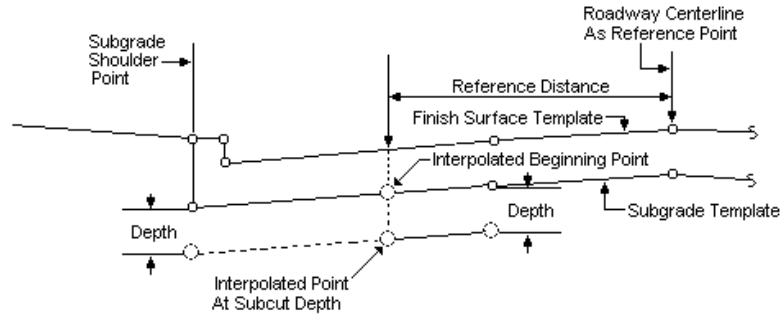
Rural Option



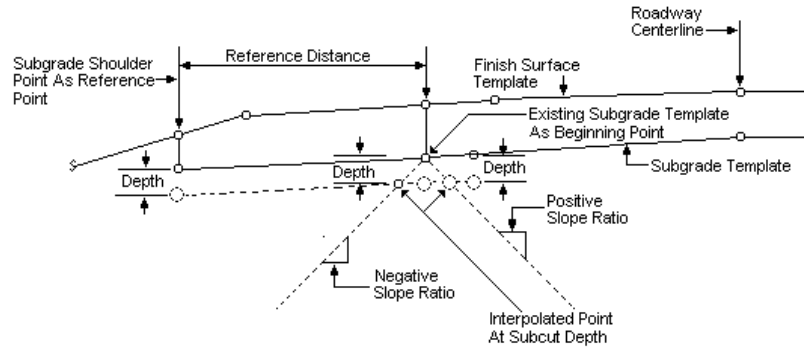
Rural Option

Figure N-8a

Template Subcut Slope and Depth Parameters



Urban Option



Urban Option

Figure N-8b

Template Subcut Slope and Depth Parameters

Subcut Shape

There are two options for defining the subcut shape - follow template and straight line. Follow template is the default option. This implies that the template subcut section will follow the template at the specified depth. Straight line indicates that the section will follow a straight line between the beginning and ending points. See Figure N-9 for example of both types.

Material Sensitive

The material sensitive toggle indicates whether the template subcut process checks the material type to determine whether the material is to be subcut. The default value is Yes. The effect of the material sensitive toggle is shown in Figures N-10a, b, and c. If the toggle is set to No, then the final visible shape of the template subcut section is always the same as the preliminary section. If the toggle is set to Yes, then the final visible shape may vary according to the material type encountered.

Figure N-10a shows the condition in which the preliminary template subcut section is totally contained within a material layer that is subject to subcut. In this case, the final visible shape of the template subcut section is the same as the preliminary shape. Figure N-10b shows the condition in which the preliminary template subcut section intersects the boundary between two materials. Since both of these materials are subject to subcut, the visible shape of the final section is also the same as the preliminary section. Figure N-10c shows a condition in which the preliminary subcut section intersects more than one material layer. Since one of these material layers is not subject to subcut, then the final subcut section is not visible in the layer as shown.

In either case, No or Yes, the final shape of the visible shape of the template subcut section is sensitive to the terrain surface and, if specified, any surface material removal since subcut is only performed in excavation sections. See the subsection entitled Process Methodology for a more complete discussion.

Process Methodology

The template subcut process is performed in conjunction with and after the template, median, sideslope and surface material removal processes. The process is triggered by the design cross section computation flag. The template subcut process is performed for a design roadway only if there is data stored in the template subcut structure for that design roadway (i.e., at least one entry). The process is performed for the same baseline station range as defined for design cross section computations, taking station equations and design exceptions into account.

The following paragraphs discuss the template subcut process in a step-by-step fashion.

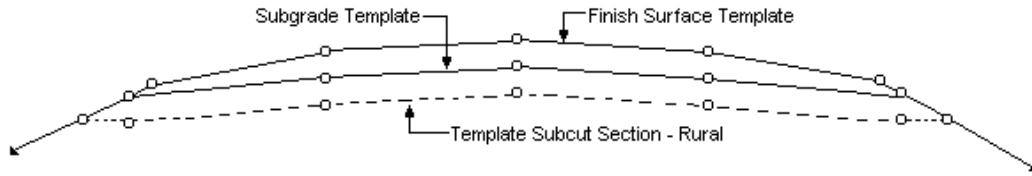


Figure N-9a
Subcut Section Follows Subgrade Template - Rural

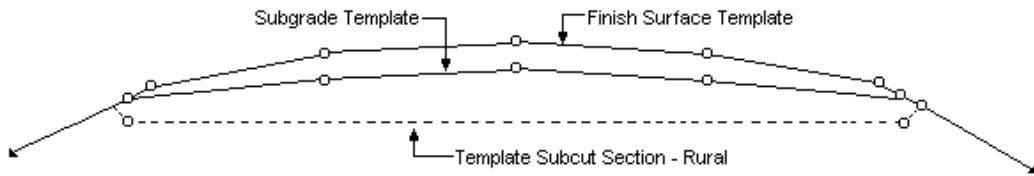


Figure N-9b
Subcut Section Follows Straight Line Between Shoulder Points - Rural

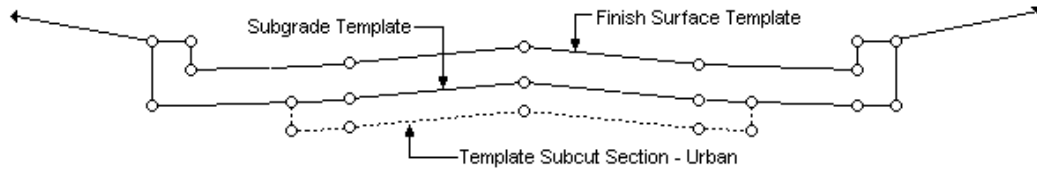


Figure N-9c
Subcut Section Follows Subgrade Template - Urban

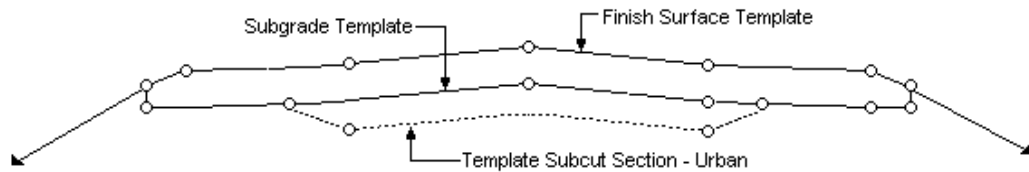


Figure N-9d
Subcut Section Follow Straight Line Between Lowered End Points - Urban

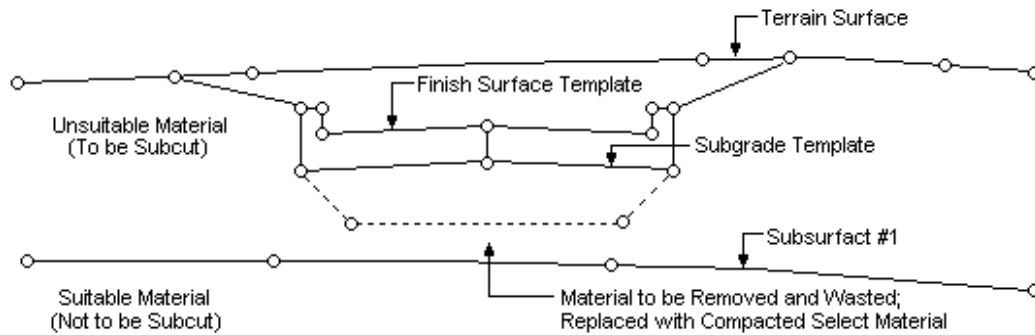


Figure N-10a

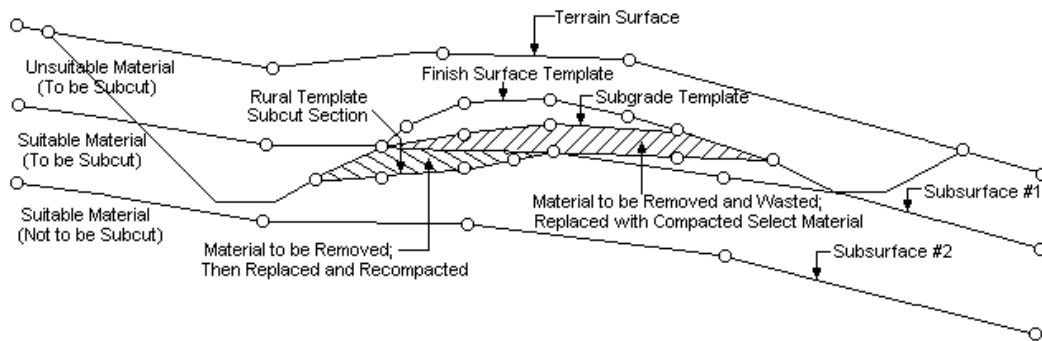


Figure N-10b

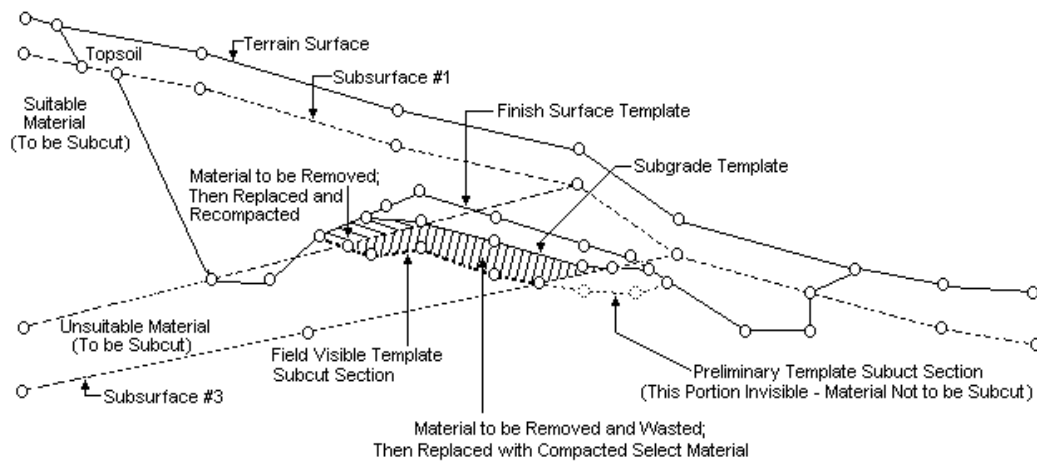


Figure N-10c
 Subcut Material Sensitive Conditions

Baseline Station Processing

For each baseline station in the station range defined above, the template subcut process is performed in design roadway order, not in left to right order. At each baseline station, each design roadway is compared with entries in the template subcut input structure for that design roadway to determine whether the roadway should be processed. If the roadway has parameter data stored at this baseline station, the data is retrieved from the structure and the process is performed; otherwise, the next roadway is checked.

Preliminary Template Subcut Section

If a design roadway is to be processed, the preliminary template subcut section for the roadway is created. The subcut creation process varies, depending on the rural or urban subcut type. As mentioned earlier, the shape of the preliminary subcut section is the primary difference between the two options. Input parameters are also interpreted differently to achieve the two shapes. Each variation is discussed in turn, rural and urban.

Under the rural option, the distance parameters are interpreted as maximum intercept distances. The cut slope parameter is applied to the lowered shoulder points and is used to create the beginning and ending points of the preliminary subcut section. The actual processing steps follow.

- First, the subcut depth is applied to the left subgrade shoulder point to create a lowered shoulder point.
- Then, if the cut slope parameter is blank, the subcut depth parameter is applied to the next subgrade point toward the roadway centerline, creating a lowered segment. This segment is then extended until it intersects with the front slope of the ditch forming the beginning point for the preliminary subcut section. If no intercept has occurred before the left maximum intercept distance, then an intersection is forced at this distance, and a warning message is issued into the error log.
- If the cut slope parameter is not blank, then the given cut slope ratio is applied from the lowered shoulder point until it intersects with the front slope of the ditch forming the beginning point. A positive slope ratio creates a trial slope up and away from the centerline, and a negative slope creates a trial slope down and away from the centerline. If no intercept has occurred before the left maximum intercept distance, then an intersection is forced at this distance, and a warning message is also issued.
- The ending point of the preliminary subcut section is created in a similar fashion on the right side. At this juncture, four points of the preliminary section have been created.

- Finally, the intervening points of the preliminary template subcut section, if any are required, are created by either following the subgrade template at the specified depth (follow template option), or by constructing a straight line between the two lowered shoulder points (straight line option).

Under the urban option, the distance parameters are used to determine the beginning points of the preliminary subcut section. The cut slope parameter is used to locate the first and last lowered points of the preliminary subcut section. The actual processing steps follow.

- First, the left distance is applied from the left reference point to determine the distance to the beginning point. If this distance coincides with the distance to a point within the subgrade template, then this point is used as the beginning point. If not, then a point is interpolated on the subgrade template at the specified distance forming the beginning point.
- Then, if the cut slope parameter is blank, the subcut depth parameter is applied to the beginning point creating the first lowered point of the preliminary subcut section directly below the beginning point.
- If the cut slope parameter is not blank, then lowered trial segments are created by applying the subcut depth parameter to subgrade points in the vicinity of the beginning point. The slope ratio is then applied from the beginning point until an intersection occurs on one of the lowered trial segments forming the first lowered point of the preliminary subcut section. A positive slope is down and toward the centerline; a negative slope is down and away from the centerline.
- The ending point and last lowered point of the preliminary section are created in a similar fashion on the right side. At this juncture, four points of the preliminary section have been created.
- Finally, the intervening points of the preliminary template subcut section, if any are required, are created by either following the subgrade template at the specified depth (follow template option) or by constructing a straight line between the first and last lowered points (straight line option).

Typical preliminary template subcut sections for both rural and urban options are shown in Figure N-9.

Final Template Subcut Section

The visible shape of the final template subcut section is affected by the terrain surface and, if specified, any surface material removed. Similarly, the visible shape may be affected by subsurface materials if the material sensitivity flag is set to Yes. The impact of these factors is discussed below.

Terrain Surface and Surface Material Removal Impact

Since template subcut is performed only in excavation, the terrain surface and any surface material removed must be accounted for when creating the final template subcut section. The actual processing steps follow.

- First, a check is made to determine whether surface material removal has been performed for this roadway at this baseline station.
- If no subsurface material removal has been performed, then the preliminary template subcut section is compared with the terrain surface. If the preliminary subcut section is always below the terrain surface, then all points in the preliminary section are transferred to the final template subcut section. All points and segments within the section are set to be visible for displaying or plotting and processing continues with the material sensitive impact below. See Figure N-11a. If the preliminary subcut section is not always below the terrain surface, then intersection points between the terrain and the preliminary section are determined and inserted in the preliminary subcut section. Then all points within the preliminary section are transferred to the final template subcut section. All points and segments below the terrain surface are set to be visible for displaying and plotting, and all points and segments above the terrain are set to be invisible. See Figure N-11b. Processing then continues with the material sensitive impact, below. If the preliminary subcut section is always above the terrain surface, then all points within the preliminary subcut section are deleted and there is no final template subcut section for this roadway. See Figure N-11c. Processing then continues with the next roadway.
- If surface material removal has been performed, then the preliminary template subcut section is compared with the surface material removal section in lieu of the terrain surface and the final template subcut section is created in the same fashion as described above. See Figures N-12a, b, and c for examples.

Material Sensitive Impact

The visible shape of the final template subcut may be affected by subsurface materials if the material sensitive flag is set to Yes. The actual processing steps follow.

- If the material sensitive flag is set to No, then there is no change to the status of the final template subcut section and processing continues with the next roadway.
- If the material sensitive flag is set to Yes, then the final subcut section is compared with each subsurface, in turn, progressing downward from the terrain surface. Intersection points between the final section and each subsurface are determined and inserted in the proper location within the final template subcut section.
- Then, using data stored in the material criteria table regarding whether materials are subcuttable, the visibility of all points and segments within the section are determined.

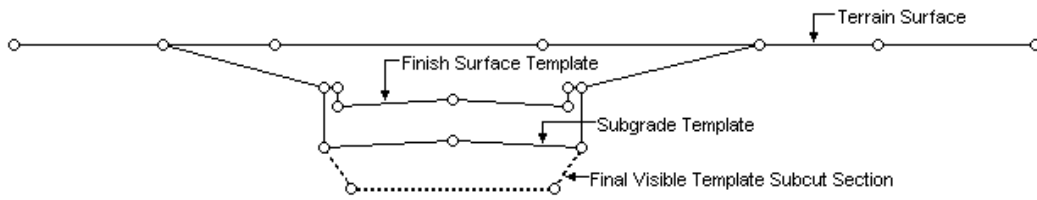


Figure N-11a
Template Subcut Section versus Terrain Surface (All Cut)

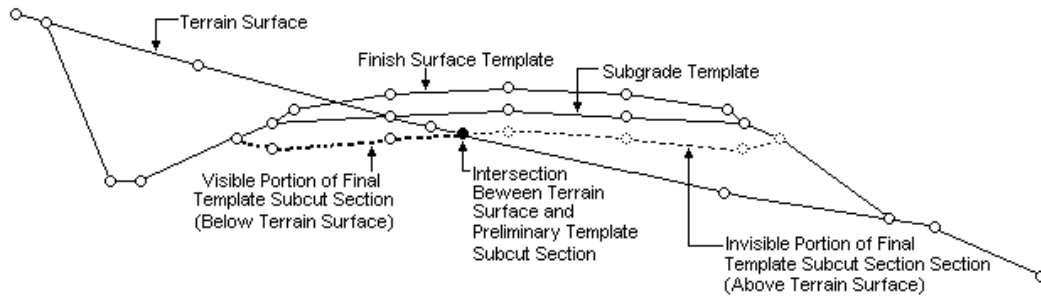


Figure N-11b
Template Subcut Section versus Terrain Surface (Cut and Fill)

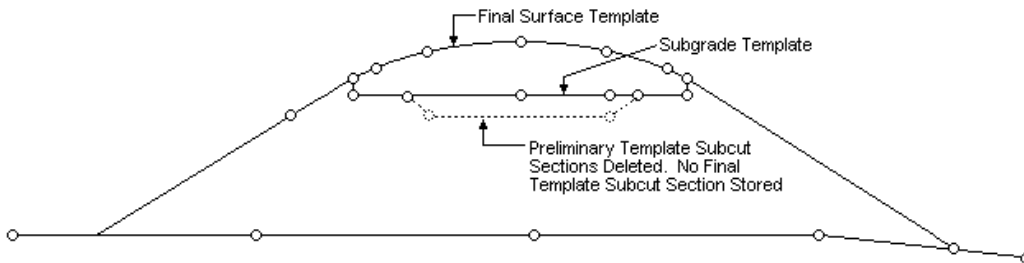


Figure N-11c
Template Subcut Section versus Terrain Surface (All Fill)

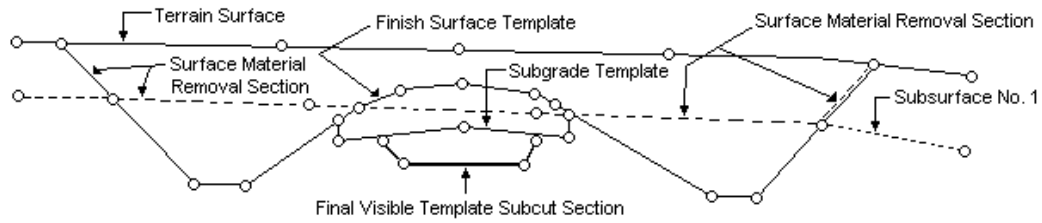


Figure N-12a
 Template Subcut Section versus Surface Material Removal Section (All Cut)

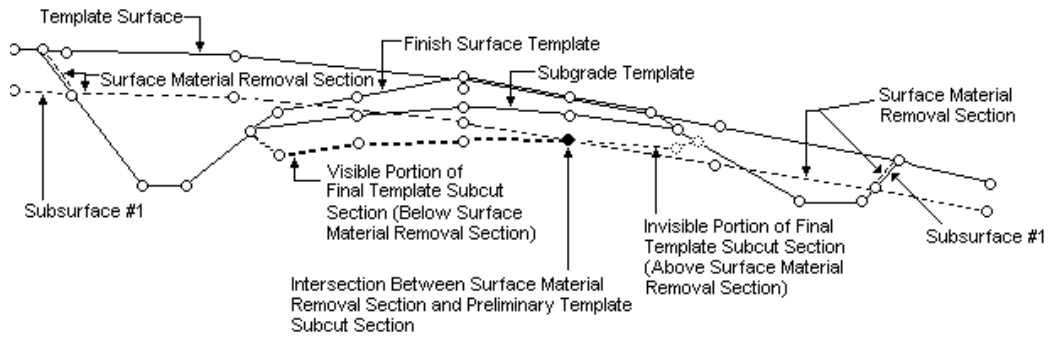


Figure N-12b
 Template Subcut Section versus Surface Material Removal Section (Cut and Fill)

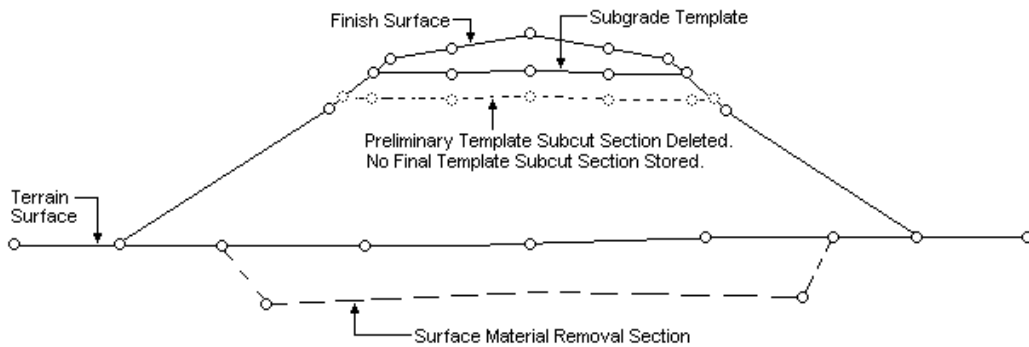


Figure N-12c
 Template Subcut Section versus Surface Material Removal Section (All Fill)

- Points and segments within materials that are subcuttable are set to be visible for displaying or plotting. Points and segments within materials that are not subcuttable are set to invisible for displaying or plotting. Processing then continues with the next roadway.

Typical final template subcut sections showing material sensitivity are shown in Figures N-10a, b and c, shown earlier in this Appendix.

When all roadways have been completed, the template subcut process continues with the next baseline station. When all baseline stations within the defined station range have been completed, the process is finished. End area calculations for the entire design cross section are then performed for all baseline stations within the defined station range.

Output

Output from the template subcut process is in the form of final template subcut sections which are stored in an output data structure for use in end area and earthwork volume and mass ordinate calculations. These sections are also available for interactive display, hard copy plots and reports.