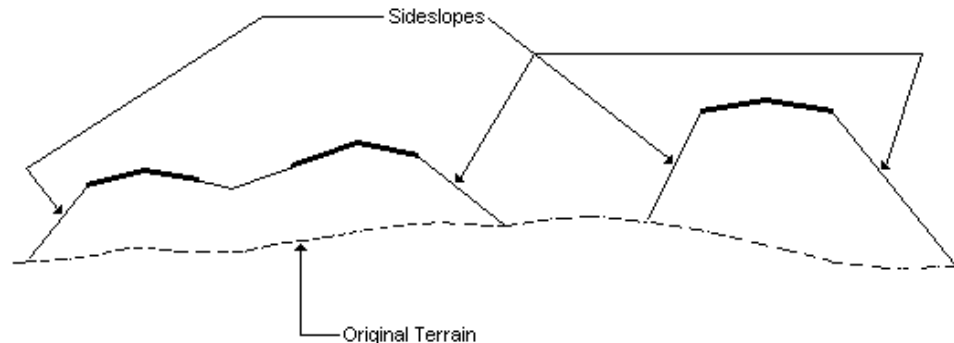


APPENDIX J

SLOPE SELECTION PROCESS

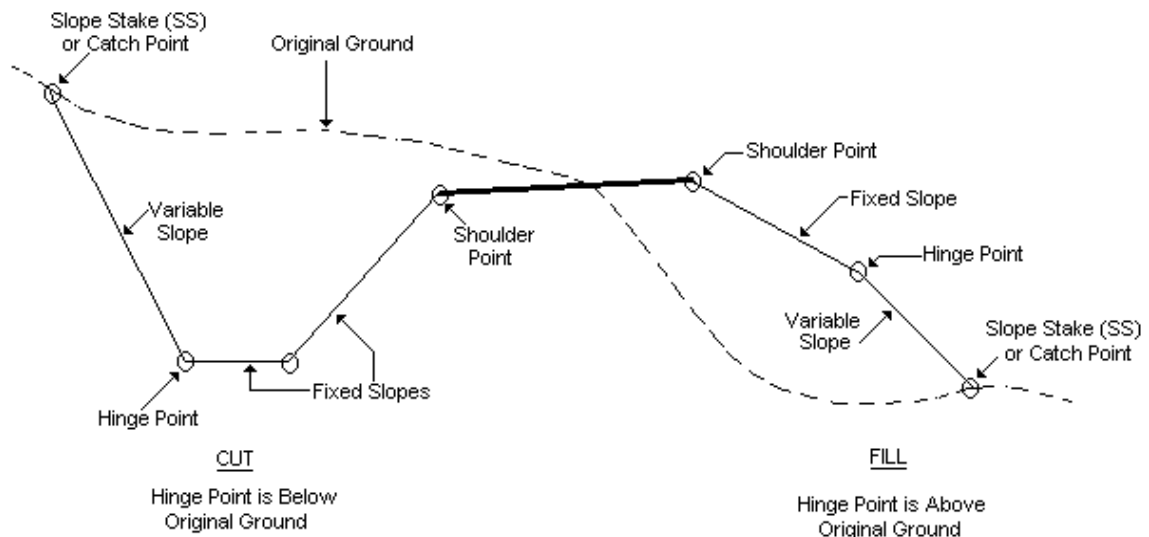
Sideslope (slope selection) data are used to link all remaining shoulder points to the original terrain or to nearby roadway slopes. This completes the design section, as shown below.



Slope selection data are similar to median data in that the sideslope shape is defined as a pattern and can be applied over a station range, or two patterns can be linearly transitioned over a station range. It differs from median data in that median data are related to two adjacent roadways, whereas sideslope data are related to a single roadway shoulder. Slope selection data should be given on both sides of each roadway (can be omitted where covered by medians), and should be given for both cut conditions and fill conditions for the entire length of the roadway. Special ditch grades may be introduced into sideslope patterns. (See Appendix I.)

SIDESLOPE SHAPES

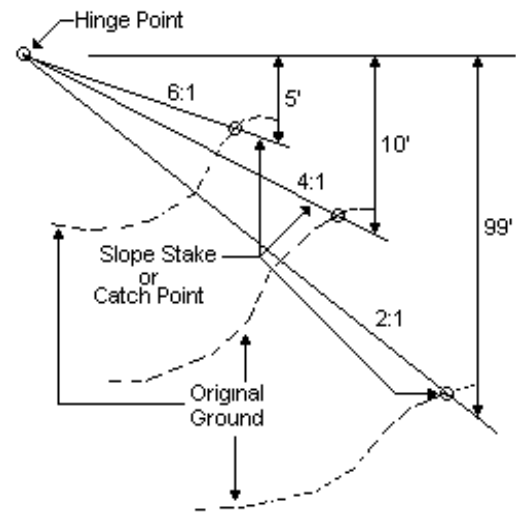
Sideslope patterns are made up of slope segments that may be defined in several ways. Since the edge of the roadway may be either in cut or in fill, it is necessary to describe a pattern for the cut condition and a pattern for the fill condition. The sketch below depicts cut and fill sideslope patterns.



A slope pattern can contain from 1 to 16 slope segments. It can have from 0 to 15 fixed slopes, but it must have at least one variable slope at the end of the pattern. Fixed slopes are slope segments that have a fixed slope and a fixed length. Variable slopes are slope segments that have a fixed slope and a variable length. The point at the end of the last fixed slope (or shoulder point, if there are no fixed slopes) is called the hinge point of the pattern. Fixed slopes are normally used to determine the portion of the sideslope pattern that extends from the shoulder point to the hinge point and that always stays the same shape. If a slope pattern has no fixed slope segments, the hinge point is located at the shoulder point. The use of fixed slopes may be modified by use of fixed slope segment options, discussed later in this Appendix.

A variable slope extends until it intersects with the ground or reaches the input vertical distance. The designer will normally enter more than one variable slope and let IGrds select the one that fits the condition. The following Imperial unit example shows three options the designer might specify. Study the options and the resulting cases shown in the drawing.

- If vertical distance on the sideslope is 5' or less, use a 6:1 slope
- If the vertical distance is greater than 5; but no greater than 10', use a 4:1 slope
- If the vertical distance is greater than 10', use a 2:1 slope, regardless of vertical dimension



Slope selection data is used to define the shape of sideslope patterns and to indicate the station limits where the pattern applies. After a specific slope selection pattern has been defined and given a number, it can be specified to apply at various locations by referring to its number.

A cut/fill section tables form is used in conjunction with the slope selection form in the IGrds/AN Option to facilitate the definition of individual segments. This form makes it possible to define the properties of a segment once and then refer to it by number. The IGrds/IG Option provides for direct input of slope segments, using the sideslope shape builder facilities.

During the design process, medians are designed before sideslopes. If both median and sideslope patterns are specified at the same station, a median will be designed. When no median or slope selection pattern has been entered covering a station, IGrds will connect the shoulder point to the original ground with a one-to-one slope extending outward.

The following types of cut and fill slope selection patterns may be defined:

- Fixed Slopes
- Variable Slopes
- Benches (repeating slope combinations)
- Slopes with Special Ditches
- Combinations of Fixed and Variable Slopes
- Combinations of Fixed and Constant Distance Slopes

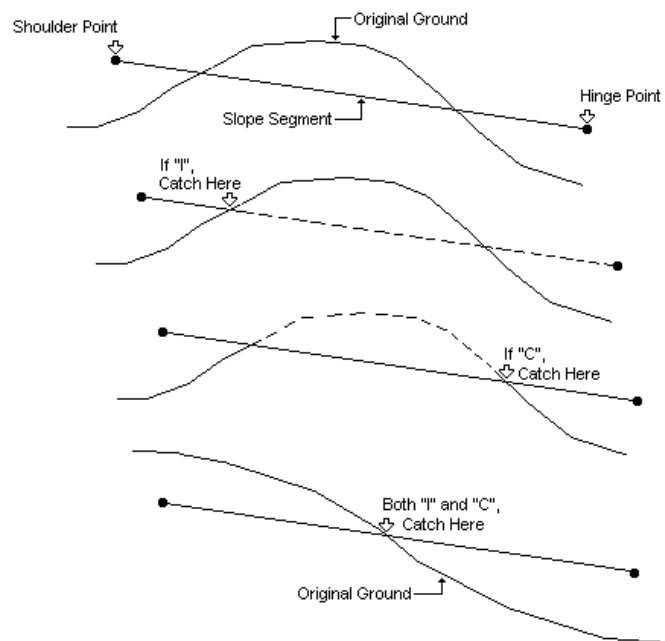
The above capabilities provide considerable flexibility to the designer. A good understanding of the options available and the slope selection process logic, discussed later, is important to the designer.

Slope Segment Options

Fixed Slope Options

Fixed slopes are normally built as designed. However, a review of the section on how IGrds approaches the slope selection process shows that there are cases where it is desirable to have fixed slopes treated as variable slopes; that is, to have them intersect the original ground and stop. The fixed slope options are a blank, I or C. These options provide the designer considerable flexibility. It is normally desirable to code either an I or a C option on all fixed slopes, since this will usually build the desired section. However, there will be occasions where the options need to be omitted. Fixed slope options can be used on both cut and fill pattern fixed slopes. These intercept options are only used when the cut hinge point is above the terrain or the fill hinge point is below the terrain. (See Table J-1.)

- Option blank - The slope will be built as defined.
- Option I - Defines the catch point at the FIRST intercept with the terrain for this segment.
- Option C - Defines the catch point at the LAST intercept with the terrain for this segment.
- If there is only one catch point, there is no difference between Option I and Option C.



SELECTING OPTION SYMBOLS FOR SLOPE SELECTION		
SYMBOL	USE	RESULTS
Blank	When no option is required Fixed slopes	Fixed slopes will be built exactly as indicated.
Blank	When no option is required Variable slopes	Variable slopes will be built exactly as indicated if the slope intersects the terrain within the vertical distance given; otherwise ignored.
I	To override fixed slopes	Defines the slope stake (catch point) and terminates selection at the FIRST intercept with the terrain.
C	To override fixed slopes	Defines the slope stake (catch point) and terminates selection at the LAST intercept with the terrain.
B	With benching patterns	Defines the first segment of a variable slope's benching pattern. May be used to define any other segment of a bench pattern which is to be tested to a catch point within the bench tolerance.
R	With benching patterns	Defines the slope segment of a variable slope's bench pattern.
S	With a special ditch	Fixes the slope while the horizontal distance varies. If a 3D geometry element is specified as the special ditch grade, then the segment will be extended to the elevation of the 3D element. The horizontal or offset component of the 3D component of the 3D geometry element will be ignored.
D	With a special ditch	Fixes horizontal distance while the slope varies. If a 3D geometry element is specified as the special ditch grade, then the segment will be extended to the elevation of the 3D element. The horizontal or offset component of the 3D component of the 3D geometry element will be ignored.

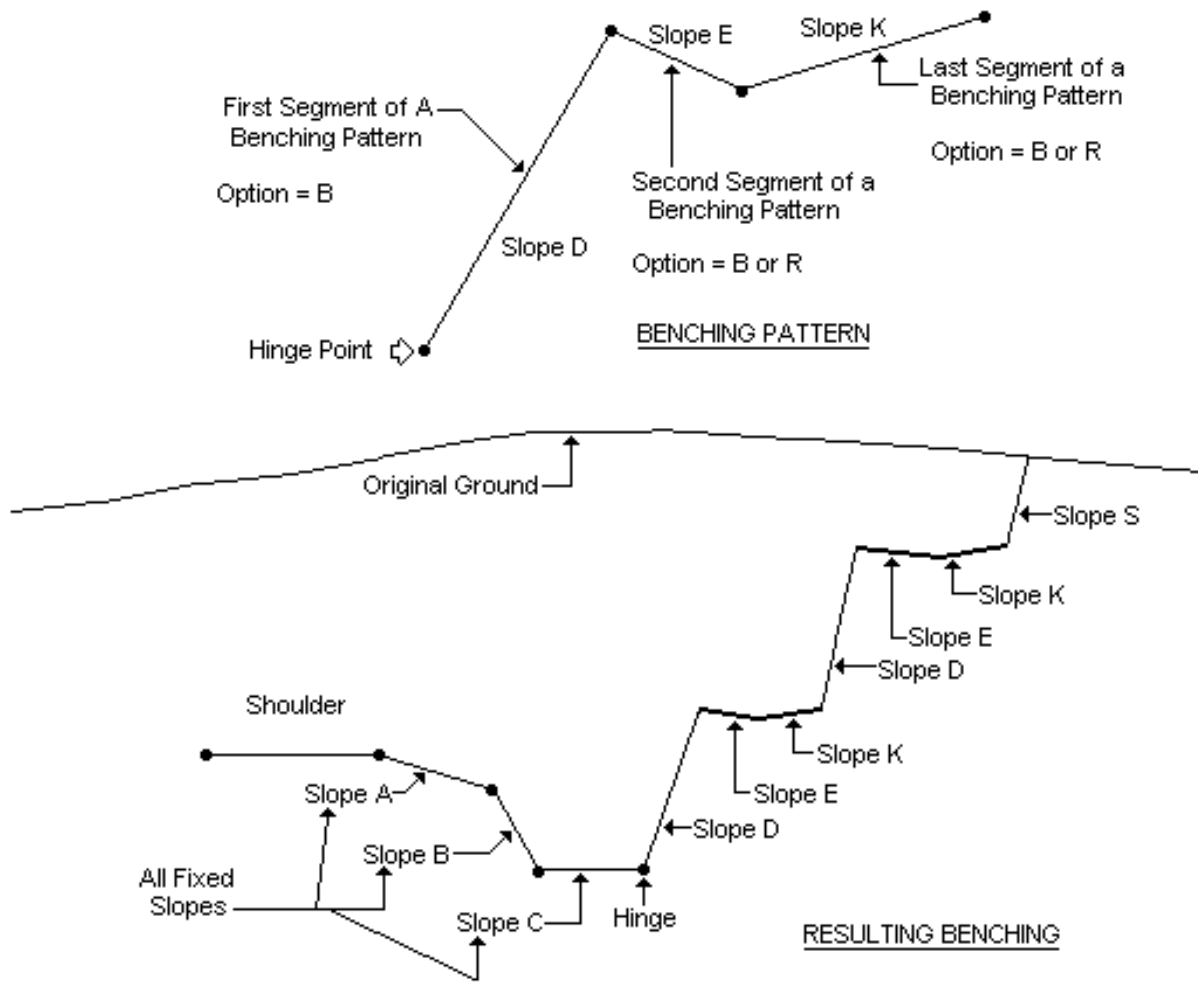
SYMBOL	USE	RESULTS
E	With a special ditch	<p>Horizontal distance held from a 3D geometry element.</p> <p>The E option specifies that the end of the segment defined will coincide with the elevation and offset of the 3D element. The beginning of the segment will be calculated by projecting the distance of the segment being defined backward toward the previous segment, thereby establishing the elevation of the point along the previous segment (or an extension of the previous segment). Again, the ending point of the previous segment will be moved to this point (elevation and offset)</p>
T	With a special ditch	<p>Slope held from a 3D geometry element.</p> <p>The T option specifies that the end of the segment being defined will coincide with the elevation and offset of the 3D geometry element. The beginning of the segment will be calculated by projecting the slope of the segment backward toward the previous segment until an intersection occurs with the previous segment (or an extension of the previous segment). The ending point of the previous segment will be moved to this intersection point.</p>
G	With a special ditch	3D geometry element controls end of segment.
Ditch ID (IG only)	With special ditch options	Defines which ditch to apply to the segment.
L	Daylighting	Daylight to ditch.
L	Daylighting	Daylight to shoulder.

Slope Selection Options

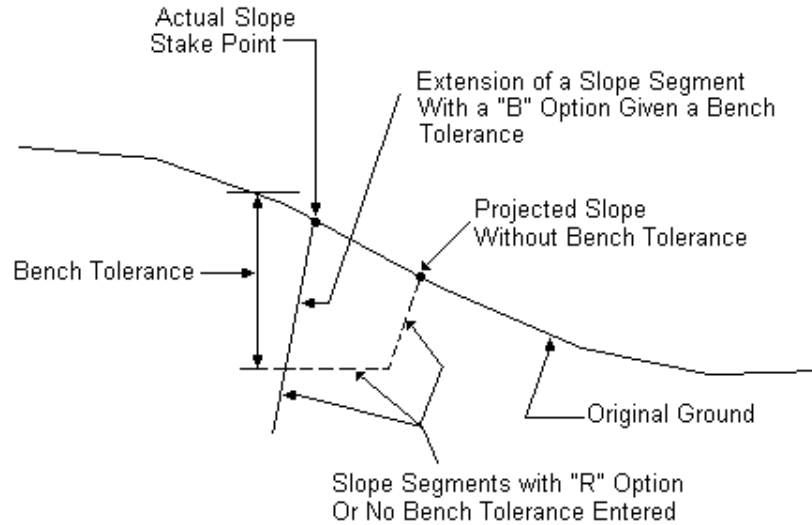
Table J-1

Benching Options

Benching may be used in place of normal variable slopes to connect the hinge point with the original ground. A set of slopes, called a bench pattern, is repeated until a slope intersects the ground or 15 segments are designed (the last slope would be connected vertically to the terrain). Benching can apply to either cut or fill sideslope patterns.



A bench tolerance may be specified. This is the vertical distance by which IGrds will try extending a bench pattern segment to see if a slope stake can be established. If no bench tolerance is entered, the slope stake point will be established in accordance with the normal benching rules. Any segment of the bench pattern which has a B option will be tested for bench tolerance.



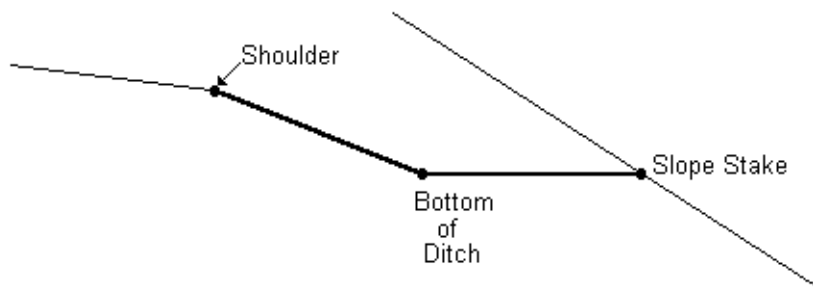
Typically, one or more variable slopes might be specified after the last segment of the repeating bench pattern. These would be slopes to be used in overburden overlying rock. They would be tried before the bench pattern was repeated. The designer can insert variable slopes to be tried this way anywhere within the repeating bench pattern. If they do not intersect the ground, they are ignored.

The elevation of the first bench can be controlled by using a special ditch option to set the ditch grade. One or more fixed slopes must precede the bench pattern.

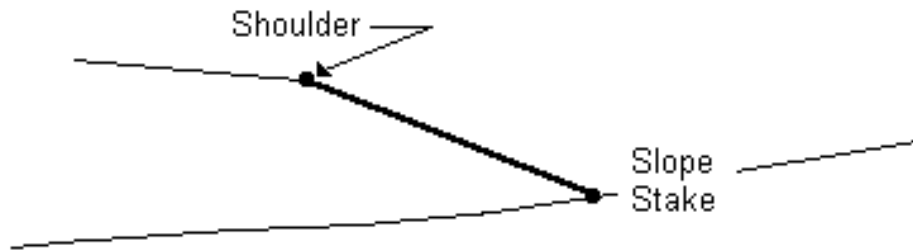
Daylight Option

The daylight option is used to help the designer determine where the daylight is located on the staking detail report. The daylight slope is simply the slope which intersects the ground and makes the stake. No calculations are performed when this option is specified. If the slope segment tagged with the L option is selected, that daylight location is flagged on the staking detail report.

Daylights from any cut slope will be reported as Cut 0 DD (daylight to ditch) and plus or minus the slope on the staking detail report.

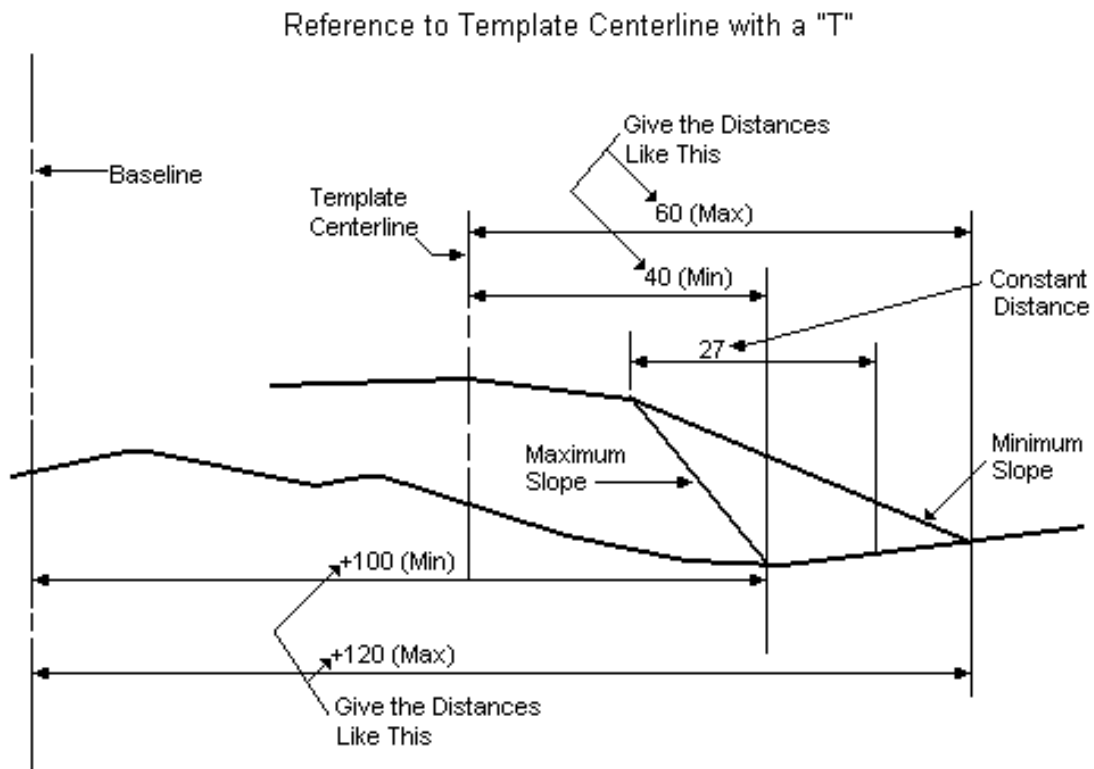


Daylights from any fill slope will be reported as Fill 0 DS (daylight to shoulder) and plus or minus the slope on the staking detail report.

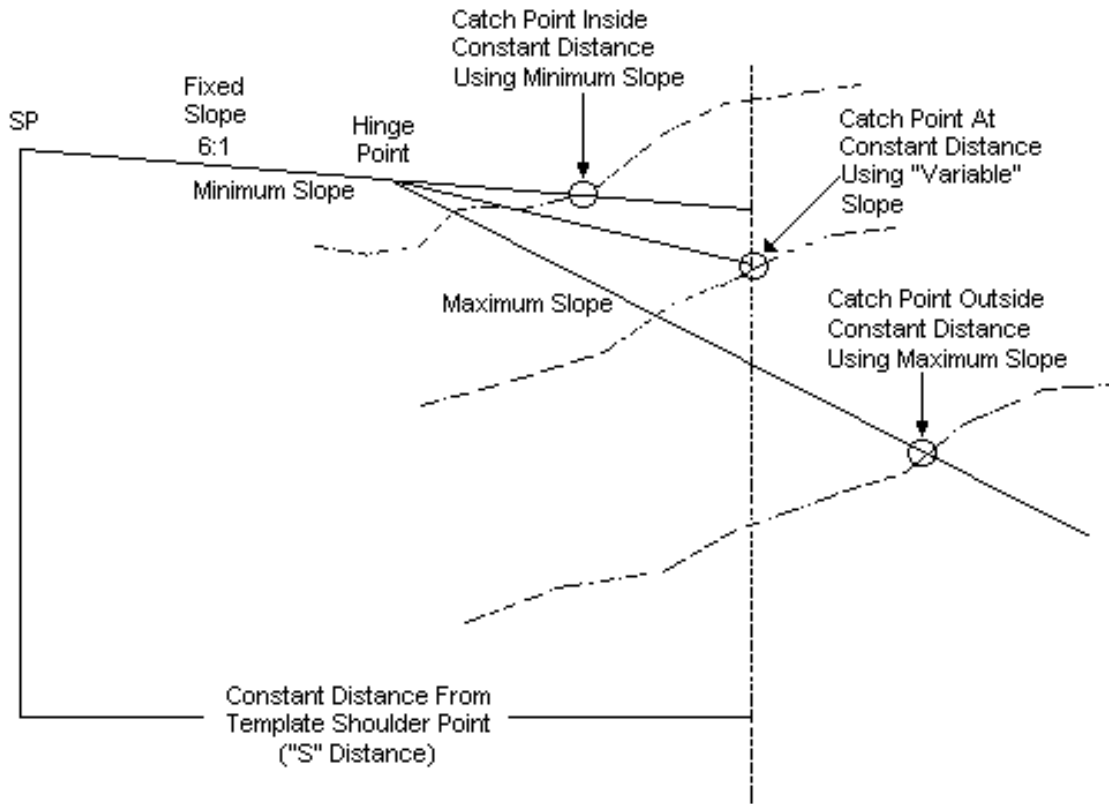


Control of Catch Point

The slope selection process also provides options for controlling maximum and minimum distances of the catch point from the base line or template centerline. These options, illustrated below, are in addition to those provided by right-of-way/maximum slope intercept data. (See Appendix K.)



A third option of referencing a constant distance to the shoulder point is shown below.



Reference to Template Shoulder Point with an S

The constant distance S option varies the sideslope to intercept terrain at a constant distance from the shoulder point, provided that the resulting sideslope is within a minimum/maximum slope range. Note that if the resulting slope is flatter than the minimum slope, the minimum slope is used and the resulting catch point is inside the constant distance. If the maximum slope is exceeded, the maximum slope is used and the resulted catch point is outside the constant distance.

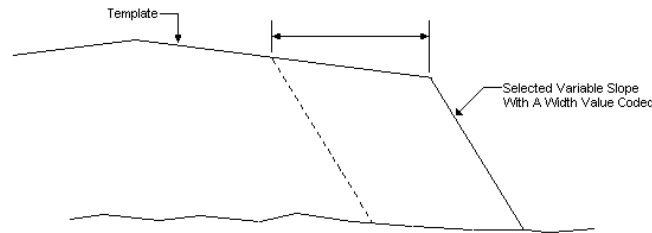
It should be noted that, using the S option, it is possible for the catch point to be outside the maximum slope intercept limit established as described in Appendix K. If this occurs, a message is entered in the error log indicating the baseline, station, and direction (left or right).

ADDITIONAL SIDESLOPE CAPABILITIES

IGrds offers several additional sideslope capabilities that are discussed below.

Automatic Fill Widening

The fill shoulder point can be moved outward by a specified horizontal distance. The last segment of the template is extended at its own slope (with superelevation if it applies). This extension will occur only if the segment for which the width is specified is selected by IGrds as the variable slope segment. This feature is not used for cut slopes.



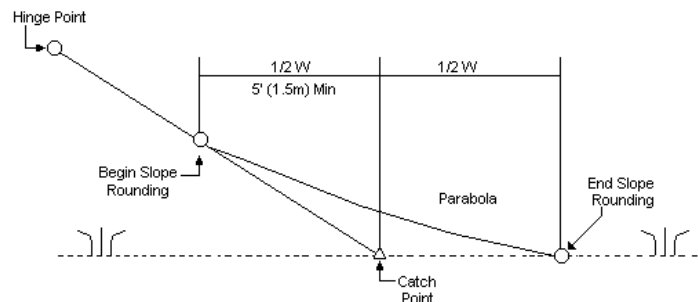
This feature is especially useful for adding an area for guardrail in high fills.

Slope Rounding

Slope rounding may be specified for both cut and fill slope patterns over a given station range. The slope rounding process occurs after the catch point has been determined. The user defines the desired slope rounding width on the slope rounding dialog box by specifying one-half of the rounding width; the distance from the beginning of rounding to the catch point. A parabola is then fitted between the slope and the terrain as shown below.

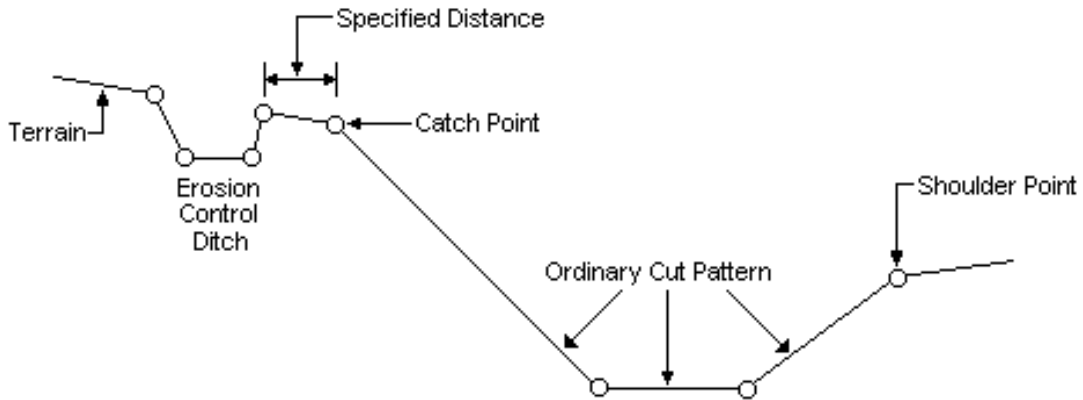
If the half-width is greater than the distance between the hinge point and the catch point, the half-width will be reduced to fit. In no case will it be reduced to less than five feet (1.5 meters), at which point slope rounding will not be applied. An informational message will be printed advising if the rounding has been reduced or eliminated.

Note: Slope rounding cannot be applied to median data. Care must be taken if converging roadways are being rounded. The rounding must be stopped prior to the proposed median design, or the process may terminate abnormally or make erroneous calculations.

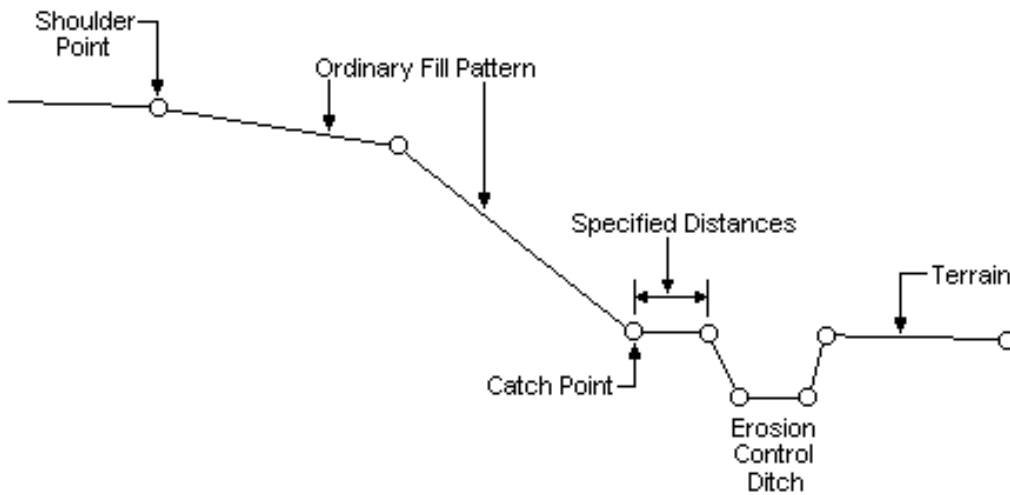


Erosion Control Ditches

Erosion control ditches can be specified for both the top of backslope (cut condition) or toe of slope (fill condition) over a given station range at a user-defined distance from the catch point. Erosion control ditches are specified like any other cut pattern and can include both fixed and variable slopes. They can also include special ditch grades. The examples below show both cut and fill erosion control ditches.



Cut Condition Erosion Control Ditch



Fill Condition Erosion Control Ditch

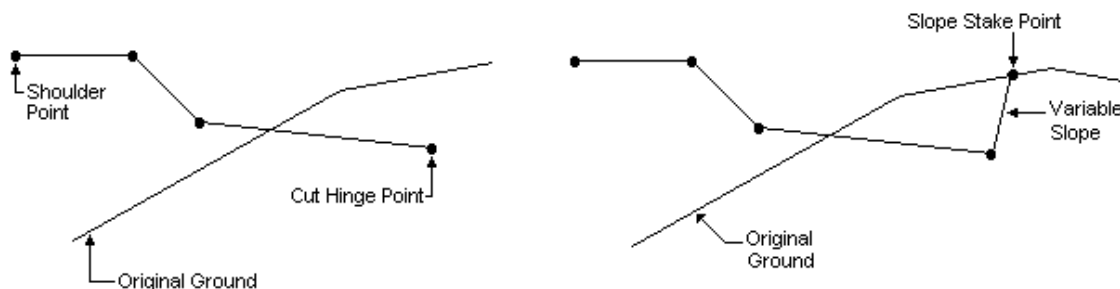
SLOPE SELECTION PROCESS LOGIC

The following discussion illustrates why this is called the slope selection process. The process considers the variable slopes in the order in which they are entered; therefore, in the example on page J-3, it can be seen that the 6:1 slope should be entered first, then the 4:1 and 2:1, with the 2:1 having the largest vertical distance.

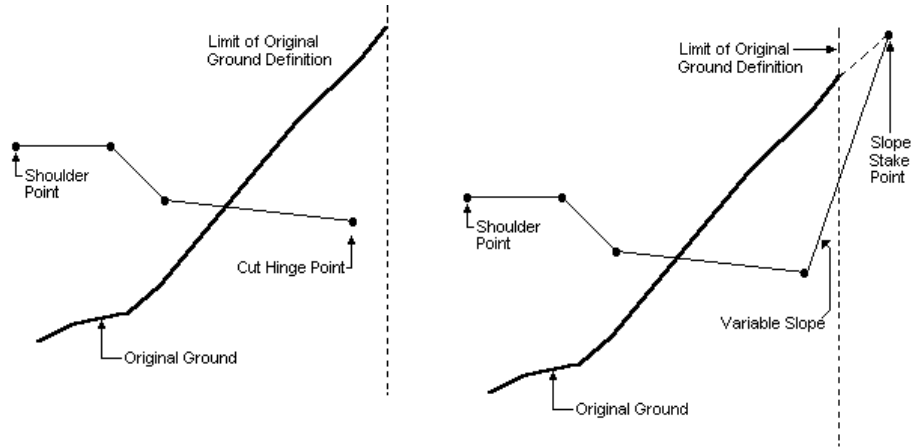
The slope pattern can contain benches and special ditches. Benches and special ditches can be selected by using the appropriate option symbol shown in Table J-1. In addition, the slope pattern can be modified by use of right-of-way widths, slope intercepts, and maximum and minimum slope stake distance criteria.

IGrds approaches the problem of establishing a slope stake (catch point) by following the sequence of steps outlined below.

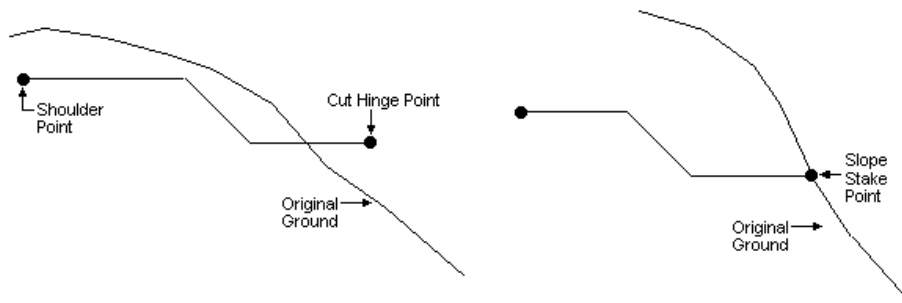
1. The position of the applicable CUT pattern hinge point is located relative to the original ground.
 - a. If there are fixed slopes, the hinge point is the end of the last fixed slope.
 - b. If there are no fixed slopes, the hinge point is the shoulder point.
2. If the cut hinge point is below (or on) the original ground and:
 - a. If a cut pattern variable slope intersects the original ground, then a slope stake (catch point) is established at that intersection. (Fixed slope intersection options are not applied.)



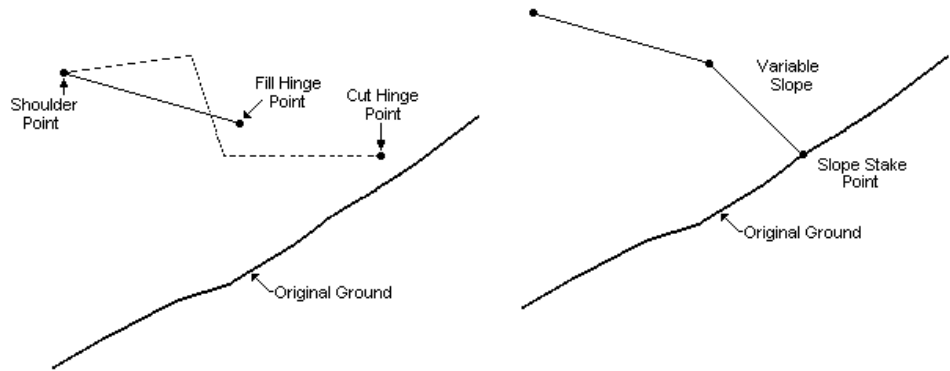
- b. If none of the cut pattern variable slopes intersect the original ground within the limits of original ground definition, within the maximum slope intercept specification, or within other maximum and minimum limits specified, the slope stake (catch point) will be established by IGrds extending the slope of the last pair of terrain points until an intersection with the last slope is found. A message will be logged when this occurs.



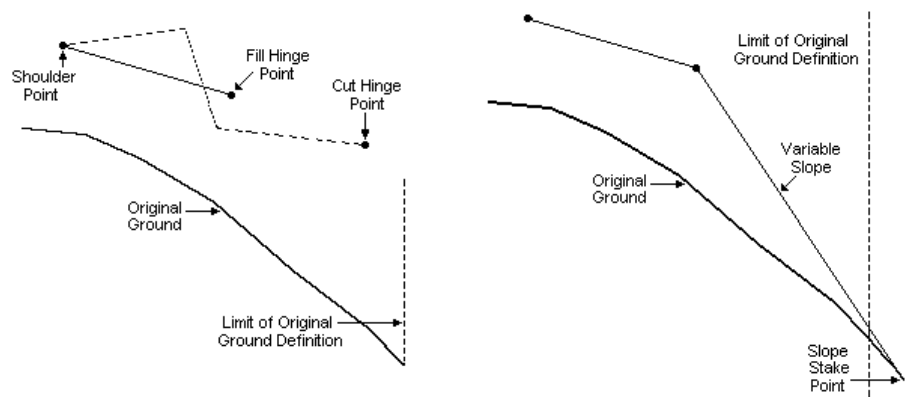
- c. If all the variable slope alternatives have been exhausted and IGrds has not found an intersection with extended terrain, a slope will be built from the hinge point to the original end of terrain or to the maximum slope intercept or maximum distance, whichever is smallest, and a message will be logged.
3. If the cut hinge point is above the original ground, a check will be made to see if one of the two fixed slope intersection options (I or C) has been specified. (These options are shown in Table J-1.) If one of these options has been specified for a fixed sideslope segment which intersects the ground line (starting at the furthest segment and checking inward), the slope stake (catch point) will be established at that intersection.



4. If a slope stake (catch point) cannot be established by the normal cut slope selection process, the position of the applicable FILL pattern hinge point is located relative to the original ground.
5. If the fill hinge point is above (or on) the original ground and:
 - a. If a fill pattern variable slope intersects the original ground, then a slope stake (catch point) is established at that intersection. (Fixed slope intersection options are not applied.)

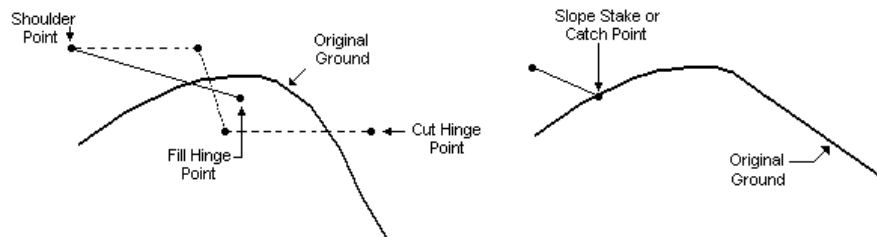


- b. If none of the fill pattern variable slopes intersect the original ground within the limits or original ground definition, within the maximum slope intercept specifications or within other maximum and minimum limits specified, the slope stake (catch point) will be established by IGrds extending the slope of the last pair of terrain points until an intersection with the last slope is found, and a message is logged.

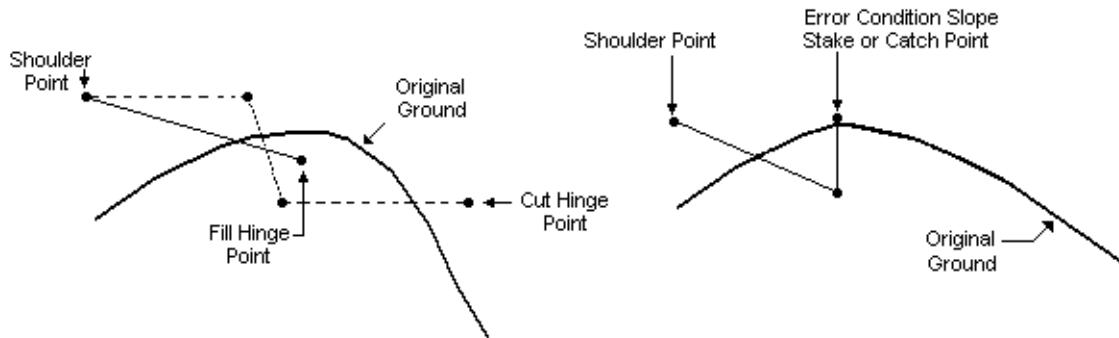


- c. If all the variable slope alternatives have been exhausted and IGrds has not found an intersection with extended terrain, a slope will be built from the hinge point to the original end of terrain or to the maximum slope intercept or maximum distance, whichever is smallest.

6. If the fill hinge point is below the original ground, the fixed slope intersection option, if specified, will be applied in the same fashion as indicated above in Step 3 for the cut pattern.



7. If a slope stake (catch point) cannot be established by the normal fill slope selection process, an error condition slope stake point is established by drawing a vertical line from the fill hinge point to the original ground.



In addition to the sequence of steps enumerated above, the designer may specify that each slope stake (catch point) is established within defined distances from an indicated centerline. When the slope stake, as established by the above steps, is located beyond a maximum specified distance, IGrds will establish the slope stake at the maximum distance and modify the final sideslope segment accordingly. Should this final segment modification result in an overhang (backwards slope), successive fixed slope segments will be eliminated until a hinge point, without overhang, can be defined which is within the maximum distance specifications. Then the final segment is defined as the connection between the new hinge point and the maximum distance slope stake. When the slope stake would be located short of a minimum specified distance, IGrds will establish the slope stake at the minimum distance and extend the final sideslope segment accordingly. In the absence of specific maximum and minimum distance specifications, these are assumed to be, respectively, the limits of defined original ground and the template shoulder point.

MULTIPLE SUBSURFACE SLOPE SELECTION LOGIC

If multiple subsurfaces are defined, then the slope selection logic is slightly different. The differences are discussed below.

- All cut fixed slopes (i.e., ditches) are built in the normal IGrds fashion to determine the cut hinge point.
- The variable slope process is then begun. The process determines which slope would be used if there were no multiple materials. The variable slope process includes normal IGrds bench pattern calculations. Also, the maximum/minimum slope intercept conditions are honored.
- The multiple subsurface slope selection process then determines which layer the hinge point is within. The correlation between layers at a cross section station and the material criteria table is accomplished through the material code.

- The material criteria table is accessed for the necessary parameters for the material encountered.
- The slope determined from the variable slope process above (trial slope) is compared with the material cut slope tolerance depth. If the depth of material is less than the tolerance depth, then the trial slope is built to the top of the material layer without regard to the maximum and minimum cut slopes for the material. This step avoids abrupt changes of slope for thin layers of material.
- If the depth of material is greater than the tolerance depth, then the trial slope is compared to the maximum and minimum cut slopes for the material. If the trial slope is within the minimum/maximum slope band, then the trial slope is built to the top of the material layer.
- If the trial slope is not within the band, then either the minimum slope (if trial slope is flatter than the minimum) or maximum slope (if trial slope is steeper than the maximum) will be built to the top of the material layer.
- A check is then performed to determine whether the top of this layer is coincident with the terrain; if so, the process is finished; if not, the process continues with the next higher material layer.
- If a top bench set back is specified for the layer just processed, then the bench set back is performed. Likewise, if a bottom bench set back is specified for the next material layer, then the bench set back is performed. If a bench set back is specified for both materials, then the largest set back is performed.
- If the terrain has not been encountered, then the process repeats as described above until the terrain is encountered. The entire process is sensitive to minimum and maximum slope intercept conditions.

Material "tail out" or "tail in" transitions are handled in the standard IGrds fashion. For example, if a material exists at the just previous station and does not exist at the current station, then the end area for that material at the current station is set to zero.

SIDESLOPE STATIONS

In addition to defining sideslope patterns, it is necessary to specify where slope selection patterns apply. Beginning and ending stations must be entered. The pattern is then applied at all sections between these limits. If different slope selection patterns are given for the beginning and ending stations, then the segments will be linearly transitioned over the station range.