The following techniques during tag line installation should be followed to avoid increased final design grades:

1. In the case of steep draws, run the desired grade into the draw until the opposite hillside is at a distance equal to twice the minimum radius. Now, sight across the draw at zero grade, find that point on the other hillside and continue from that point with the original grade (Figure 18).

2. In the case of sharp ridges, the procedure is similar. Find the starting point for the curve. At that point, lay the tag line at zero percent around the ridge until you are opposite your beginning point and at the desired ending point for the curve. At this point resume your original grade.

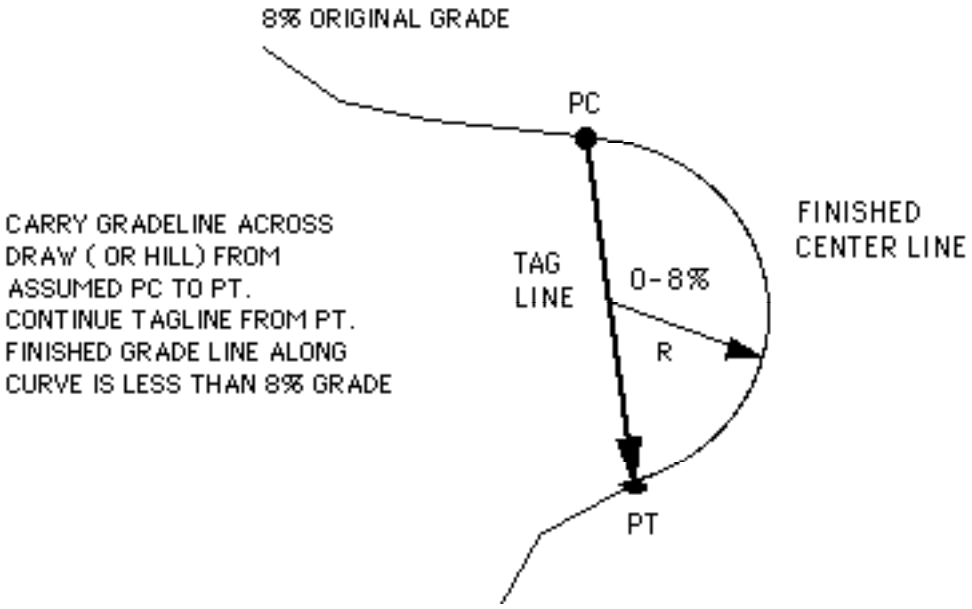

Figure 18. By sighting across draw at 0 percent grade, the desired curve is laid out without increasing the grade.

For more information on reconnaissance and road location procedure, the reader is referred to Forest Engineering Handbook (1960), by J. K. Pearce.

Location of switchbacks requires careful location in the field in order to minimize impacts on travel (excessive grades) as well as on road construction (excessive cuts and fills). As a rule, grades through a switchback at centerline should not exceed 6 to 8 percent. Because of the shortened distance along the inside road edge, the grade there will typically be 2 to 3 percent steeper. The result is that inside truck wheels will start to slip causing a "wash-board" effect. Likewise, increased erosion and sedimentation rates will result because of the continued spinout of the traction wheels. The grade along the inside edge of the road can be calculated by the following formula:

$$\text{Grade}_{R_i} = \text{Grade}_{CL} * \frac{R_{CL}}{R_{CL} - \frac{W}{2}} \frac{\Delta}{180}$$

where Grade_{R_i} = grade along the inside road edge

Grade_{CL} = grade along the center line of the road

R_{CL} = radius of curve to center line

Δ = deflection angle at PI

W = road width

Example: A switchback has a grade at centerline of 8 %. The deflection angle measures 160 degrees and road width (travelled width) is 3.6 meters. Additional curve widening of 1.5 meters is required on the inside of the switchback.

What is the grade along the inside edge of the road?

$\text{Grade}_{CL} = 8\ \%$

$\Delta = 160^\circ$

$R_{CL} = 10\ m$

$W = 3.6\ m$

$$R_{CL} - \frac{W}{2} - \text{additional widening} = 6.7\ m$$

$$\text{Grade}_{R_i} = 8 * (10/6.7) * (160/180) = 10.6\ \%$$

The grade along the inside would be 10.6%, considerably higher than what is desirable.

Several steps can be taken to minimize the impact of excessive grade. If the grade cannot be reduced through a larger radius, for example, adequate surface material should be used that can withstand the added tire action and provide enough traction to prevent spinout. Switchbacks should not be located on slopes in excess of 35 percent because of the excessive amount of earthwork required. Natural topographic features, such as benches, saddles, or ridge tops should be used for locating switchbacks. The following example illustrates the effect of slope on cuts and fills (Figure 19):

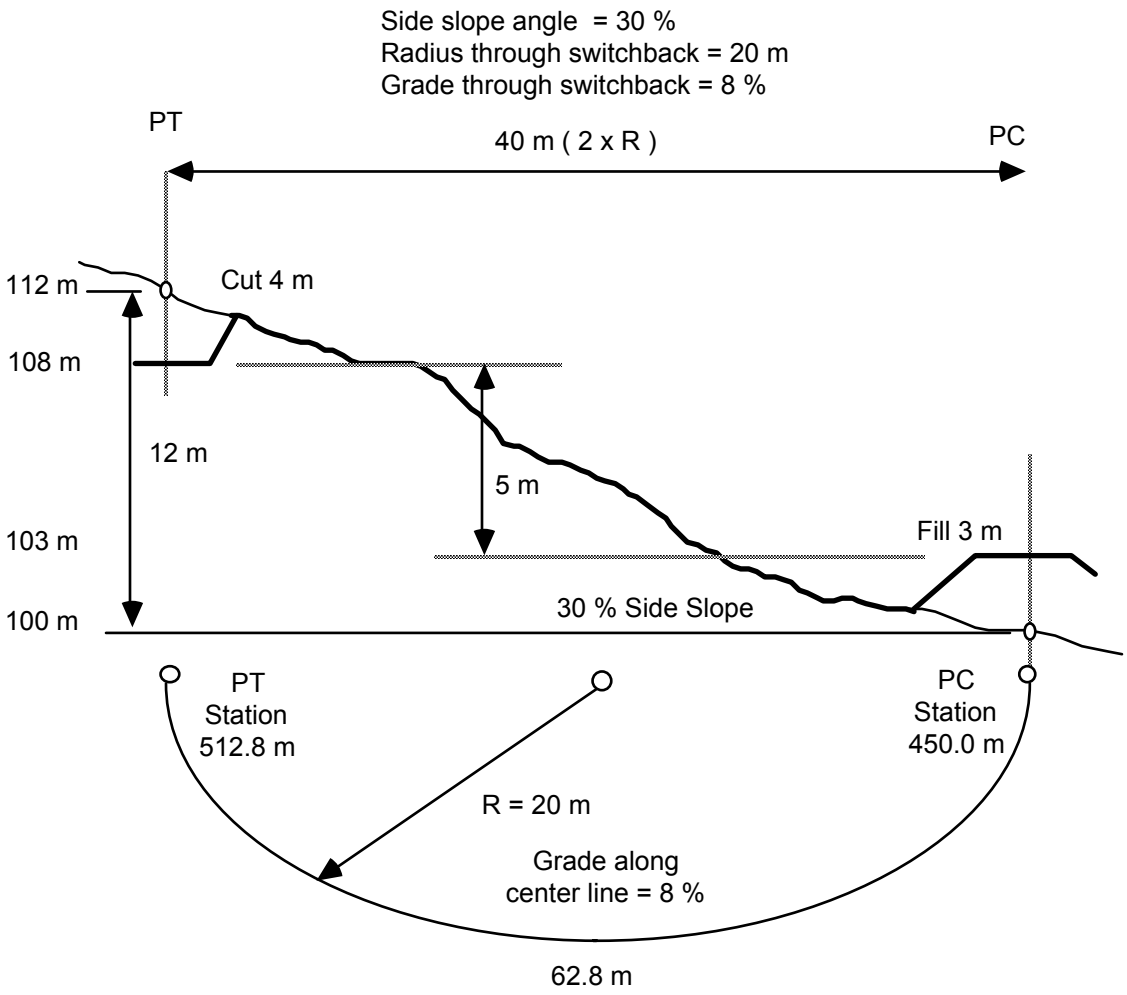

Figure 19. Cut and fill apportioning through a switchback to maintain a given grade.

From this it follows that an elevation difference (DE) of 12 m has to be overcome between the PC (beginning point) and PT (ending point) of the switchback. However, road length along centerline is 20 * π = 62.8 m. The required grade of 8 % along 62.8 m overcomes only 5.0 m of the total DE of 12 m. Therefore, 7 m (12 m - 5 m) have to be made up through either cuts or fills. Local conditions would dictate how the 7m would be apportioned between cuts and fills. (For example, 4 m of cut at the PT and 3 m of fill at the PC would be required to overcome the elevation difference on a 30 percent sideslope.). As a general rule "cutting" or excavation should be favored over filling or embankments. Proper fills are more difficult to construct than excavations.

2.3.2 Faults

Alternative routes should be carefully reviewed in the office and at the site, utilizing all available background information and technical expertise. Among the most useful tools available to the road engineer is a recent set of aerial photos. These must be of a scale small enough to reasonably identify surface features such as natural drainage characteristics, topographic characteristics (ridgelines, slope gradients, floodplains, wet areas, landslides), existing cultural features (roads, buildings, etc.), vegetation or stand type and density, bare soil areas, and geologic features such as faults.