Vertical Curves

Vertical Curves

- In vertical planes, to provide smooth transitions between grade lines of tangent sections.
- Almost always parabolic to provide constant rate of change of grade.
- Crest and sag curves.

Design Criteria

- Minimize cut and fill.
- Balance cut and fill.
- Maintain adequate drainage.
- Not to exceed max. Grade.
- Meet fixed elevations, other roads or bridges.
- Provide sufficient sight distance.

General Equation of a Vertical Parabolic Curve

- For a second order parabola:

$$Y_p = a + bX_p + cX^2_p$$

- What is the physical meaning of: a, b, c?

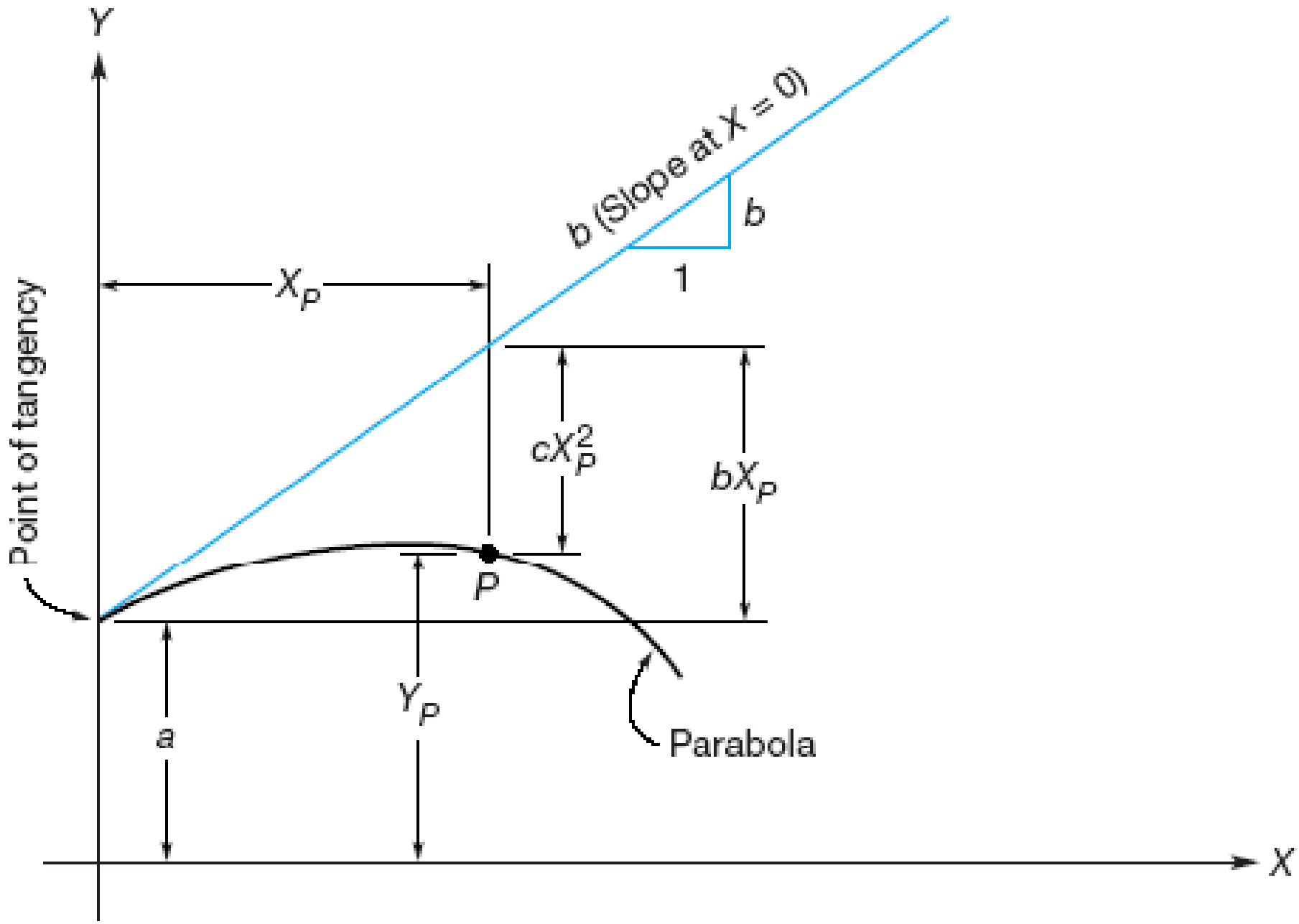


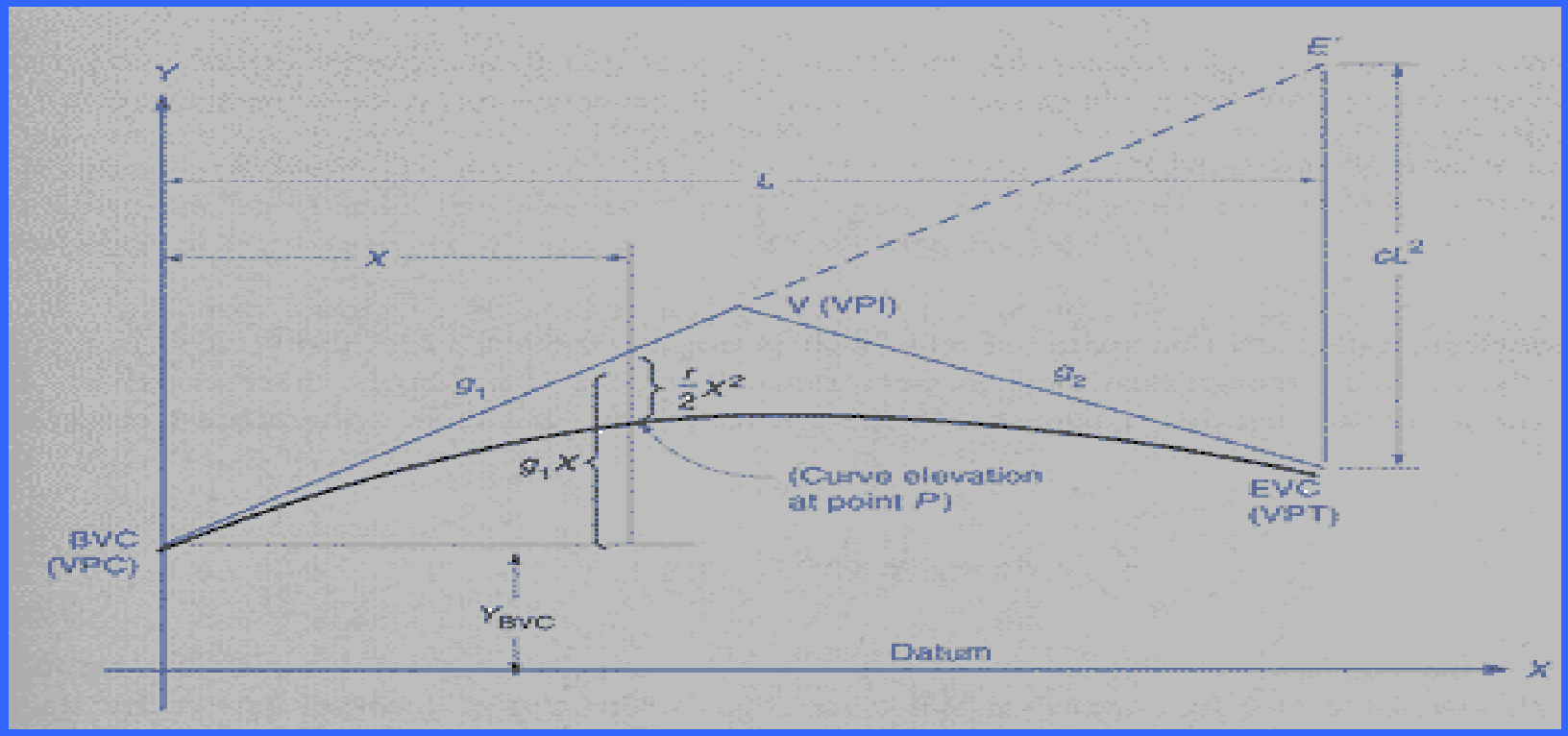
Figure 25–2 Terms for a parabola.

Definitions

Define:

- BVC = VPC V= VPI EVC = VPT
- Percent grades g1, g2, r = rate of change of grade = $(g_2 - g_1)/ L$

  L in stations, g not divided by 100
- The curve length L in stations, is it horizontal or curved length?
- What is an equal tangent vertical curve?



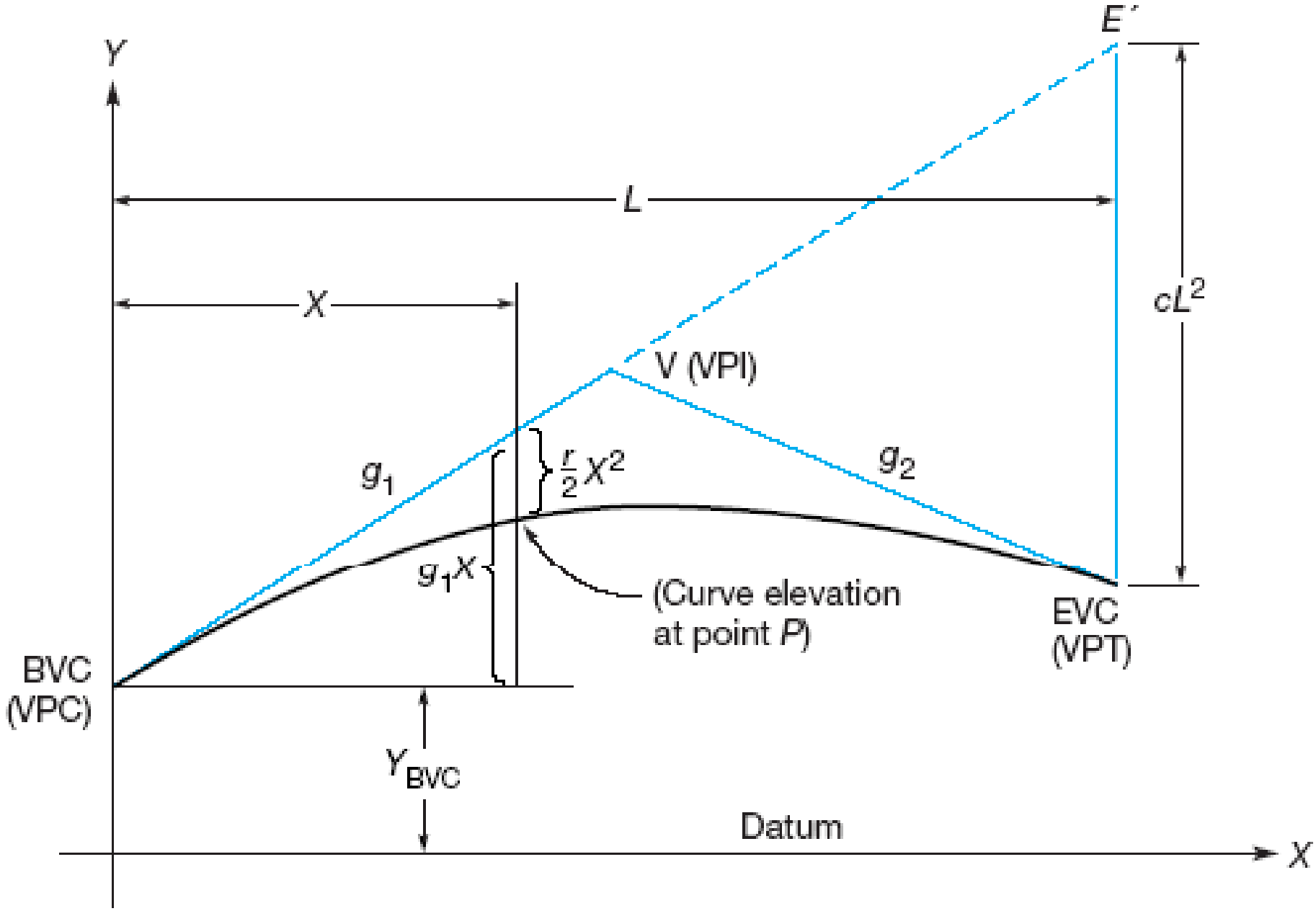
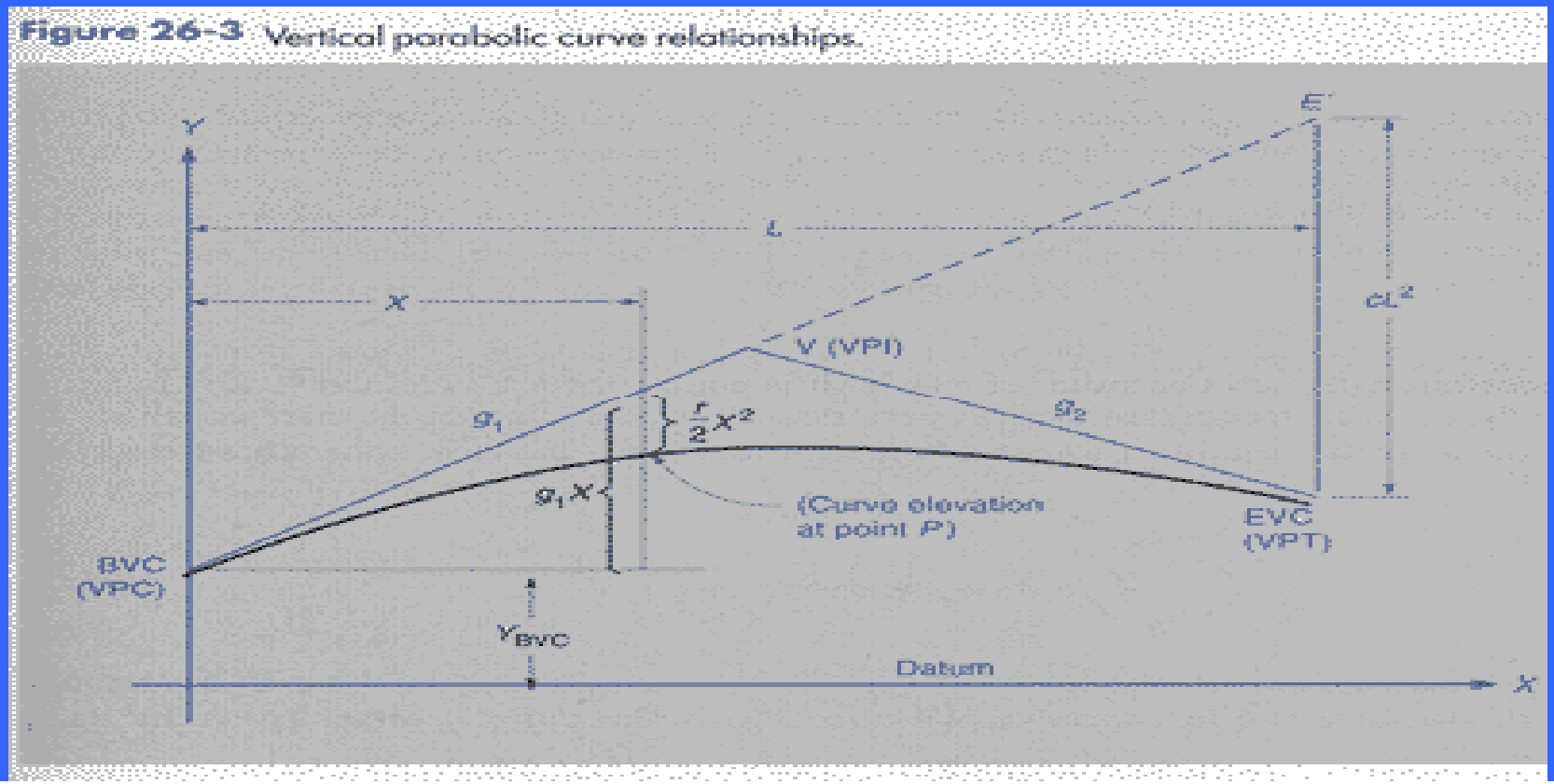


Figure 25–3 Vertical parabolic curve relationships.

Equation of an Equal Tangent Vertical Parabolic Curve in Surveying Terminology

- $\boxed{Y = Y_{BVC} + g_1 X + (r/2) X^2}$ (r) is -ve for crest
  - Note that the value $\{(r/2) X^2\}$ is the offset from the tangent, the equation is called *tangent offset equation*



Vertical Curve Computation Using the Tangent offset Equation

- Select the grades, and hence find V's
- The designer defines L, sight distance maybe?
- Compute the station of BVC, from the station of V and L, then compute the station of EVC, add L/2 to V?
- Note that you are not trying to locate the curve in the horizontal plane, just compute the elevations
- The problem:
  - Given: g1, g2, station and elevation of V, and L
  - Required : Elevation at certain distances (stations)

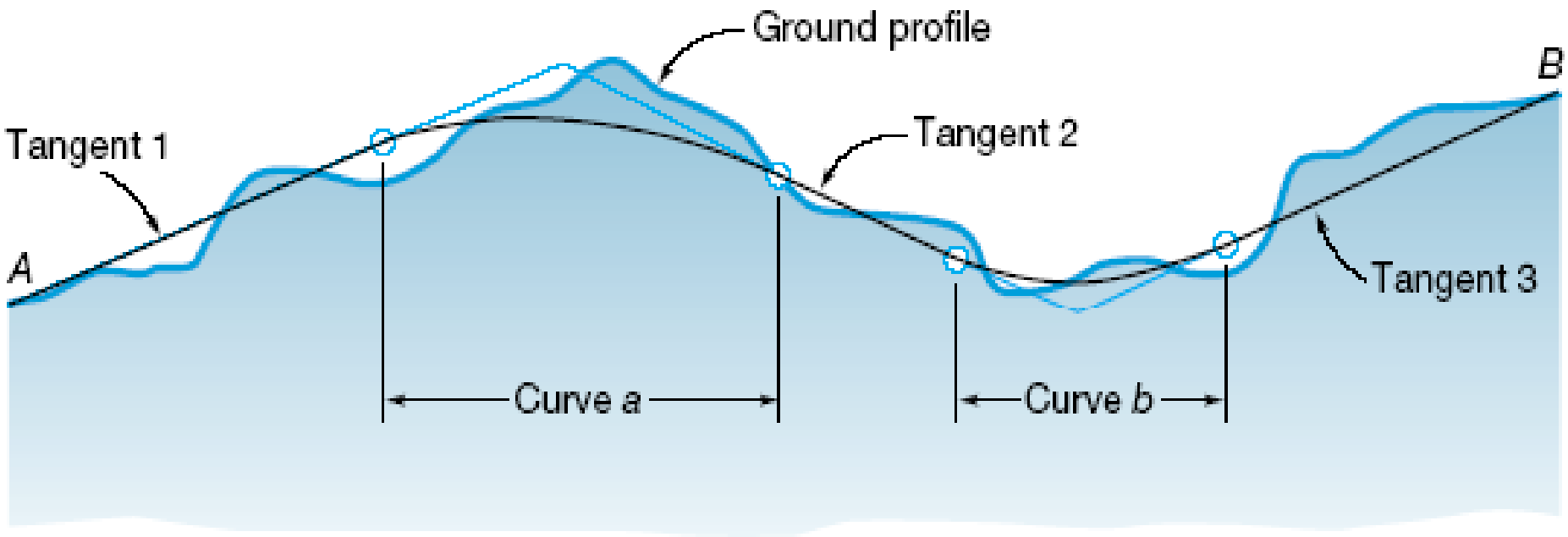


Figure 25–1 Grade line and ground profile of a proposed highway section.

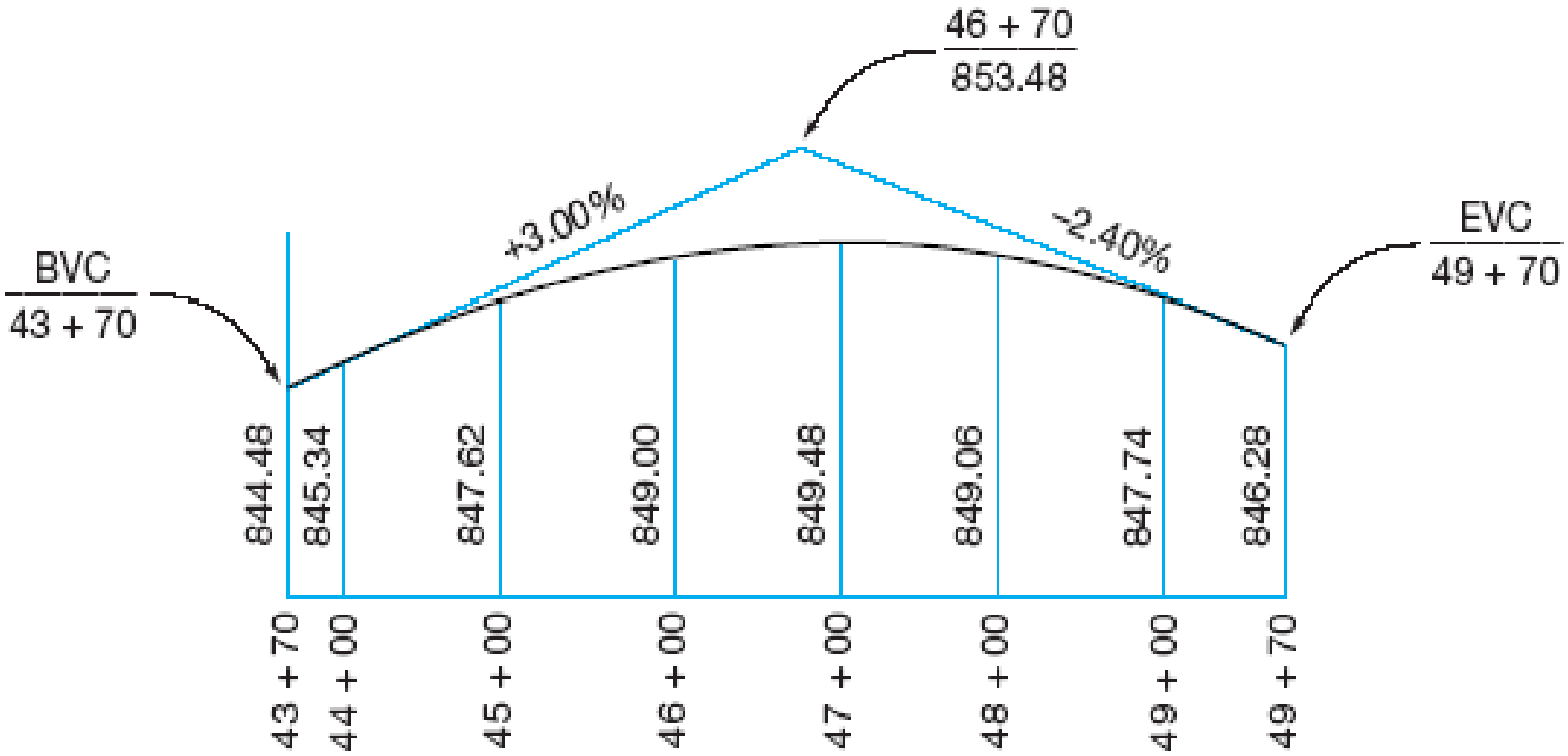
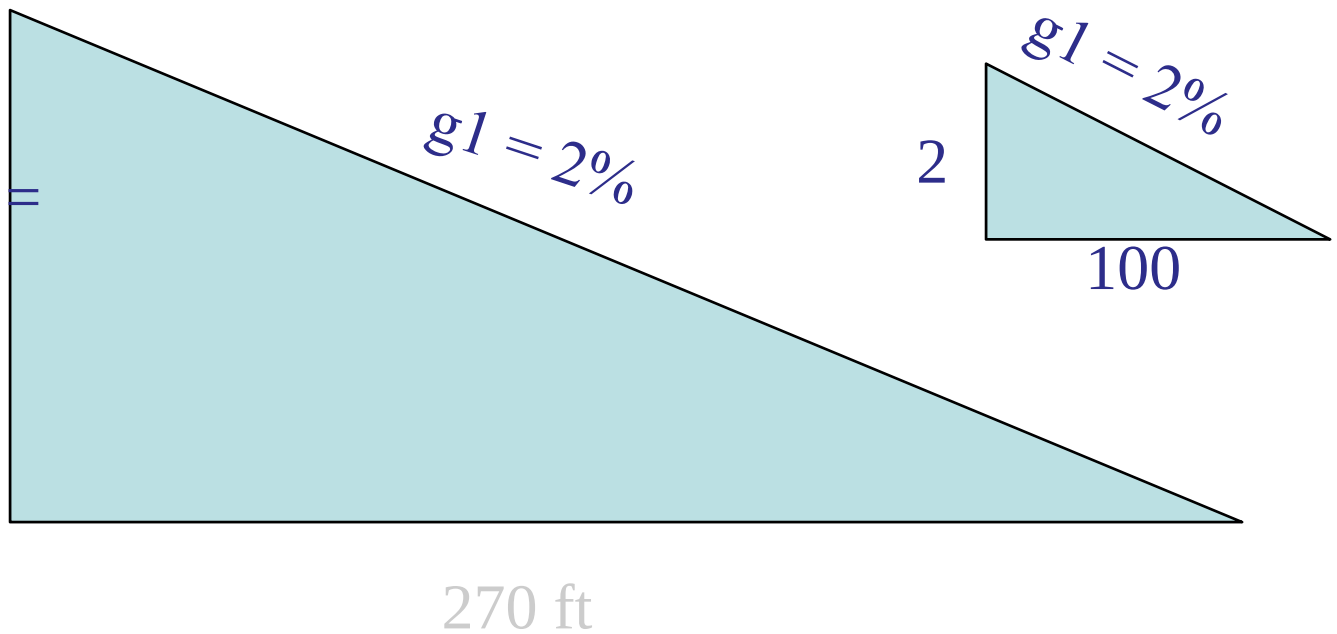


Figure 25–4 Crest curve of Example 25–1.

Slope = g1 = 2%
What is that mean?

= ?
0.02 X 270 =
5.4 ft
or 2 X 2.70
stations=
5.4 ft



g1 = +3.00%, g2 = -2.40%, V station is 46+70 and V elevation is 853.48, L = 600 ft, compute the curve for stakeout at full stations.

Answer:

r =

BVC station =

EVC station =

Elevation of BVC = 853.48 – (3.00) (3) = 844.48

For each point, compute X and substitute in the equation below to compute Y: $Y = 844.48 + 3.00 (X) + (-0.90/2) X^2$

For example, at station 44+00: X = 0.3,

Then, X = 1.3, 2.3, 3.3, 4.3, 5.3, end at station 49+70: X =

High or Low Points on a Curve

- Why: sight distance, clearance, cover pipes, and investigate drainage.
- At the highest or lowest point, the tangent is horizontal, the derivative of Y w.r.t x = 0.
- Deriving the general formula gives:
- $X = g_1 l/(g_1 - g_2) = -g_1/r$ where: X is the distance in stations from BVC to the high or low point.
- Substitute in the tangent offset equation to get the elevation of that point.
- Example 25-4: compute the station and elevation of the highest point on the curve in example 25-1
- Answer: X = -3.00/-0.9 = 3.3333 stations

Plug X back into the equation get elevation = 849.48

Designing a Curve to Pass Through a Fixed Point

- Given: g_1, g_2 , VPI station and elevation, a point (P) elevation and station on the curve.
- Required: You need five values to design a curve: g_1, g_2 , VPI station and elevation, and curve length. The only missing value is the length of the curve.
- Solution:
  - Substitute in the tangent offset formula, the only unknown is L:

$$\boxed{Y = Y_{BVC} + g_1 X + (r/2) X^2}$$

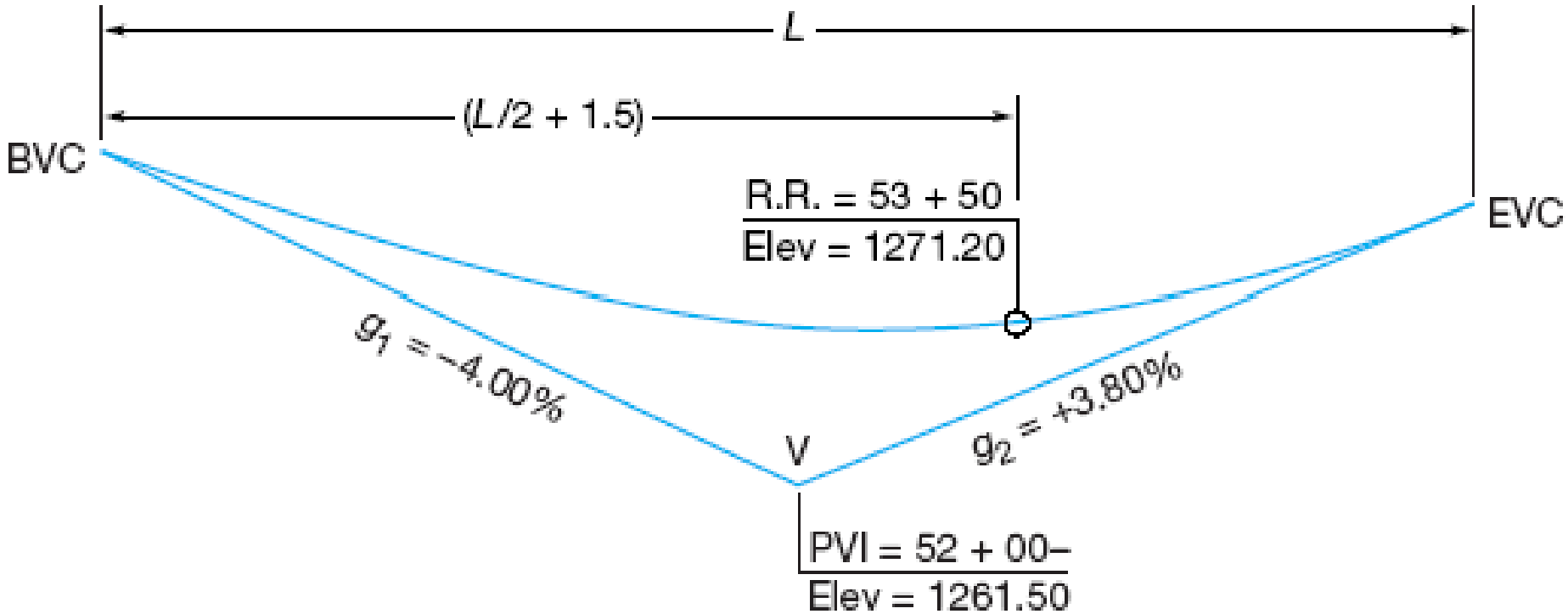


Figure 25–8 Designing a parabolic curve to pass through a fixed point.

Solution:

Substitute in the tangent offset formula, the only unknown is L: $Y = Y_{BVC} + g_1 X + (r/2) X^2$

Remember that:

- $Y_{BVC} = Y_V - g_1 (L/2)$, only L is unknown
- X is distance from BVC in stations, it is not the given station of P, to compute it, add or subtract the distance V-P to/from L/2.

$$\boxed{X = (L/2) \pm (V\text{-}P)_{stations}}$$

Since you are given stations of VPI and the unknown point, you should be able to tell whether to add or to subtract.

- $r = (g_2 - g_1)/ L$

Example 25-5:

..g1 = -4.00, g2 = +3.80 %, V station is 52+00 and elevation is 1261.5 ft, the curve passes by point P at station 53+50 and elevation 1271.2 ft.

Answer (sag curve)

X = (L/2) + 1.5

Then;

Y_{BVC}

g1 X

1271.2 = {1261.5 +4.00 (L/2)} + { -4.00((L/2) +1.5)} + {(3.8+4.00)/2L)(L/2 +1.5)}

(r/2) X2

$0.975\ L^2 - 9.85\ L + 8.775 = 0$

Then,

L = 9.1152 stations

Sight Distance

- SSD : is the sum of two distances: perception reaction time, and the vehicle stopping distance.
- The length of the curve should provide enough SSD at design speed, and minimize cut and fill if possible.
- AASHTO design standards (2004): H_1= 1.08m, driver's eye height, and
- H_2 = 0.6 m, roadway object height.
- SSD given in tables.

fig 3.6 , 3-6 mannering

Safe Length of Crest Curve

- To determine the safe length of a curve :
  - compute the SSD, or use tables, according to design conditions.
  - Compute (A): the absolute difference in grade.
  - Apply one of the formulas, neglecting the sign of (A):
    - $Lm = 2\ SSD - \{200(\sqrt{H_1} - \sqrt{H_2})^2/A\}$ Substituting for H1 = 1.08m and H2 = 0.6m get

      $Lm = 2\ SSD - (658/A)$ if SSD>L
    - Similarly, $Lm = A\ (SSD^2/658)$ if SSD < L
    - Assume that SSD < L first, then check the answer.

Example:

At one section of a highway an equal tangent vertical curve must be designed to connect grades of +1.0% and – 2.0%. Determine the length of curve required assuming that the SSD = 220.6m.

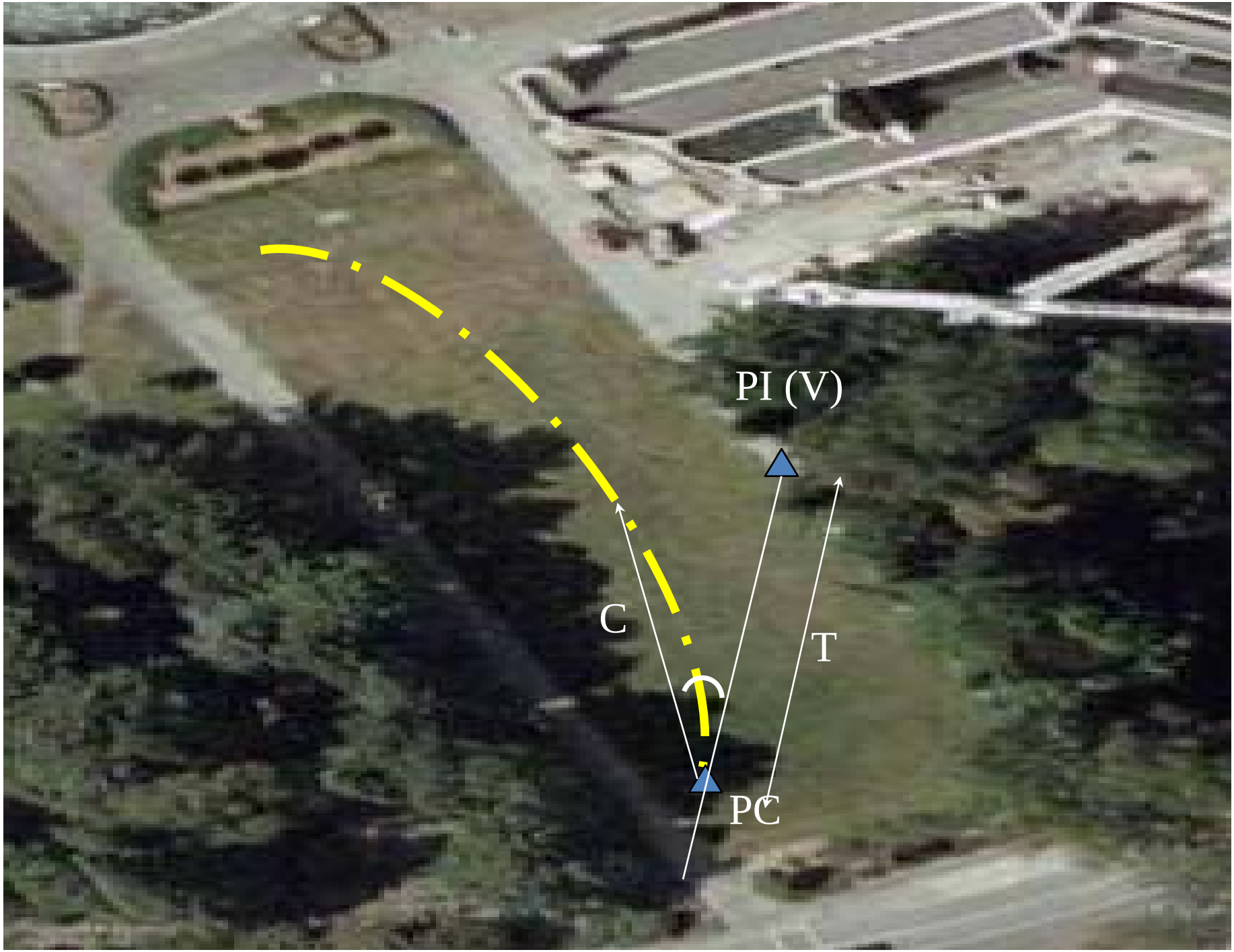
Answer:

Assume that L > SSD (general assumption), then;

$L_m = A\ (SSD^2/658) = 3(220.6)^2 / 658 = 221.9m$

Since 221.9 m > 220.6 m so the assumption that

L >SSD is correct.


PI (V)
C
T
PC

Two vertical curves can be set-out at the same time from either BVC 1 or BVC 2. The direction of each of the Centerlines curves is shown to the left. Assume that the BM for elevation is BVC and IS NOT 20

Last tree