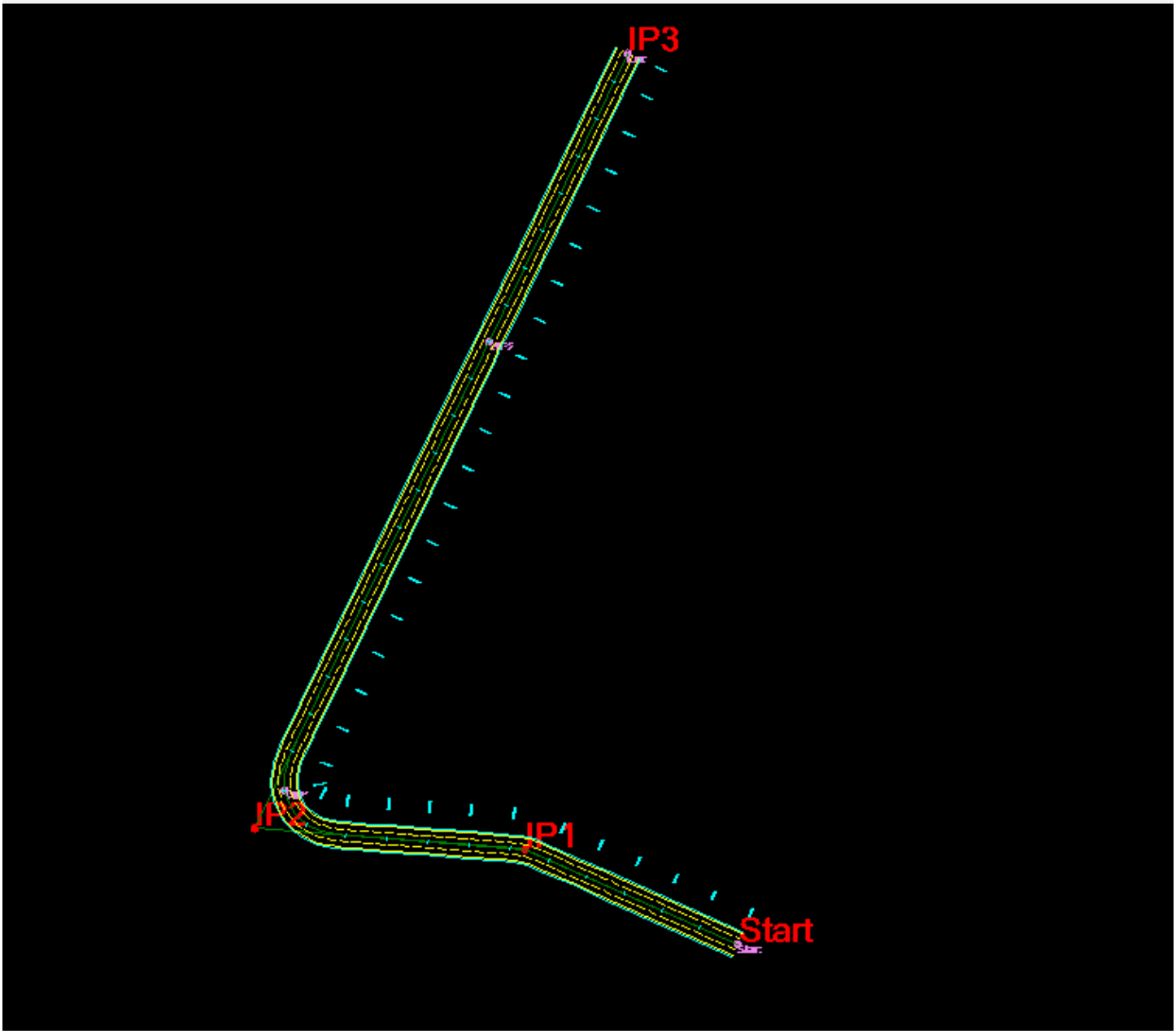
Detailed Calculation of Road: Horizontal & Vertical Alignment

Road · https://mes100.com/docs/detailed-calculation-of-road-horizontal-vertical-alignment/

The Horizontal and Vertical detailed calculation displayed is based on the road design below.

Road Textual Report Sample **here**.

** Note: The detailed textual report is available from MiTS 3.3 and above.



Components of Horizontal Alignment

It is the road’s drawn path on a flat map, consisting of straight lines connected by curves. The horizontal alignment must be designed correctly for the safety and comfort of drivers and passengers.

Details of the curve:

Curve Type: Spiral

Curve: IP2

Central Angle of Circular Curve: 0°56’ 32”

Radius (Rc): 30 m

Design Speed: 30 kph

Super Elevation (SE): 6.00%

Degree of Curvature

D_{c}=\frac{100}{R_{c}}

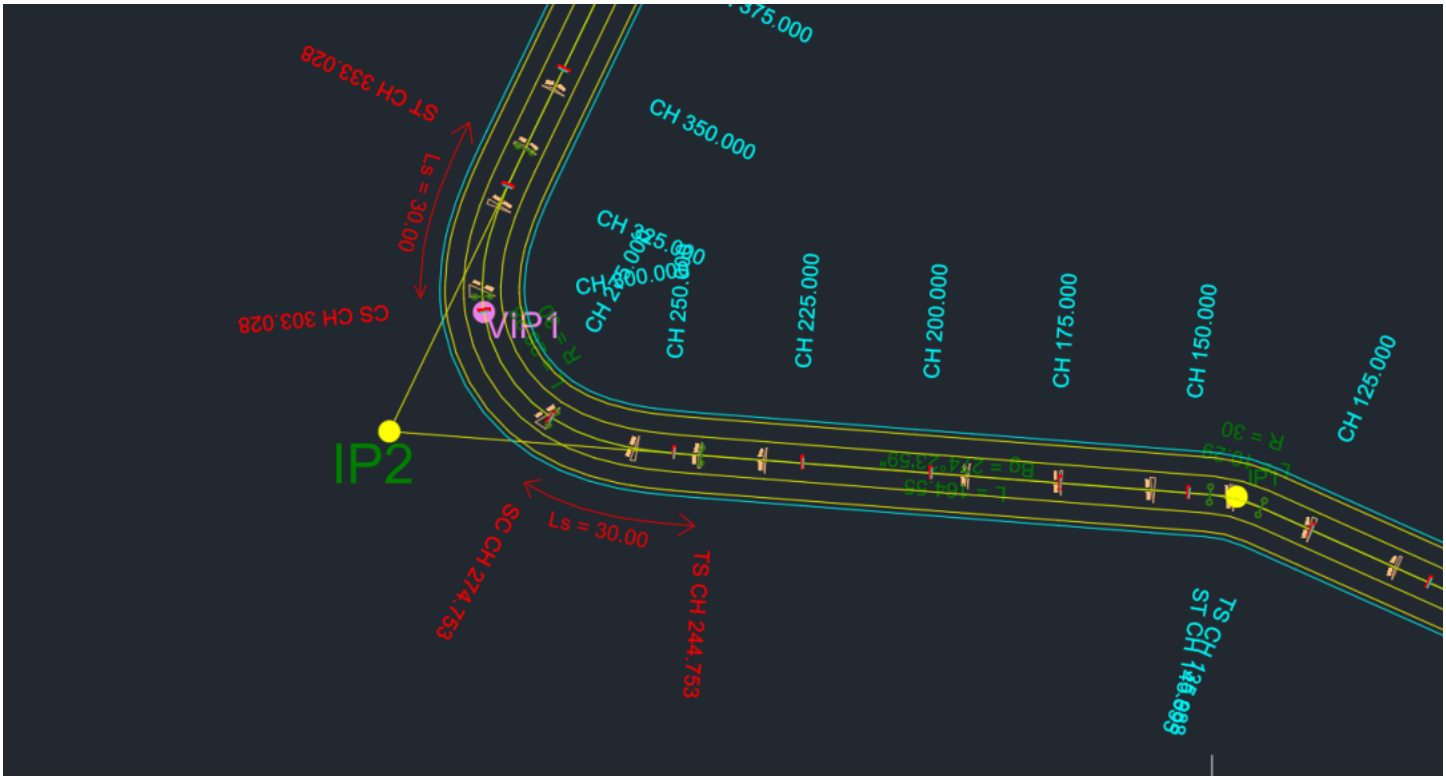
Where:

{R_{c}} = Radius of circular curve, in radians

For example,

Dc=1000.523599=190.9858499Dc=190∘ 59′ 9″\begin{aligned} D_c &= \frac{100}{0.523599} = 190.9858499 \\ D_c &= 190^\circ\,59'\,9'' \end{aligned}

Spiral length from TS to SC or ST to CS, Ls

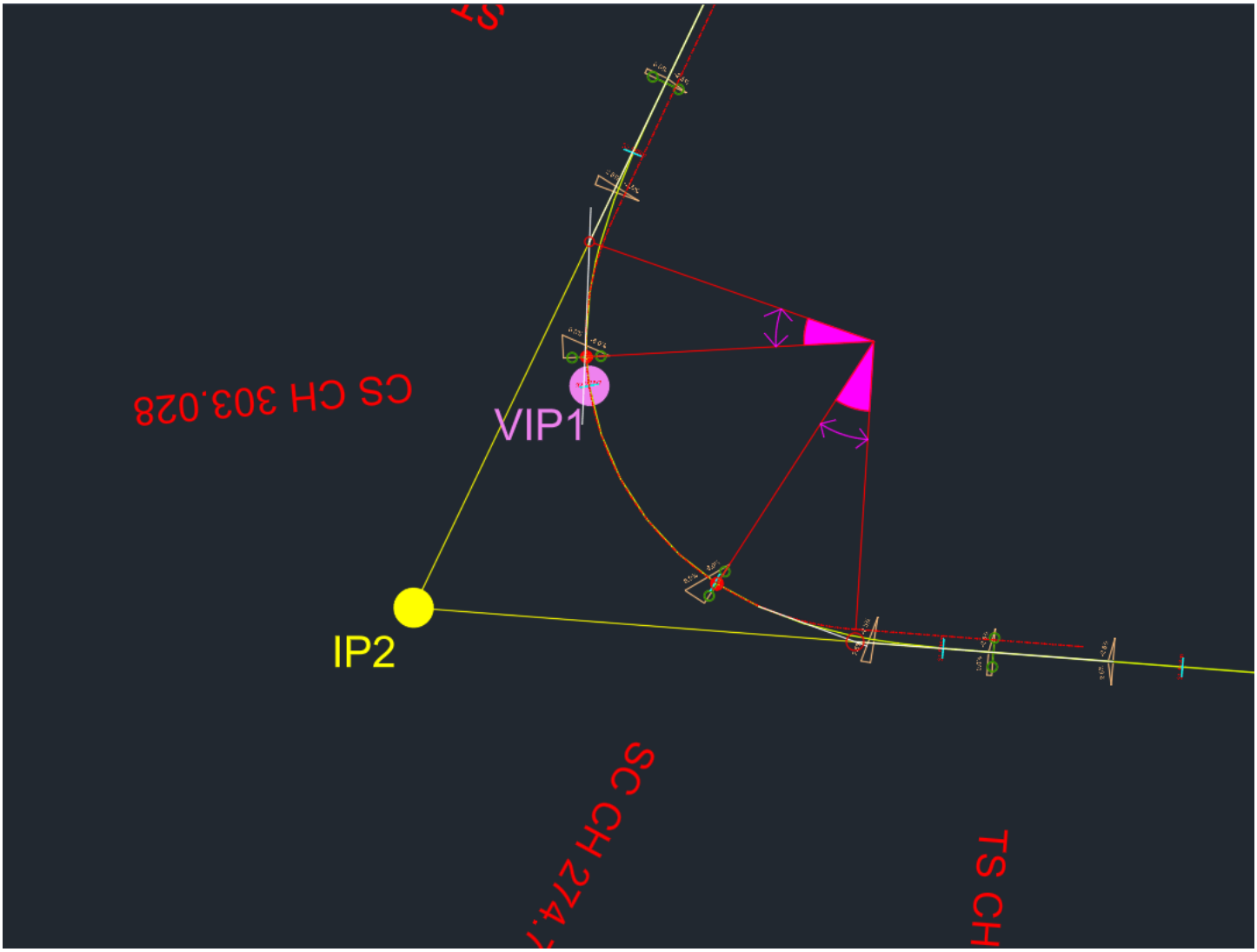


For a spiral curve, Spiral Length is equivalent to Runoff Length (the value obtained depends on the calculation type **here**)

For example, the calculation type is **Fixed Mode with Adjustment Factor**

Ls=Input Spiral Length×Adjustment FactorsLs=20×1.5=30.000 m\begin{aligned} L_s &= \text{Input Spiral Length} \times \text{Adjustment Factors} \\ L_s &= 20 \times 1.5 = 30.000\,\text{m} \end{aligned}

Central angle of Spiral arc Ls (Spiral angle), \theta _{s}



\theta _{s}=\frac{L_{s}\times D_{c}}{200}

Where:

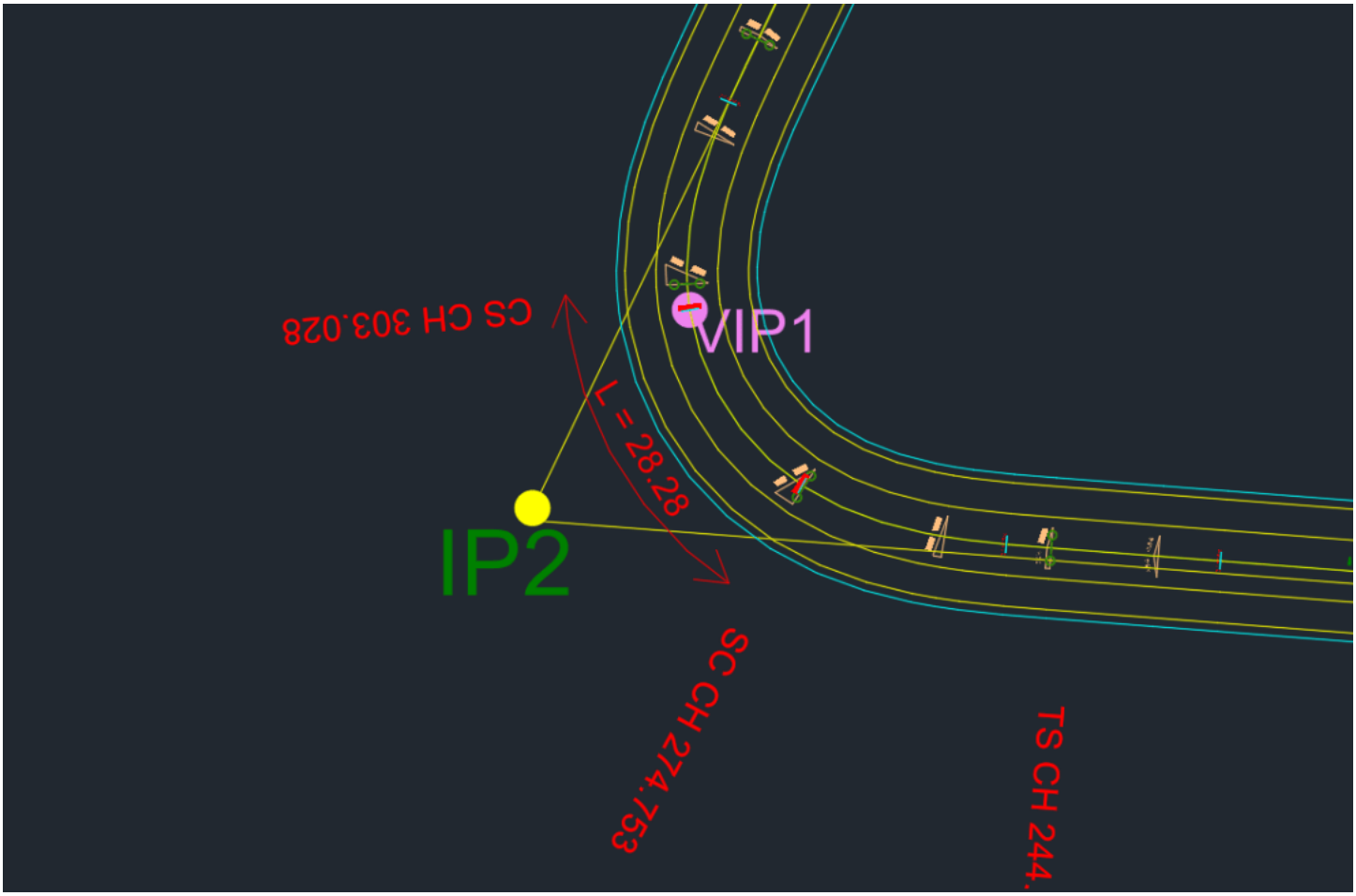
L_{s} = Spiral length from TS to SC or ST to CS

D_{c} = Degree of circular curve

For example,

θs=30.000×190.9858499200=28∘38′52.4″\begin{aligned} \theta _{s} &=\frac{30.000\times 190.9858499}{200}=28^\circ 38'52.4'' \end{aligned}

Length of Circular curve, L_{c}



L_{c}=R_{c}\times\Delta _{c}

Where:

R_{c} = Radius of circular curve

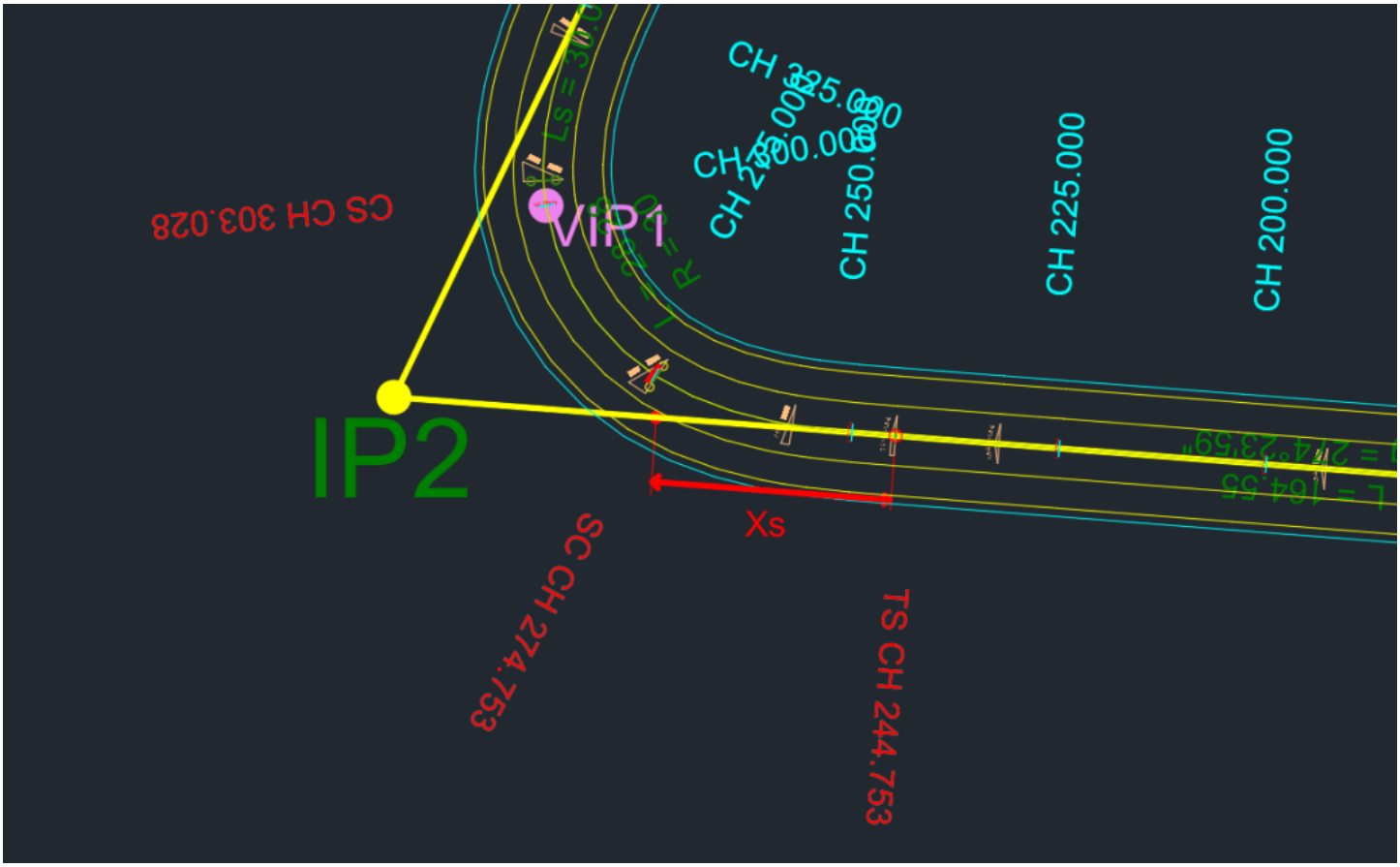
\Delta _{c} = Central angle for circular curve; in radians

For example,

Δc=Δ−2θs=111.297699−2×28.64787749=54.00194402=54∘0′7″\begin{aligned} \Delta_{c} &= \Delta - 2\theta_{s} = 111.297699 - 2 \times 28.64787749 = 54.00194402 = 54^{\circ} 0' 7'' \end{aligned}

$$Lc=30\times0.942817=28.285 \text{ m}\begin{aligned} L_{c} &= 30 \times 0.942817 = 28.285 \text{ m} \end{aligned}$$

Tangent distance along initial tangent of any point on Spiral with reference to TS or ST, X_{s}



$$X_{s}=L\left(1-\frac{\theta^{2}}{10}+\frac{\theta^{4}}{216}-\frac{\theta^{6}}{9360}+\frac{\theta^{8}}{685440}\right)$$

Where:

L = Spiral Length from TS to SC or ST to CS

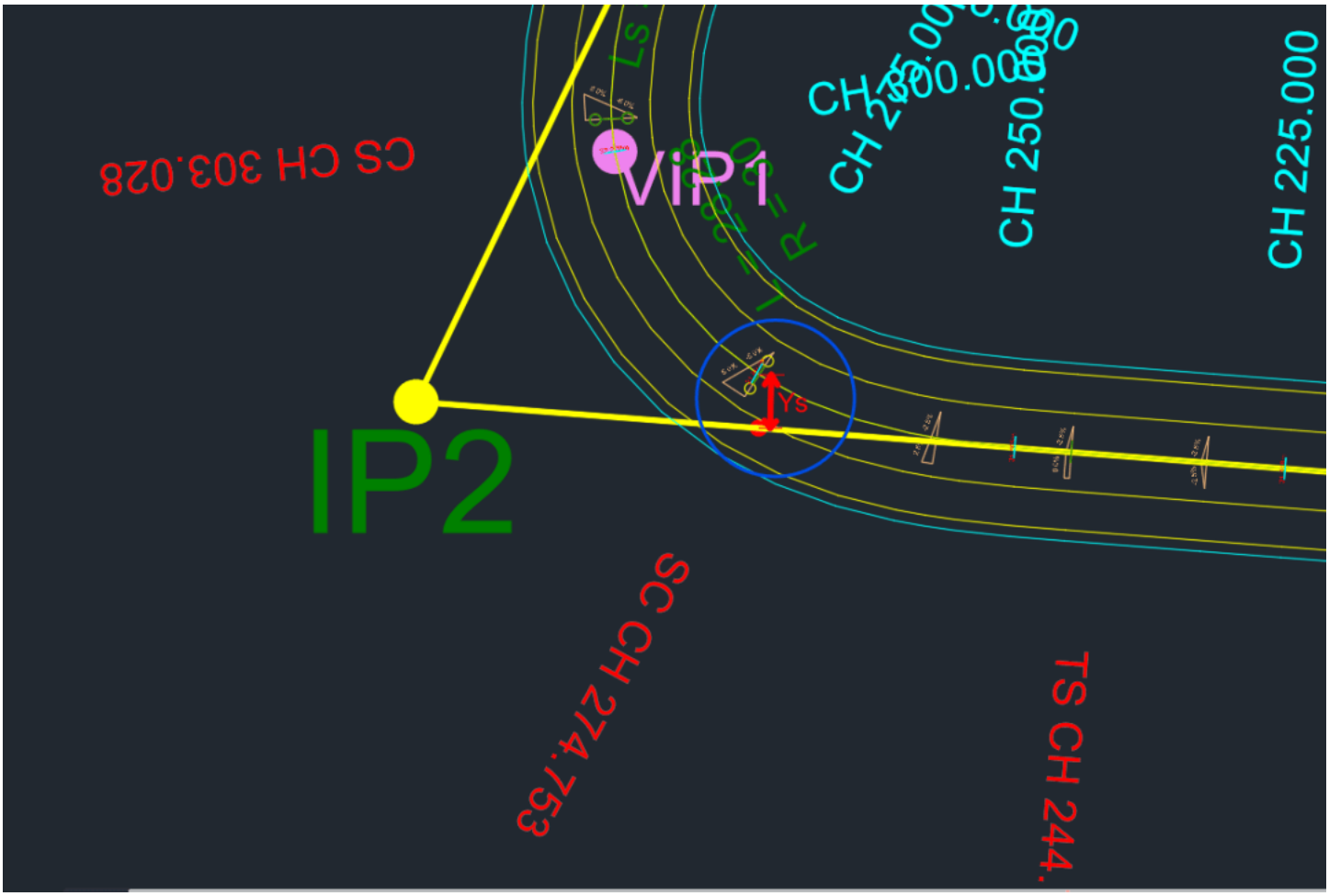
θ = Central angle of spiral arc, L_{s} (Spiral angle); in radians

For example,

Xs=30.000(1−0.49993210+0.499934216−0.4999369360+0.499938685440)Xs=29.259 m

$$\begin{aligned} X_{s} &=30.000\left(1-\frac{0.49993^{2}}{10}+\frac{0.49993^{4}}{216}-\frac{0.49993^{6}}{9360}+\frac{0.49993^{8}}{685440}\right) \\ X_{s} &=29.259\,\text{m} \end{aligned}$$

Tangent offset from initial tangent of any point on Spiral, Y_{s}



$$Y_{s}=30.000\left(\frac{\theta}{3}-\frac{\theta^{3}}{42}+\frac{\theta^{5}}{1320}-\frac{\theta^{7}}{75600}+\frac{\theta^{9}}{6894720}\right)$$

Where:

L = Spiral length from TS to SC or ST to CS

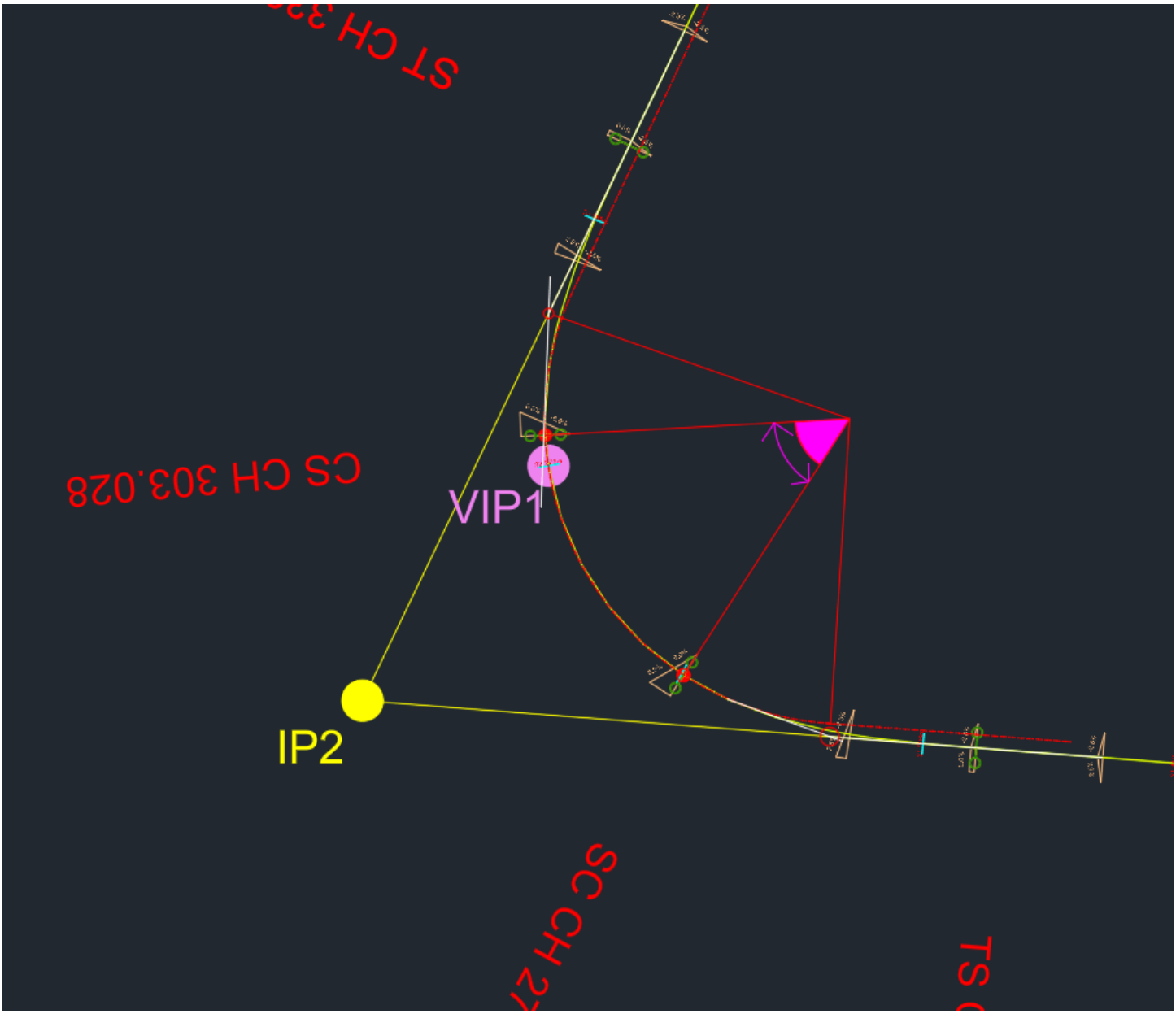
θ = Central angle of spiral arc, L_{s} (Spiral angle); in radians

For example,

$$Ys=30.000(0.499933-0.49993342+0.4999351320-0.49993775600+0.4999396894720)Ys=4.911\ m$$

$$\begin{aligned} Y_{s} &=30.000\left(\frac{0.49993}{3}-\frac{0.49993^{3}}{42}+\frac{0.49993^{5}}{1320}-\frac{0.49993^{7}}{75600}+\frac{0.49993^{9}}{6894720}\right) \\ Y_{s} &=4.911\,\text{m} \end{aligned}$$

Deflection angle at TS from initial tangent to SC, \theta _{c}



$$\theta _{c}=tan^{-1}\frac{Y_{s}}{X_{s}}$$

Where:

Y_{s} = Tangent offset from initial tangent of any point on Spiral

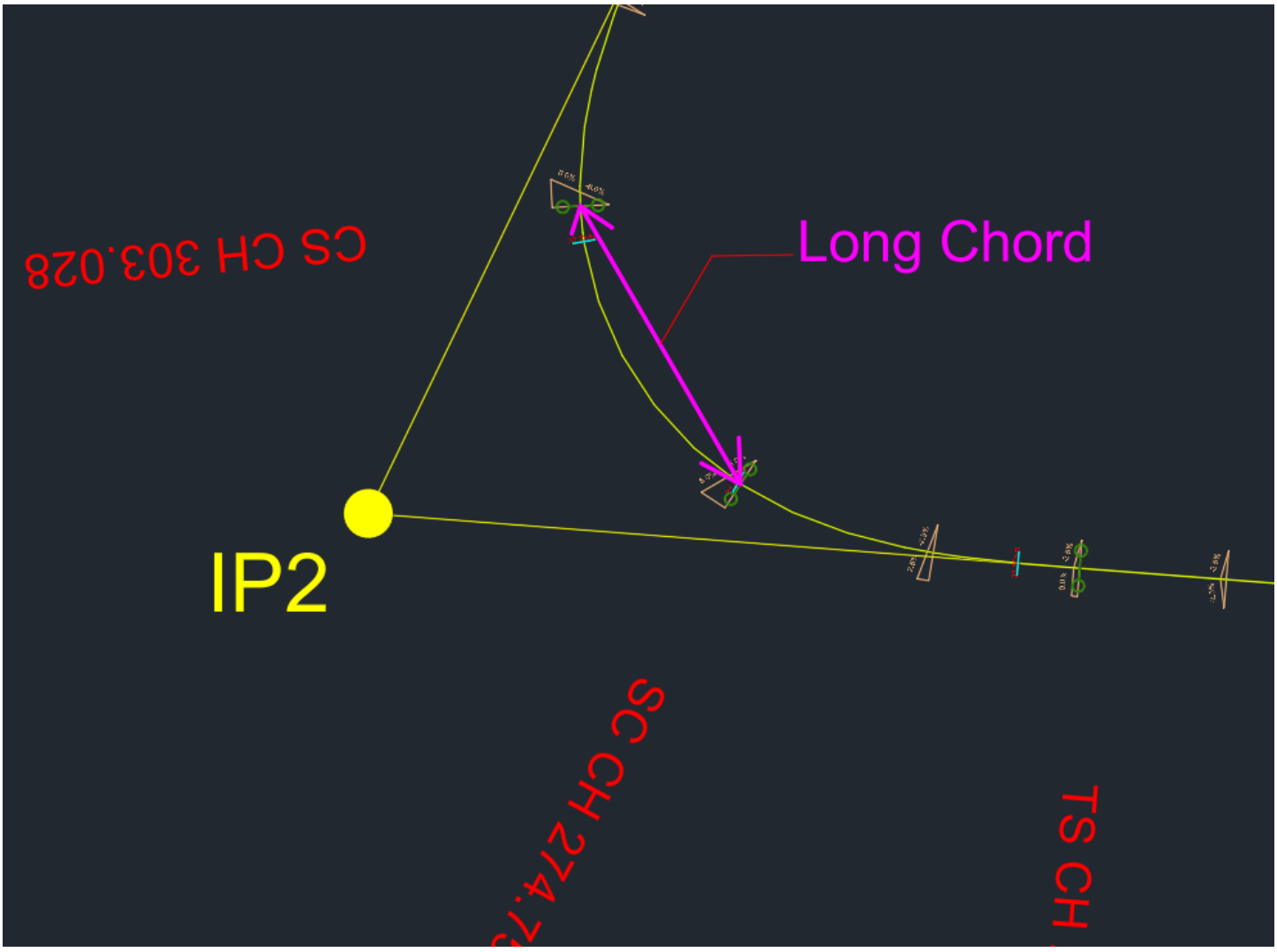
X_{s} = Tangent distance along initial tangent of any point on Spiral with reference to TS or ST

For example,

$$\theta c=tan-1(YsXs)=tan-1(4.91129.259)=9.5280=9\circ 31'41''$$

$$\begin{aligned} \theta_{c} &= \tan^{-1} \left(\frac{Y_{s}}{X_{s}} \right) = \tan^{-1} \left(\frac{4.911}{29.259} \right) = 9.5280 = 9^{\circ} 31' 41'' \end{aligned}$$

Long Chord (TS to SC or CS to ST), LC



LC=\sqrt{\left(X_{s}^{2}+Y_{s}^{2}\right)}

Where:

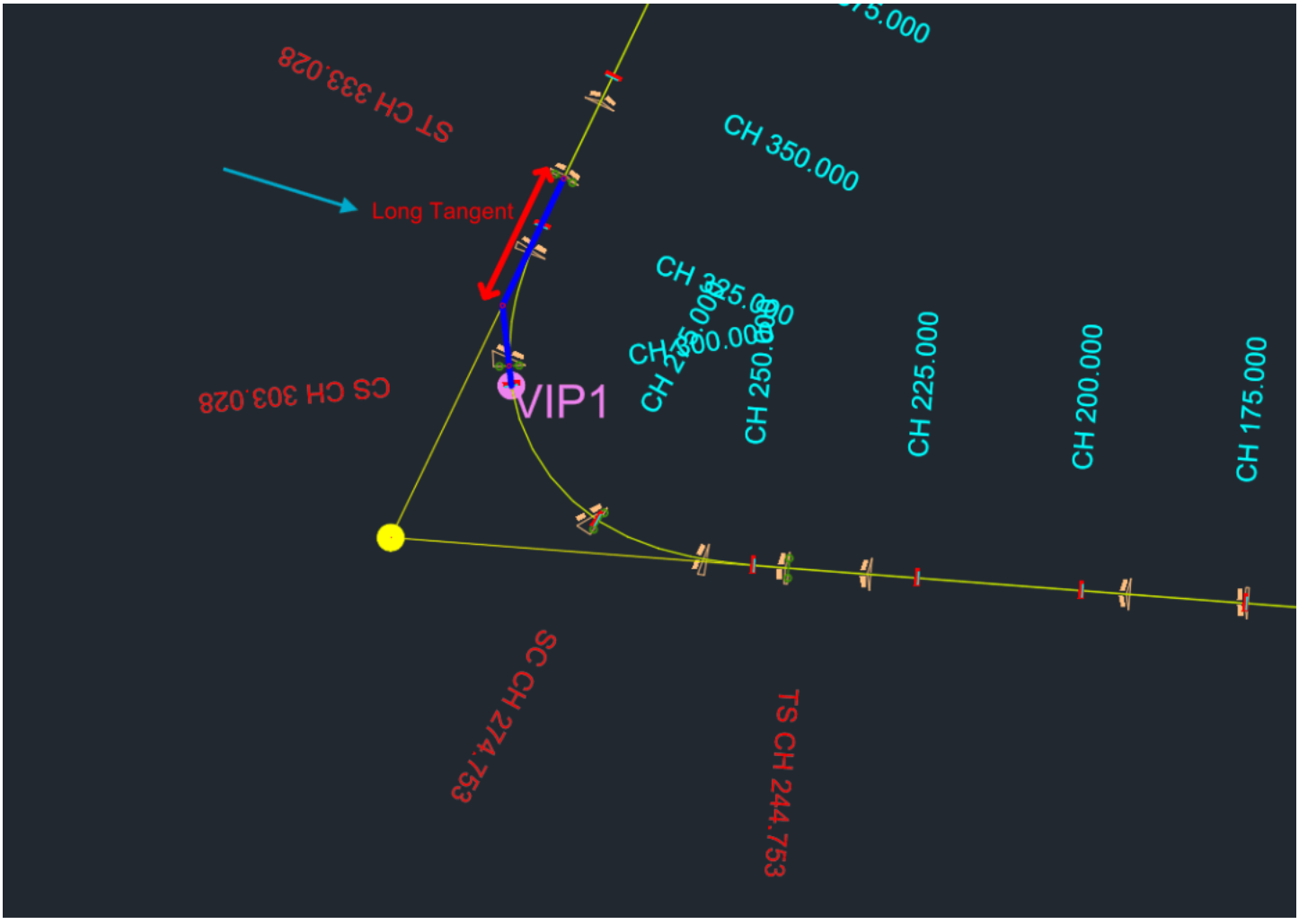
Y_{s} = Tangent offset from initial tangent of any point on Spiral

X_{s} = Tangent distance along initial tangent of any point on Spiral with reference to TS or ST

For example

LC=(29.2592+4.9112)=29.668 m\begin{aligned} LC
&=\sqrt{\left(29.259^{2}+4.911^{2}\right)}=29.668\,\text{m} \end{aligned}

Long Tangent of Spiral, LT



LT=X_{s}-Y_{s}Cot\theta _{s}

Where:

Y_{s} = Tangent offset from initial tangent of any point on Spiral

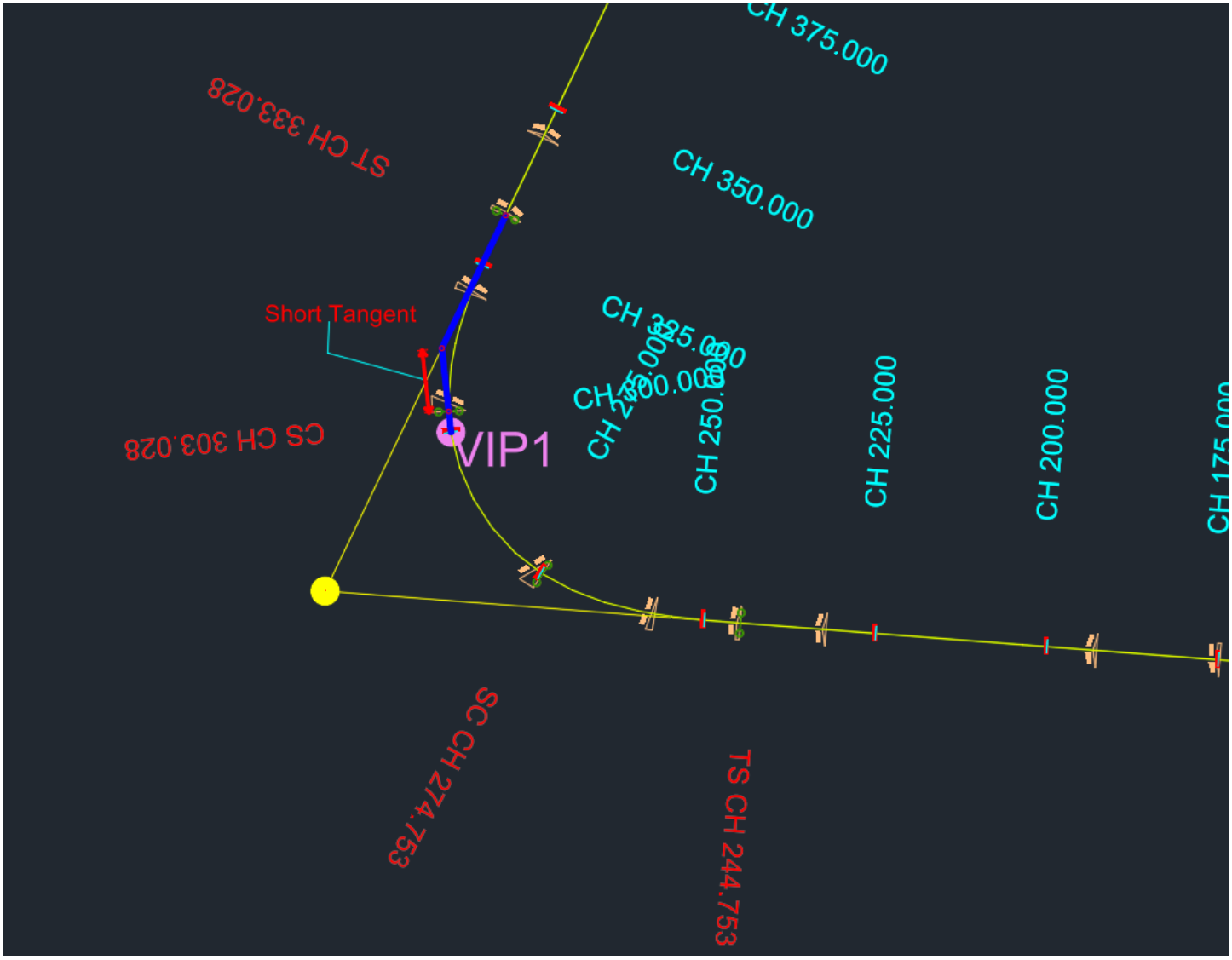
X_{s} = Tangent distance along initial tangent of any point on Spiral with reference to TS or ST

\theta_{s} = Central angle of Spiral arc Ls (Spiral angle)

For example,

LT=29.259−4.911Cot(28.64787749)=20.269 m\begin{aligned} LT &=29.259-4.911Cot\left(28.64787749\right)=20.269\,\text {m} \end{aligned}

Short Tangent of Spiral , ST



$$ST=\frac{Y_{s}}{Sin\theta _{s}}$$

Where:

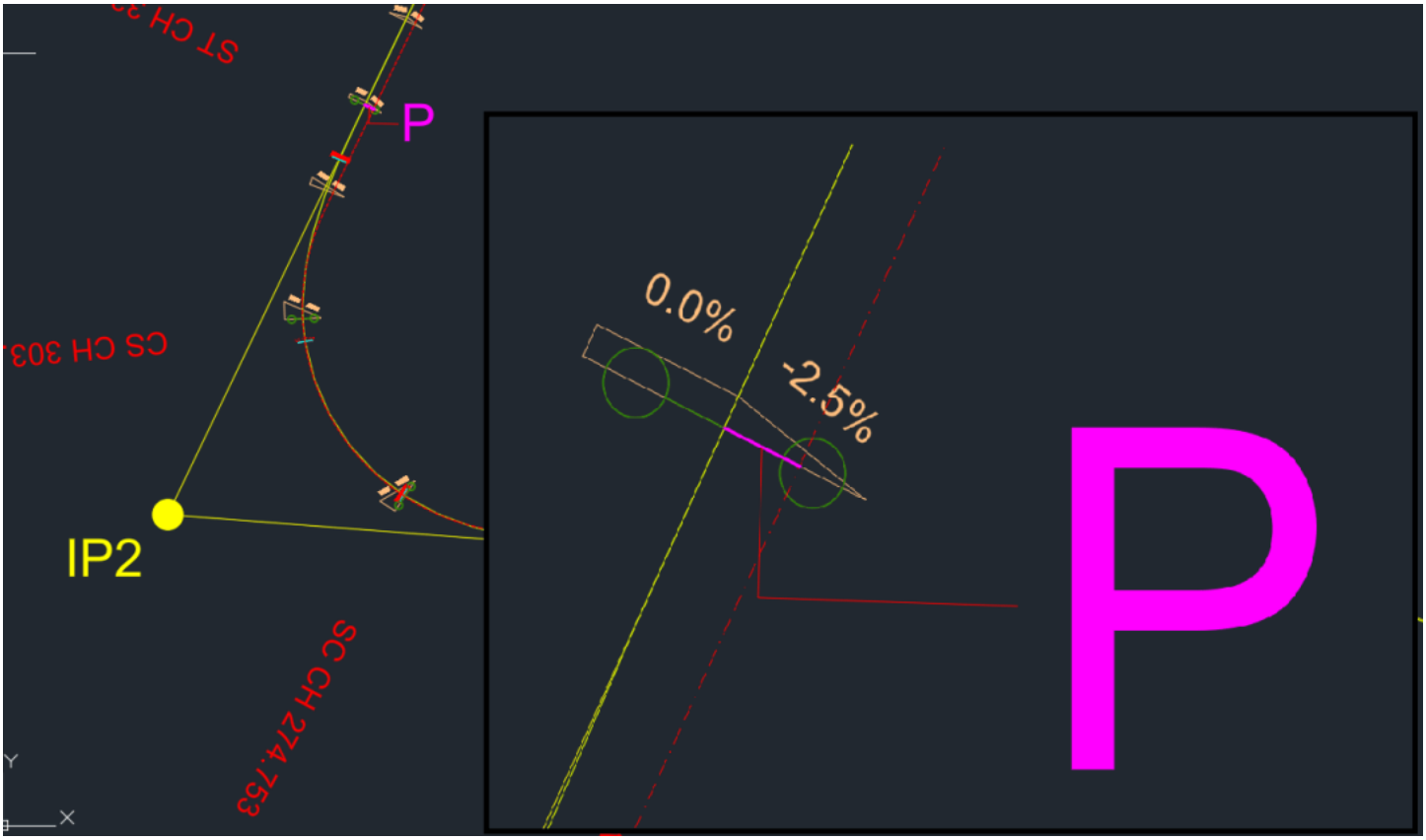
Y_{s} = Tangent offset from initial tangent of any point on Spiral

θ_{s} = Central angle of Spiral arc Ls (Spiral angle)

For example,

$$ST=4.911Sin(28.64787749)=10.244 \text{ m}\begin{aligned} ST &=\frac{4.911}{Sin\left(28.64787749\right)}=10.244\,\text {m} \end{aligned}$$

Offset from initial tangent to PC of shifted circle, P



$$P=Y_{s}-R_{c}\left(1-Cos\theta _{s}\right)$$

Where:

Y_{s} = Tangent offset from initial tangent of any point on Spiral (Y_{s} for SC or CS)

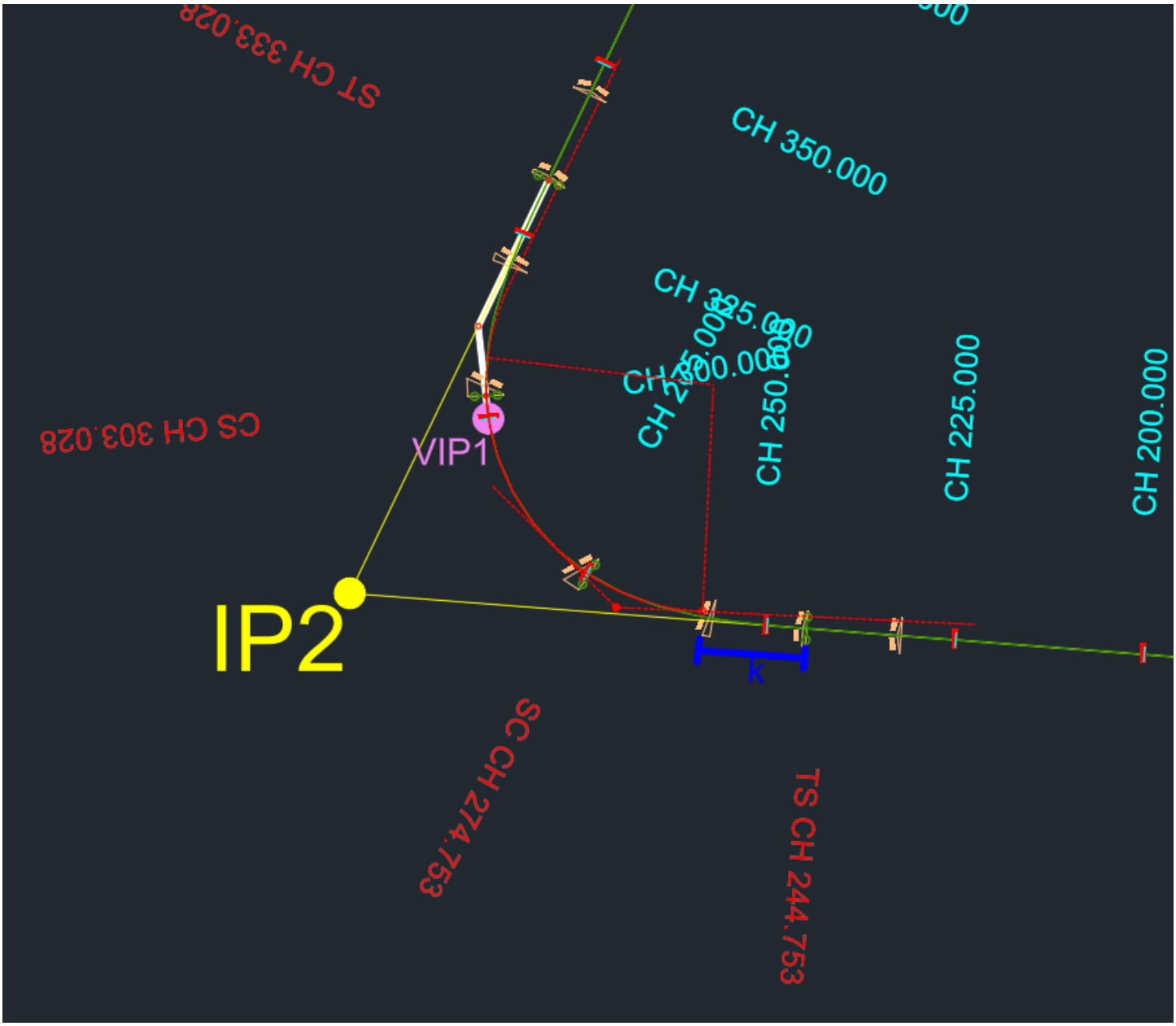
R_{c} = Radius of circular curve

θ_{s} = Central angle of spiral arc, L_{s} (Spiral angle)

For example,

$$P=4.911-30(1-\text{Cos}(28.64787749))=1.238 \text{ m}$$

Tangent distance from TS to PC of shifted circle, k



$$k=X_{s}-R_{c}\left(Sin\theta _{s}\right)$$

Where:

X_{s} = Tangent distance along initial tangent of any point Spiral with reference to TS or ST

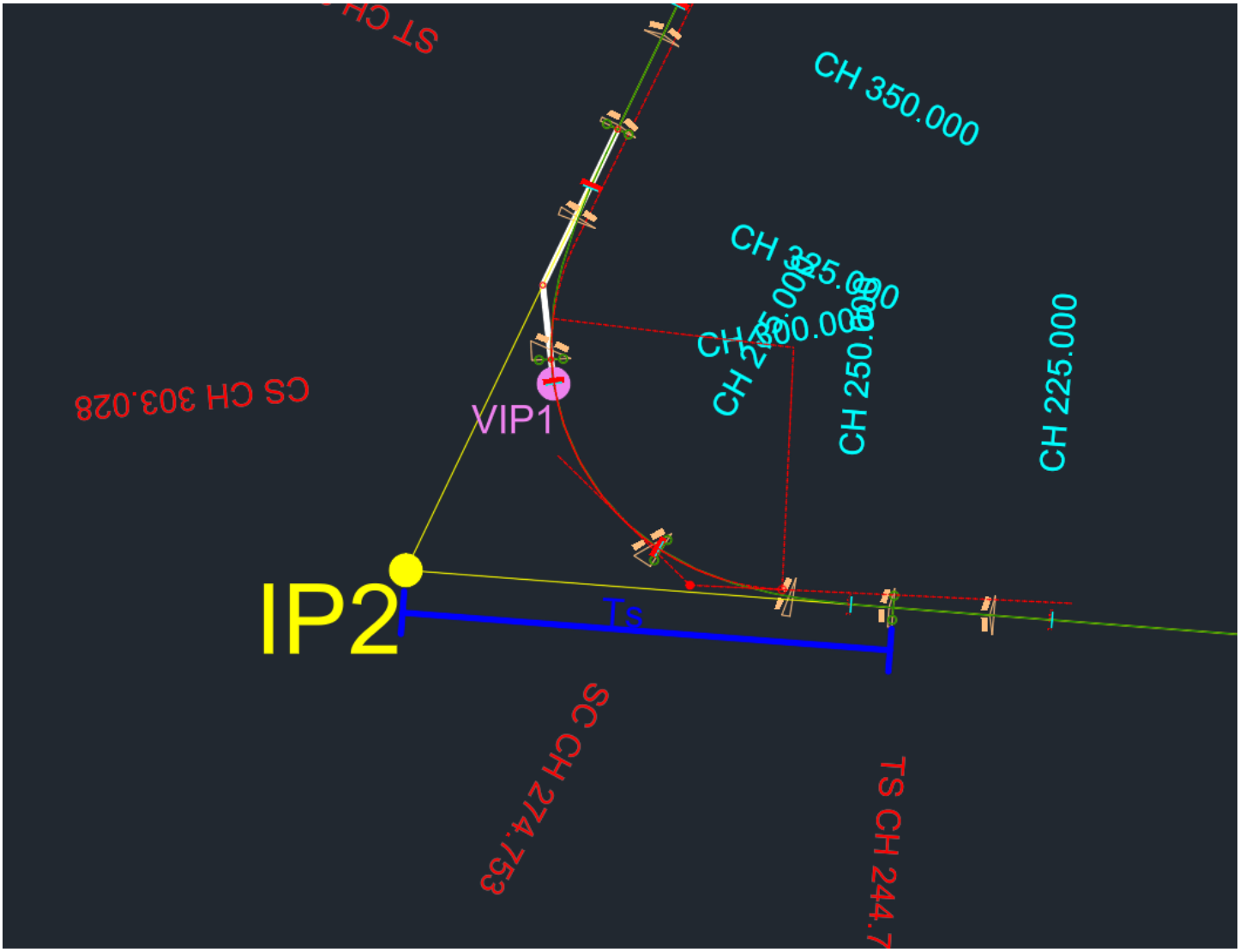
R_{c} = Radius of circular curve

θ_{s} = Central angle of spiral arc, L_{s} (Spiral angle)

For example,

$$k=29.259−30(Sin(28.64787749))=14.876 \text{ m}\begin{aligned} k &=29.259-30\left(Sin\left(28.64787749\right)\right)=14.876\,\text{m} \end{aligned}$$

Total Tangent Distance, T_{s}



$$T_{s}=\left(R_{c}+P\right)Tan\left(\frac{\Delta}{2}\right)+k$$

Where,

R_{s} = Radius of circular curve

P = Offset from initial tangent to PC of shifted circle

Δ = Total deflection angle of curve

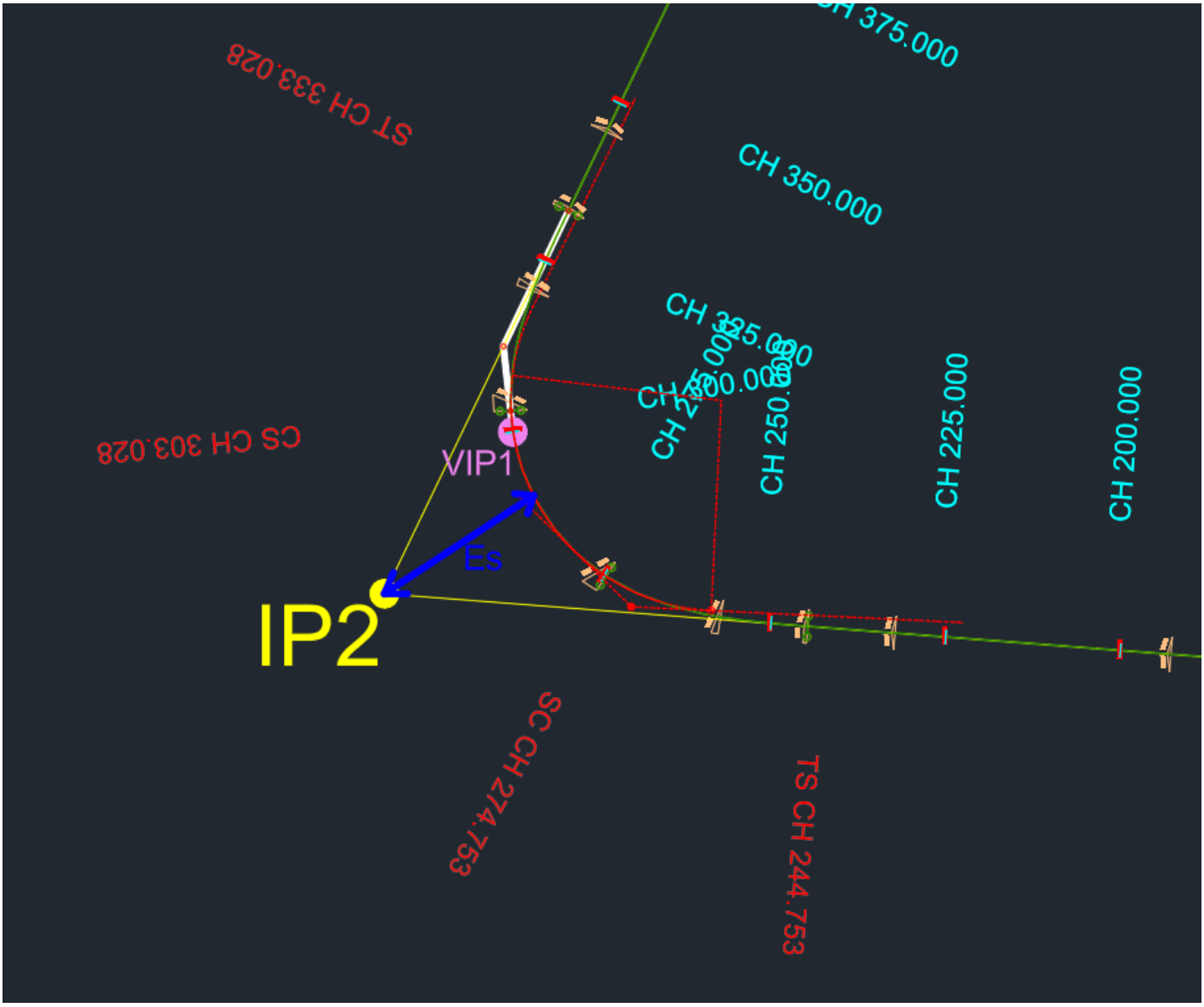
k = Tangent distance from TS to PC of shifted circle

For example,

$$Ts=(30.000+1.238)Tan(111.2976992)+14.876=60.581\ m$$

$$\begin{aligned} T_{s} &=\left(30.000+1.238\right)Tan\left(\frac{111.297699}{2}\right)+14.876=60.581\,\text {m} \end{aligned}$$

External distance, E_{s}



$$E_{s}=\left(R_{c}+P\right)Sec\left(\frac{\Delta}{2}\right)-R_{c}$$

Where:

R_{c} = Radius of circular curve

P = Offset from initial tangent to PC of shifted circle

\Delta = Total deflection angle of curve

For example:

$$Es=(30.000+1.238)Sec(111.2976992)-30.000=25.361 \text{ m}$$
$$\begin{aligned} E_{s} &=\left(30.000+1.238\right)Sec\left(\frac{111.297699}{2}\right)-30.000=25.361\,\text {m} \end{aligned}$$

Components of Vertical Alignment

Vertical alignment in road design refers to the longitudinal profile of the road along the designed path, displaying the changes in elevation along the alignment. Proper design of the vertical alignment, in accordance with standards, is required to provide adequate sight distance, ensuring safe stopping and overtaking conditions for vehicles while navigating the road.

Details of the curve:

VIP No.: VIP2

VIP CH.: 600

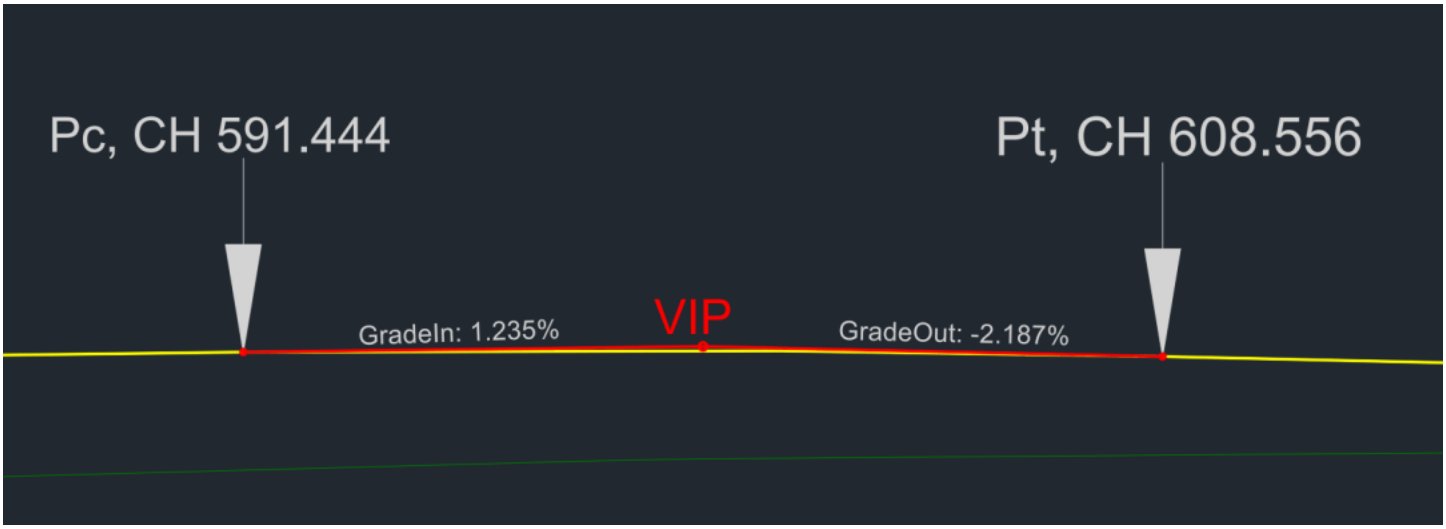
VIP Elevation: 35.91

Grade In: 1.235%

Grade Out: -2.187%

Design Speed: 30 kph

Delta Grade, \Delta G (%)



G=OutgoingGrade-IncomingGrade

For example:

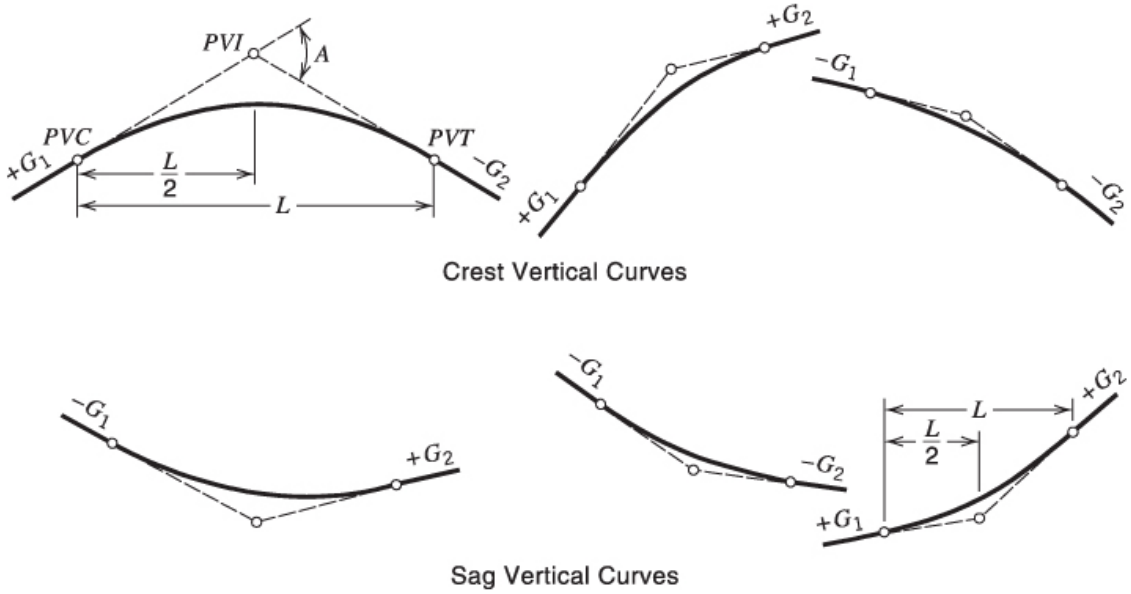
$$G=(-2.187)-1.235 G=-3.422 \begin{aligned} G &= \left (-2.187 \right)-1.235 \\ G &=-3.422 \end{aligned}$$

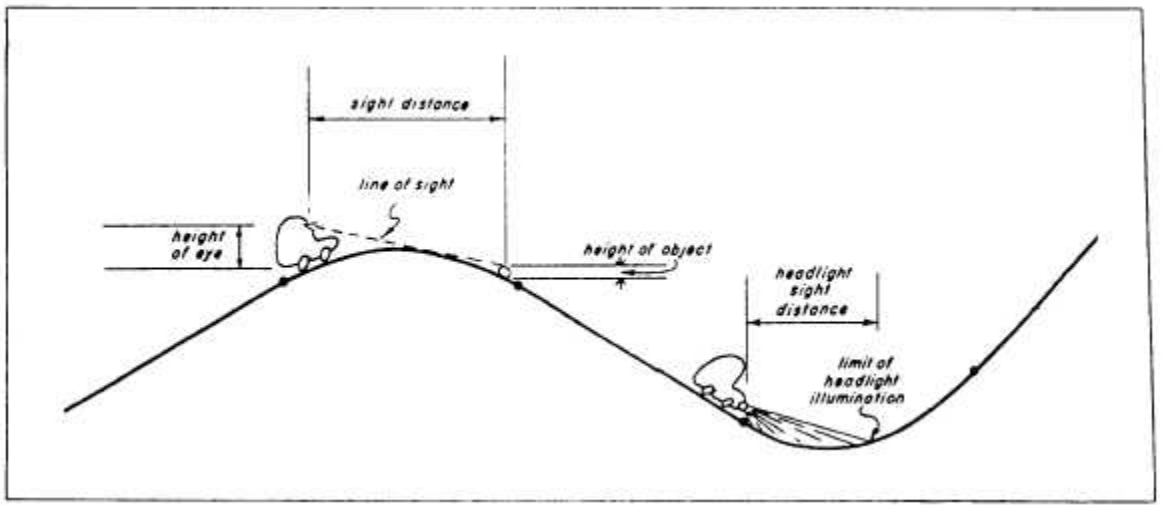
Crest & Sag Curves

The vertical curves established during grade changes represent the road's transition as it goes up or down along the terrain. There are two types of curves, **crest** and **sag**.

Curve Type	Description
Crest	This curve occurs when the road goes uphill, experiencing a positive grade change (e.g, +3.00%) With this type of curve, it is crucial to maintain a safe sight distance to ensure drivers can see objects beyond the hill.

Sag	This curve occurs when the road goes downhill, experiencing a negative grade change (e.g., -2.00%) For this curve, maintaining a safe headlight distance is important to ensure drivers can see clearly while driving through the “dip”.





Crest and sag curves on a Vertical Profile

K & Vertical Curve Length (VCL)

Vertical Curve Length (VCL) represents the horizontal distance required to achieve a specific change in grade, while K is the curvature coefficient required to obtain the VCL. The two components are linearly interrelated, in which an increase in K will increase the VCL as well.

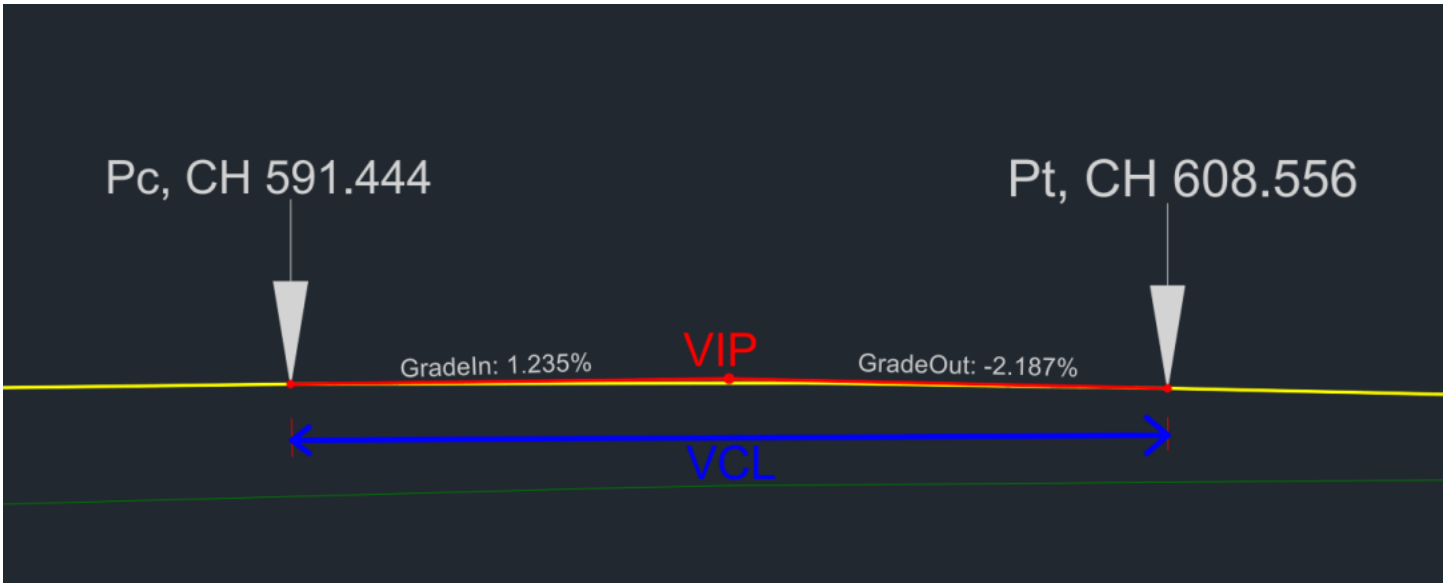
This relationship can be expressed mathematically by the formula:

VCL=K\times A

Note: A represents the change in grade.

In road design, we usually aim for a longer VCL; it is equivalent to a smoother, flatter curve, which requires a higher K value. The rule of thumb is that the longer the curve, the better it is, whether it is a crest or a sag, as it provides a safe sight distance and better driving comfort.

Vertical Curve Length (m)



VCL=k\times\Delta G

For example:

VCL=5.000×|(−2.187)−1.235|VCL=5.000×3.422VCL=17.11 m\begin{aligned} VCL &=5.000\times\left|\left(-2.187\right)-1.235 \right | \\ VCL &=5.000\times 3.422 \\ VCL &=17.11\,\text{m} \end{aligned}

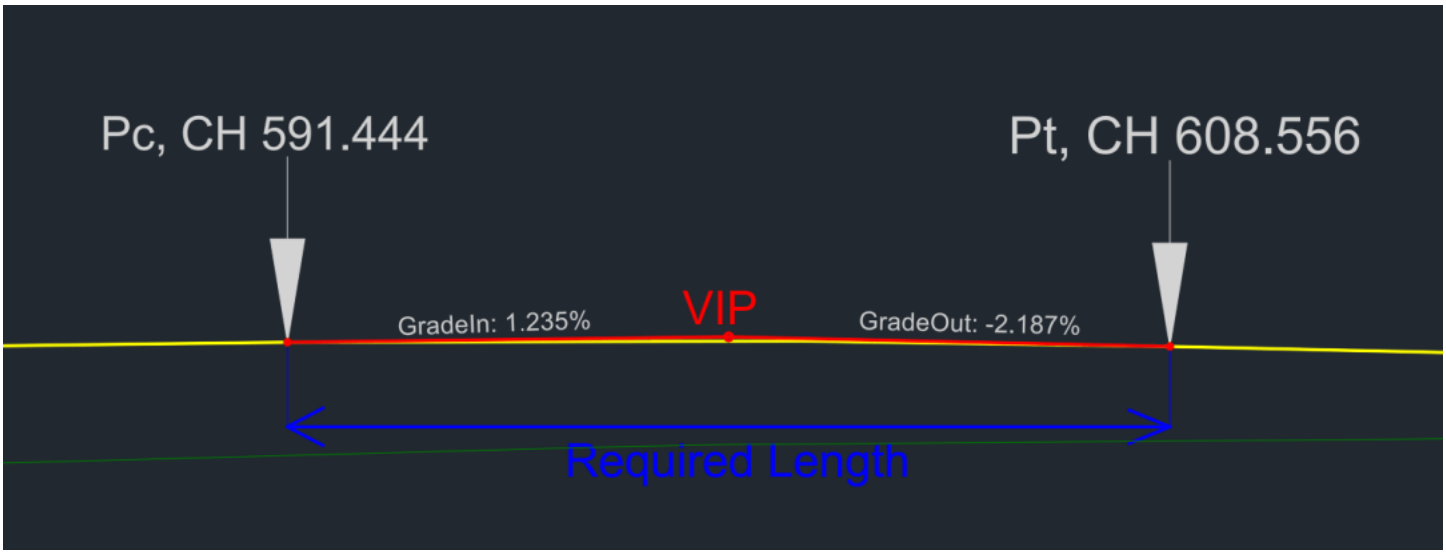
K value, K

$$K=\frac{VCL}{\Delta G}$$

For example:

$$K=17.11|(-2.187)-1.235|K=5.000\begin{aligned} K &=\frac{17.11}{\left|\left(-2.187\right)-1.235\right|} \\ K &=5.000 \end{aligned}$$

Required Length (m)

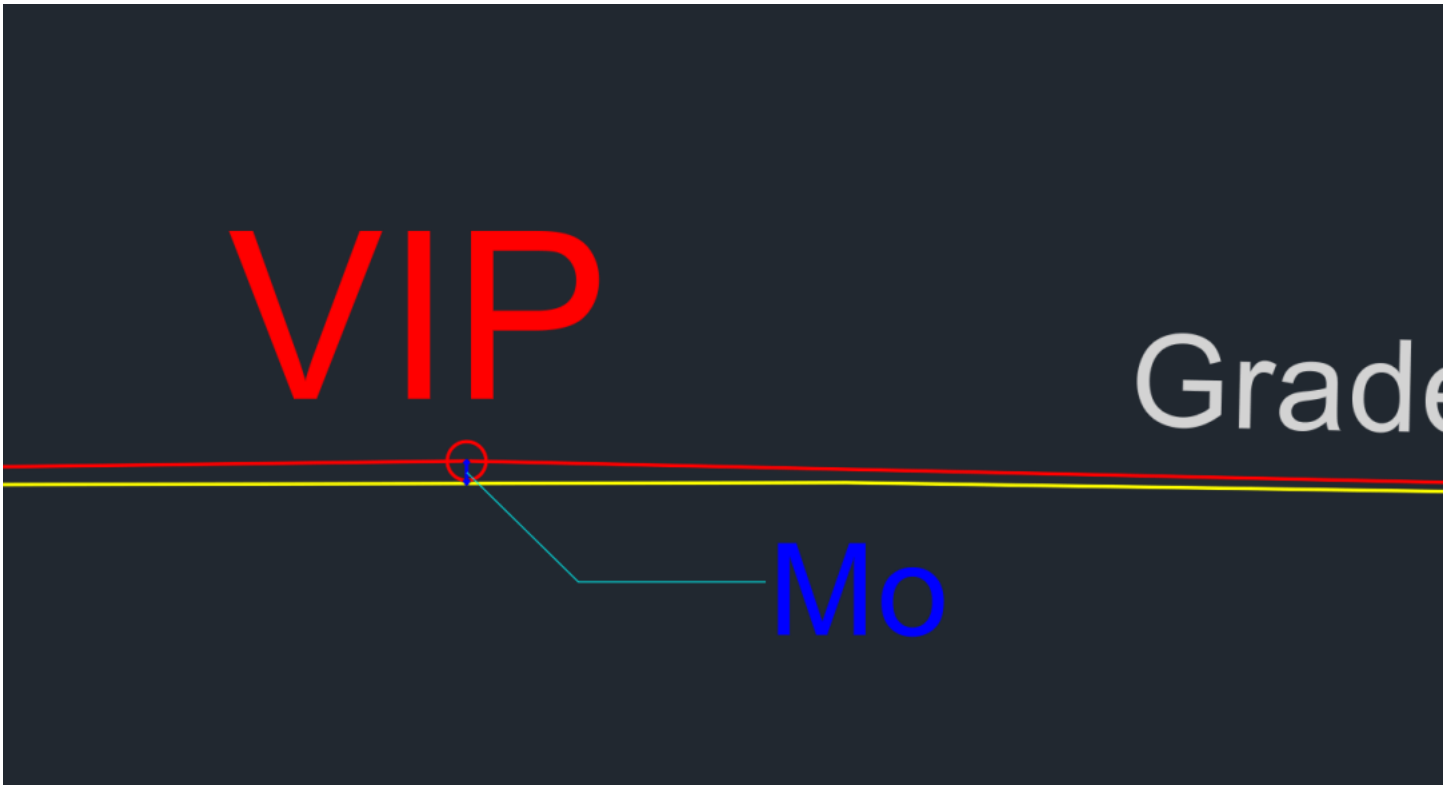


$$Length=MinK\times\Delta G$$

For example:

$$Length=5.000\times|(-2.187)-1.235|Length=5.000\times3.422Length=17.11\ m\begin{aligned} Length &=5.000\times\left|\left(-2.187\right)-1.235\right| \\ Length &=5.000\times 3.422 \\ Length &=17.11\,\text{m} \end{aligned}$$

Middle Ordinate, M_o



$$M_{o}=\frac{\left(\Delta G\times VCL\right)}{800}$$

For example:

$$Mo=|(-2.187)-1.235|\times 17.11800Mo=58.55042800Mo=0.073\begin{aligned} M_{o} &=\frac{\left|\left(-2.187\right)-1.235\right|\times 17.11}{800} \\ M_{o} &=\frac{58.55042}{800} \\ M_{o} &=0.073 \end{aligned}$$

Related



Ngu Soon Hui

I'm the Benevolent Dictator for Life for MiTS Software cum Editor of this website. Read more here.

You can also contact me at soonhui@mes100.com