Conceptual Report - Culvert Sizing Calculations

For culverts with smaller catchment areas (less than 100 ha), we have used the Rational Method for estimating post-development flows.

The time of concentration, Tc, was calculated using the Airport Formula (min) for overland flow, and assumed velocities based on a typical 3:1 ditch cross section for channel flow (min). The Rational Method and the Smith Falls rainfall intensities were used to calculate the drainage flow for runoff on site.

Runoff quantity, $Q = 2.78 * I * SUM(C * A) / 1000$ (m^3/s)

Where: C = Roughness coef.
A = Catchment Area (ha)
I = Intensity (mm/hr)

For Time of Concentration,

Tc = Overland Flow Time + Channel Flow Time (T)

$$Tc = \frac{3.26\,(1.1 - C)\,(L)^{1/2}}{(S_w)^{0.33}} + \text{Length of channel / flow velocity}$$

Where: C = Roughness coef. (Balanced 'C')
L = Sheet Flow Distance (m)
S_w = Slope of land (%)

Balanced 'C'

Road

Asphalt	C = 0.9	W = 6m
Shoulders	C = 0.5	W = 4m
Grass	C = 0.15	W = 10m

C = (0.9*6) + (0.5*4) + (0.15*10) / 20
= 0.44

Average Lot

Roof	C = 0.9	$A = 360m^2$
Driveway	C = 0.9	$A = 200m^2$
Grass	C = 0.15	$\underline{A = 19440m^2}$
		20,000

C = (0.9 * (360 + 200)) + (0.15*19440) / 20000
= 0.17

Road	C = 0.44	$A = 900m^2$
Lot	C = 0.17	$\underline{A = 20{,}000m^2}$
		20,900

C = (0.44*900)+(0.17 * 20,000) / 20,900
= 0.18

Therefore the balanced 'C' used for designing the proposed culverts is 0.18.

Crossing Culvert No. X1, (@ Crow Lake Road)

Area = 5.2 ha.
Runoff Coefficient = 0.18

Time of Concentration

$$t_c = \frac{(3.26\,(1.1 - C)\,L^{0.5})}{S_w^{\,0.33}} + (\frac{L_d}{V} \div 60)$$

C = 0.18
L = 150
S_w = 3.0%
L_d = 130 m
V = 0.5 m/s

Therefore, T_c = 25 + 4
= 29 min.

Therefore, I_{10} = 54 mm/hr.

Q_5 = 2.78 CIA
= 2.78 x 0.18 x 54 x 5.2
= 140 l/s (0.14 m^3/s)

Using a 600Φ CSP @ 0.5%, Culvert flows under inlet control, H_w = 0.35 m

Crossing Culvert No. X2, (@ existing Side Road)

Area = 1.3 ha.
Runoff Coefficient = 0.18

Time of Concentration

$$t_c = \frac{(3.26\,(1.1 - C)\,L^{0.5})}{S_w^{\,0.33}} + (\frac{L_d}{V} \div 60)$$

C = 0.18
L = 60
S_w = 4.0%
L_d = 40 m
V = 0.5 m/s

Therefore, T_c = 15 + 1
= 16 min.

Therefore, I_{10} = 89 mm/hr.

Q_5 = 2.78 CIA
= 2.78 x 0.18 x 89 x 1.3
= 58 l/s (0.06 m^3/s)

Using a 600Φ CSP @ 0.5%, Culvert flows under inlet control, H_w = 0.21 m

Crossing Culvert No. X3, (@ Lot 35)

Area = 11.5 ha.
Runoff Coefficient = 0.18

Time of Concentration

$$t_c = \frac{(3.26\,(1.1 - C)\,L^{0.5})}{S_w^{\,0.33}} + \left(\frac{L_d}{V} \div 60\right)$$

C = 0.18
L = 150
S_w = 3.8%
L_d = 200 m
V = 0.5 m/s

Therefore, T_c = 24 + 7
= 31 min.

Therefore, I_{10} = 51 mm/hr.

Q_5 = 2.78 CIA
= 2.78 x 0.18 x 51 x 11.5
= 293 l/s (0.29 m^3/s)

Using a 600Φ CSP @ 0.5%, Culvert flows under inlet control, H_w = 0.55 m

Crossing Culvert No. X4, (@ Lot 19)

Since the area draining through culvert X4 is greater than 100 ha, using the standard Rational Method is not recommended for estimating runoff volumes along the main ditch through the middle of the proposed site. For medium to large catchment areas, the Modified Flood Index Method is the preferred method of calculating surface runoff.

The general equation of the 25 year Index Flood Curve is determined as:

Q_{25} = C_{25} x $A^{0.75}$, (m^3/s)

Where: C_{25} = watershed class coefficient,
A = basin area (km^2).

The catchment area is predominantly a northern (Shield) type basin with shallow bedrock and numerous wetland areas.

Total Area, A = 155.0 ha.
= 1.55 km^2

Water storage Area, A_d
= 23.84 ha

Storage Percentage = A_d/A x 100
= 23.84 / 155 x100
= 15.4%

Watershed Base Class = 3.8

Location of storage: Well distributed throughout.

Therefore storage is type B, watershed class adjustment is zero.

Net Watershed Class = 3.8

Therefore Class Coefficient, C = 0.41

Runoff, Q_{25} = C_{25} x $A^{0.75}$, (m^3/s)
= 0.41 x $1.55^{0.75}$
= 0.57 m^3/s

For the 10 year event, Q_{10} = 0.57 m^3/s x 0.84
= 0.48 m^3/s

Using an 800Φ CSP @ 0.5%, Culvert flows under outlet control, H_w = 0.70 m

Crossing Culvert No. X5, (@ Block 39)

Area = 17.6 ha.
Runoff Coefficient = 0.18

Time of Concentration

$$t_c = \frac{(3.26\,(1.1 - C)\,L^{0.5})}{S_w^{0.33}} + \left(\frac{L_d}{V} \div 60\right)$$

C = 0.18
L = 150
S_w = 4.8%
L_d = 750 m
V = 0.5 m/s

Therefore, T_c = 22 + 25
= 47 min.

Therefore, I_{10} = 38 mm/hr.

Q_5 = 2.78 CIA
= 2.78 x 0.18 x 38 x 17.6
= 335 l/s (0.33 m^3/s)

Using a 600Φ CSP @ 0.5%, Culvert flows under inlet control, H_w = 0.58 m

Crossing Culvert No. X6, (@ Lot 31)

Area = 15.1 ha.
Runoff Coefficient = 0.18

Time of Concentration

$$t_c = \frac{(3.26\,(1.1 - C)\,L^{0.5})}{S_w^{0.33}} + (L_d \div 60 \div V)$$

C = 0.18
L = 200
S_w = 5.5%
L_d = 350 m
V = 0.5 m/s

Therefore, T_c = 24 + 12
= 36 min.

Therefore, I_{10} = 47 mm/hr.

Q_5 = 2.78 CIA
= 2.78 x 0.18 x 47 x 15.1
= 355 l/s (0.35 m^3/s)

Using a 600Φ CSP @ 0.5%, Culvert flows under inlet control, H_w = 0.65 m

Crossing Culvert No. X7, (@ Street 'B')

Area = 4.1 ha.
Runoff Coefficient = 0.18

Time of Concentration

$$t_c = \frac{(3.26\,(1.1 - C)\,L^{0.5})}{S_w^{0.33}} + (L_d \div 60 \div V)$$

C = 0.18
L = 130
S_w = 3.3%
L_d = 210 m
V = 0.5 m/s

Therefore, T_c = 23 + 7
= 30 min.

Therefore, I_{10} = 53 mm/hr.

Q_5 = 2.78 CIA
= 2.78 x 0.18 x 53 x 4.1
= 109 l/s (0.11 m^3/s)

Using a 600Φ CSP @ 0.5%, Culvert flows under inlet control, H_w = 0.31 m

Crossing Culvert No. X8, (@ Lot 27)

Area = 36.8 ha.
Runoff Coefficient = 0.18

Time of Concentration

$$t_c = \frac{(3.26\,(1.1 - C)\,L^{0.5})}{S_w^{0.33}} + (L_d \div 60 \div V)$$

C = 0.18
L = 200
S_w = 5.5%
L_d = 750 m
V = 0.5 m/s

Therefore, T_c = 23 + 25
= 48 min.

Therefore, I_{10} = 37 mm/hr.

Q_5 = 2.78 CIA
= 2.78 x 0.18 x 37 x 36.8
= 681 l/s (0.68 m^3/s)

Using a 800Φ CSP @ 0.5%, Culvert flows under inlet control, H_w = 0.81 m

Crossing Culvert No. X9, (@ Lot 26)

Area = 1.7 ha.
Runoff Coefficient = 0.18

Time of Concentration

$$t_c = \frac{(3.26\,(1.1 - C)\,L^{0.5})}{S_w^{0.33}} + (L_d \div 60 \div V)$$

C = 0.18
L = 60
S_w = 10.5%
L_d = 100 m
V = 0.5 m/s

Therefore, T_c = 11 + 3
= 14 min.

Therefore, I_{10} = 95 mm/hr.

Q_5 = 2.78 CIA
= 2.78 x 0.18 x 95 x 1.7
= 81 l/s (0.08 m^3/s)

Using a 600Φ CSP @ 0.5%, Culvert flows under inlet control, H_w = 0.27 m

Crossing Culvert No. X10, (@ Lot 12)

Area = 15.3 ha.
Runoff Coefficient = 0.18

Time of Concentration

$$t_c = \frac{(3.26\ (1.1 - C)\ L^{0.5})}{S_w^{\ 0.33}} + (\ L_d \div 60\ )\ \frac{}{V}$$

C = 0.18
L = 100
S_w = 2.0%
L_d = 600 m
V = 0.5 m/s

Therefore, T_c = 24 + 20
= 44 min.

Therefore, I_{10} = 40 mm/hr.

Q_5 = 2.78 CIA
= 2.78 x 0.18 x 40 x 15.3
= 306 l/s (0.31 m^3/s)

Using a twin 600Φ CSP's @ 0.5%, Culvert flows under inlet control, H_w = 0.37 m