Rainfall and Runoff

CONTENTS

21.1 Introduction

This chapter describes how to determine design rainfall intensity, runoff rates, and rainfall hyetographs for sizing waterway components or as input to more detailed hydraulic analysis.

How to do it...

- Surface water runoff from **non-hill catchments up to 15 hectares, and hill catchments up to 5 hectares**, may be calculated using the Rational Method. *See Section 21.3 The Rational Method.*
- For catchments larger than the areas above, the Rational Method tends to give a conservative result. Therefore for larger areas a dynamic analysis by computer modelling using a profiled hyetograph should be used. See *Section 21.4: Advanced Analysis.*
- For roof catchments and site works associated with Building Consents, refer to the Building Industry Authority (**2002**) approved document, Surface Water Clause E1.
- For flood attenuation detention volume determination see Section 21.6.
- For water quality (first flush) volume calculation refer to Chapter 6.4.
- For subsoil drains, the suggested guide is a unit flow of 1 mm/hour rainfall equivalent (2.78 l/s/ha).

The term **Annual exceedance probability (AEP)** is used throughout this chapter. AEP is defined as the probability that a given rainfall depth accumulated over a given duration will be exceeded in any one year. AEP is the reciprocal of Return Period (T) but is generally expressed as a percentage. Commonly used AEP values and the equivalent return period values are shown in Table 21-1.

Table 21-1: AEP versus Return Period.

AEP (%)	**50%**	**20%**	**10%**	**5%**	**2%**	**1%**	**0.5%**	**0.2%**	**0.1%**
Return period (yrs)	2	5	10	20	50	100	200	500	1000

21.2 Christchurch Rainfall

Christchurch's mean annual rainfall varies from less than 600 mm along the coast to more than 800 mm on the top of the western Port Hills (see *Section 21.4: Advanced Analysis*) and up to 2000mm at some high elevations out on the Peninsula. Short duration rainfall intensities do not vary much throughout the Christchurch City area but differences are apparent for durations longer than about three hours, with higher intensity rainfalls on the hills than out on the flat. The Christchurch rainfall has been analysed by Pearson (1992) and Niwa (2009). From 2020 The Council has adopted the NIWA HIRDS Version 4 methodology (NIWA 2018 https://hirds.niwa.co.nz/) for design rainfall intensities but the standard dimensionless hyetograph has been retained pending further investigations. The hyetograph is based on historic storm analyses. It is triangular in form, with a peak at twice the average intensity occurring at 0.7 of duration (time), as illustrated in Figure 21-6. Methods for determining rainfall intensity for various durations and frequency for small catchments are summarised in *Section 21.3: The Rational Method,* and for larger catchments *in Section 21.4: Advanced Analysis.*

21.3 The Rational Method

21.3.1 General

The Rational Method is a simple empirical procedure for determining runoff from small catchments (as defined in 21.1), but must be used with caution because the result is highly sensitive to correct selection of the runoff coefficient.

The rational formula has the form:

$Q = 2.78C\ i\ A$ Eqn (21-1)

where Q = runoff in litres per second (l/s)
C = runoff coefficient. (See 21.3.4)
i = average rainfall intensity (mm/hr) during the design storm of duration (D) for the appropriate design annual exceedance probability (AEP) (See 21.3.2, 21.3.3 and Appendix 10)
A = area of catchment upstream of the point being considered (hectares)

See below for procedures for determining C, i, and D.

Note that storm average rainfall intensity is used when using the rational method. The use of average intensity, combined with a rerating component included in the runoff coefficient, replicates the catchment outflow peak smoothing that happens in reality as an input triangular hyetograph transforms to an output runoff hydrograph. This is also simulated in dynamic analyses as described in Section 21.4.

21.3.2 Design Storm Duration

In the rational method the design storm duration is the time of concentration (T_C). T_C is the time taken for surface water runoff to reach the design point from the furthest point (in time) of the catchment, so that the whole catchment is contributing to the maximum discharge at the design point for any given probability of occurrence: the critical storm duration (D) has a period equal to T_C.

21.3.2.1 Time of Concentration (T_c)

T_C is calculated from the formula:

$T_C = T_e + T_t$ Eqn (21-2)

where T_e = time of entry; time taken for runoff to travel overland from properties, roofs, down pipes, etc, to the ‘point of entry’ at the road channels
T_t = travel time, being the time of network flow comprising time of flow in pipes and/or open channels, including road channels, to the design point

Note the following:

- The component times should be based on the catchment conditions likely to exist throughout the design life of the hydraulic system.
- Regardless of calculated results the minimum time of concentration shall not be less than 10 minutes in residential or commercial areas, and 25 minutes in parks and rural

areas.

21.3.2.2 Time of Entry (T_e)

Standard Times Based on Land Zoning

1) The time of entry shall be assessed according to the district zone and land use characteristics of the catchment.

   Business Areas:

   T_e = 5 minutes + flow travel time; 10 minutes minimum

   Residential Areas:

   RS: Te = 15 minutes
   RSDT: T_e = 14 minutes
   RNN T_e = 12 minutes
   RMD: T_e = 10 minutes

   Parks, rural areas, or if no side channels:

   T_e = as determined by the Overland Flow formula below (Eqn 21-3), or the nomograph of Figure 21-1.

2) For hillside catchments, use time of entry T_e = as determined by the Overland Flow formula below (Eqn (21-3)), or the nomograph of Figure 21-1. For hillside flow the designer must ensure that the flow travel time is evaluated from the very top of the catchment. If the hill catchment is at least partially channelised, then the Bransby-Williams procedure of *Section 21.3.2.4: Rural Channelised Catchments*, may have to be incorporated, or computer modelling considered.

Overland Flow

Overland flow can occur on either grassed or paved surfaces. The major factors affecting runoff flow time are the maximum flow distance, surface slope, surface roughness, rainfall intensity and infiltration rate. Overland flow over unpaved surfaces initially occurs as sheet flow for a short time and distance after which it begins to form a runnel or rill and travels thereafter in a natural channel form. In urban area, the length of overland sheet flow will typically be less than 50 metres after which it will become concentrated against fences, paths or structures or intercepted by formed drainage systems.

Ideally overland flow time should be calculated by use of the kinematic wave equation but its more complex application, requiring solution by iteration, makes it impractical for small catchment assessment.

A direct solution procedure for slightly channelised urban overland flow, (Equation (21-3) below), as modified by Friend in 1954, was originally presented as a design graph by Miller (1951; see Figure 21-1), based on USDA data of 1942. This simple formula is known to give a wide scatter of results compared with actual field data, but its simple use makes it a practical method for determination of overland flow time in small catchments. It is also the method adopted for the New Zealand Building Code, Surface Water Clause

E1 (Building Industry Authority 2002).

$$T_e = \frac{100\, nL^{0.33}}{S^{0.2}} \qquad \text{Eqn (21-3)}$$

where T_e = flow time in minutes

L = length of overland flow in metres

S = slope as a percentage (eg. 2%)

n = Horton's value for surface roughness (similar to Manning's n). Typical values are given in Table 21-2

21.3.2.3 Time of Network Flow (T_t)

The time of network flow, or travel time (T_t), is comprised of the time of road channel flow, pipe network flow, and open channel flow.

Time of Road Channel Flow

The time of road channel flow, is the time taken for water to flow from the point of entry, at the road channel, to the point of discharge to a sump, drain, or other outlet.

Figure 21-2 gives side channel velocities and flow times with flow depth to top of kerb for flat channels (Type SD601), based on a Manning ‘n’ of 0.016.

Note: Road formation crossfall is usually 3–4 % from road centre, and 5 % at the shoulder.

Time of Pipe Flow

The time of pipe flow can be derived from flow velocity obtained from the Pipe Flow Nomograph (refer to *Appendix 11*). To follow this procedure, longitudinal sections are required of the piped systems, giving internal pipe diameters, lengths, and gradients.

For preliminary calculations, if there is little detail of the final pipe systems, then the typical velocities in Table 21-3 may be used.

Time of Open Channel Flow

The time of flow in an open channel is calculated by means of the Manning equation. Refer to *Chapter 22: Hydraulics*).

If there is insufficient data available to calculate the time of open channel flow, the approximate natural stream velocities given in Table 21-4 can be used.

Table 21-2: Horton's n roughness values for overland flow.

Surface Type	n
Asphalt/concrete	0.010 – 0.012
Bare sand	0.010 - 0.060
Bare clay/loam	0.012 - 0.033
Gravelled surface	0.012 – 0.030
Short grass	0.100 – 0.200
Lawns	0.200 – 0.300
Pasture	0.300 – 0.400
Dense shrubbery	0.400

Figure 21-1: Nomograph for estimating overland sheet flow times. Modified from Miller (1951).

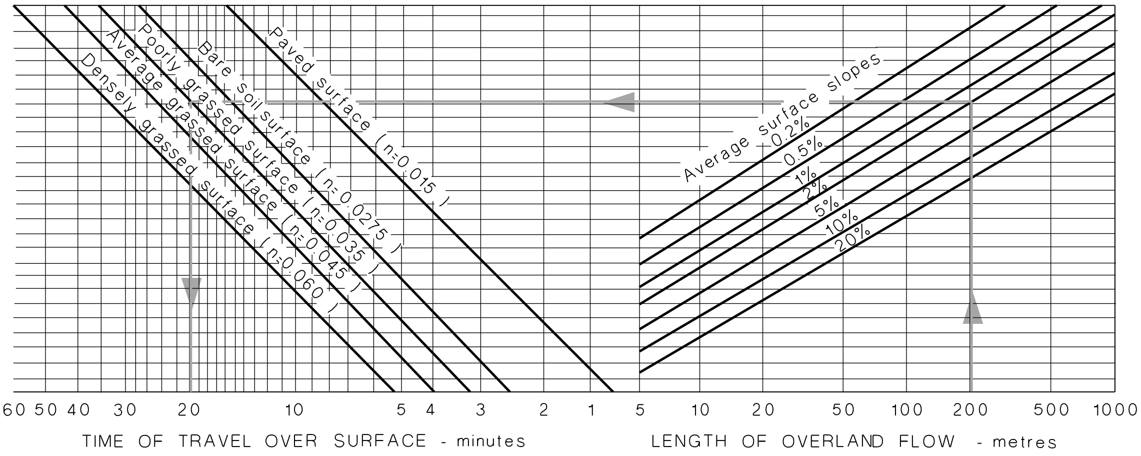


Figure 21-2: Side channel flow time from channel length and slope.

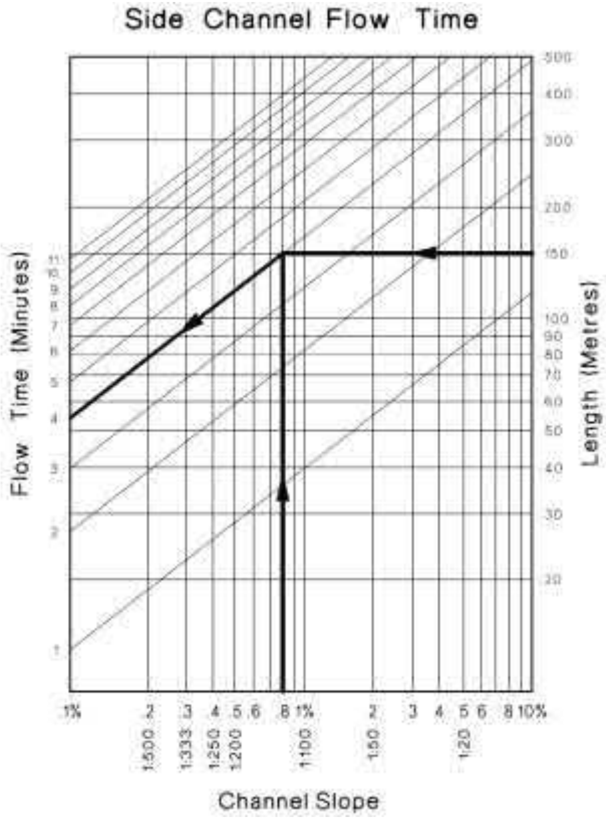


Table 21-3: Typical pipe flow velocities for various gradients.

Gradient	Grade	Typical Velocities (m/s)					
		225Dia	300Dia	375Dia	450Dia	600Dia	750Dia
Flat gradient	1 in 500	0.5	0.6	0.7	0.8	1.0	1.1
	1 in 200	0.8	1.0	1.1	1.3	1.5	1.8
Moderate gradient	1 in 100	1.1	1.4	1.6	1.8	2.2	2.5
	1 in 50	1.6	1.9	2.2	2.5	3.1	3.6
Steep gradient	1 in 20	2.5	3.1	3.5	4.0	4.9	5.6
	1 in 10	3.6	4.3	5.0	5.7	6.9	8.0

Table 21-4: Approximate natural stream velocities.

Catchment Description	Grade	Velocity
Flat	Flat to 1 in 100	0.3 - 1.0 m/s
Moderate Grade	1 in 100 to 1 in 20	0.6 - 2.0 m/s
Hillside	1 in 20 or Steeper	1.5 - 3.0 m/s

21.3.2.4 Rural Channelised Catchments

On hill areas, Time of Concentration ‘T_C’ is taken as the actual time taken for rain to arrive at the point under consideration (i.e. Time of Entry, $T_e = 0$). For larger hill catchments (over 1 km in length), where T_C cannot be computed from side channel and pipe velocities, the Bransby-Williams formula (Ministry of Works and Development 1975) can be used (Eqn (21-4)):

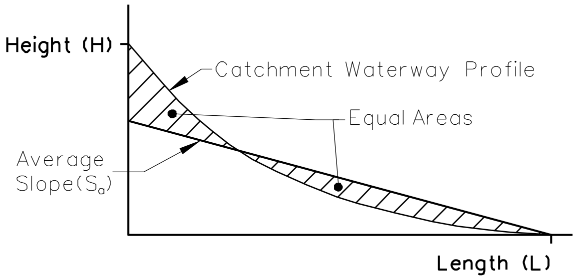
$$T_C \text{ (minutes)} = 14LA^{-0.1} S_a^{-0.2} \qquad \text{Eqn (21-4)}$$

where L = length of catchment in kilometres measured along the flow path

A = catchment area (km^2)

S_a = average slope H/L (metres vertical per metre horizontal, Figure 21-3)

Figure 21-3: Average Slope Definition.



Note the following:

1. Equation (21-4) can only be used where the catchment is fully saturated, and factors such as channel storage causing flow attenuation are low. Resulting Times of Concentration ‘T_c’ are especially low for short duration events in catchments dominated by loess soils.
2. In some catchments, due to shape, surface water network, and the varying permeabilities within the catchment, part of the catchment under consideration may produce a higher peak flow than the whole of the catchment. Although the area for the part catchment is smaller, this may be more than offset by the higher intensity storm associated with a shorter time of concentration and storm duration. This situation will arise where the upper reaches are rural and the lower reaches of a catchment are densely developed.
3. If the actual catchment slope varies significantly from the value H/L (e.g. with a sudden steepening in the upper reaches), the time of concentration shall be determined by evaluating the component travel times for the hillside, and the flat.

21.3.3 Design Rainfall Intensity

For catchments within the size suitable for analysis by the Rational Method (see section 21.1), the storm design duration will be sufficiently low to assume uniform design rainfall intensity across all of Christchurch. However, note this will not be the case for longer durations, or situations where the receiving water is from a much larger catchment. For sites in central Christchurch the assessed storm duration (D) and AEP the design rainfall intensity (i) can be read off the Botanic Gardens Rainfall Intensities Chart (*Appendix 10*).

21.3.4 Peak Runoff Discharge Coefficients

21.3.4.1 General

The runoff coefficient (C) is the ratio of the peak rate of runoff (eg. l/s) to the design storm average rainfall rate (eg. mm/hr/ha). It reflects the effects of catchment imperviousness, infiltration, storage, evaporation, natural retention, interception, etc, which all affect the volume losses and time distribution of the discharge hydrograph in arriving at the peak runoff rate. The runoff coefficient also varies with storm duration, soil type, surface slope, groundwater level, and the extent to which development has extended impervious coverage. Runoff coefficient values to determine peak discharge for various land use types can be obtained from Table 21-5.

Table 21-5: Peak Flow Rate Runoff Coefficients versus AEP

District Zone	***Storm AEP***			
	20%	***10%***	***5%***	***<=2%***
Residential Suburban (RS)	0.38	0.42	0.44	0.47
Residential: Suburban Density Transition (RSDT)	0.47	0.51	0.53	0.56
Residential New Neighbourhoods (RNN) & Residential Medium Density (RMD)	0.56	0.60	0.63	0.65
Business(industrial/commercial)	0.73	0.77	0.79	0.82
Residential Hills (RH)	0.57	0.59	0.60	0.61

21.3.4.2 Rational Method Peak Discharge Calculation

Apply this method if the catchment makeup of pervious and impervious area is typical of that zone.

The runoff coefficient is affected by the intensity of rainfall and the antecedent conditions. Hence, the runoff coefficients given in Table 21-5 are for ground considered already wet from previous rain but not saturated.

The chosen runoff coefficient should be based on realistic conditions that will ultimately exist after full catchment development that is consistent with the Christchurch City Plan zone rules.

Slope Correction

Slope has been allowed for in the runoff coefficients, assuming relatively flat terrain for all zones RS to RMD and Business, and steep for RH.

Soil Type Correction

For Christchurch it has been determined that for the range of soil infiltration types (poor, moderate, free) the effect on runoff coefficient for short duration storms is less than +/- 5% (C +/-0.01). As such it is deemed that no provision for soil type correction is necessary.

21.3.4.3 Background to Discharge Coefficient Derivation

Rational method coefficients for small areas are based on the catchment pervious/impervious makeup for each district zone along with the typical losses that occur during a 30 minute storm event.

Pervious and impervious areas as percentages of total area have been measured for each district zone type in Christchurch. In addition the percentage of each area that contributes runoff has also been assessed. These values are shown in Table 21-6.

Soil infiltration rates are based on the averages that occur into a moderate soil type over 30 minutes. These are shown in Table 21-7.

The ponding (depression storage) losses for pervious and impervious surfaces have been assessed for typical Christchurch surfaces. These are also shown in Table 21-7.

Table 21-6: Zone average effective pervious and impervious area percentages. Refer to the Christchurch District Plan maps, (See Table 21.5 for zone abbreviations).

Table 21-6: Pervious and Impervious Area% and %Contribution

District Zone	*Pervious Area% pv%*	*Pervious Contribution %PvContrib*	*Impervious Area% im%*	*Impervious Contribution %ImContrib*
Residential: RS	50%	30%	50%	90%
Residential: RSDT	35%	25%	65%	90%
Residential: RNN	30%	25%	70%	100%
Residential RMD	20%	25%	80%	100%
Residential: RH	55%	50%	45%	90%
Business (industrial/commercial)	10%	50%	90%	100%

Table 21-7: Zone 30 minute average infiltration rates and ponding losses as used to derive peak runoff coefficients.

Table 21-7: Infiltration and Ponding Losses

District Zone	*Pervious Infiltration mm/hr*	*Pervious Ponding mm*	*Impervious Infiltration mm/hr*	*Impervious Ponding mm*
Residential: RS,RSDT,RNN,RMDT	10	5.0	0	2.5
Business	10	2.5	0	2.5
Residential RH	**5.0**	1.0	0	1.0

21.4 Advanced Analysis

21.4.1 Rainfall Hyetographs

Hyetographs for use in computer catchment modelling can be derived using the HIRDS Version 4 procedure (NIWA (2018) https://hirds.niwa.co.nz/) This allows generation of rainfall depths and intensities for anywhere in New Zealand including Christchurch and Banks Peninsula

HIRDS 4 produces intensity-duration-frequency (IDF) tables which can be used for design storm assessment and in the design of flood protection works and other waterway structures. HIRDS IDF tables can also be used for flood modelling, including flood routing, retention basin design and inundation mapping activities. A spreadsheet containing the site coefficients can be downloaded from the HIRDS website and a formula is provided to allow calculation of a design rainfall for any duration or return interval for the particular site of interest. It also provides adjustments for climate change temperature increases. This procedure has been used in Appendix10 to generate present day (no climate change) design rainfall estimates for the Christchurch Botanic Gardens site.

1) Areal Reduction Factor (ARF) for Rainfall Depth

Design point rainfall depths should be reduced for application to catchment areas. The standard Areal Reduction Factors (ARF) for temperate zone climates were derived by the Natural Environment Research Council (Institute of Hydrology 1975) and recommended for use in New Zealand by Tomlinson (1980) and Pearson (1992). Equations defining the NERC ARF values appear in Kjeldson (2007) as derived by Keers and Westcott (1977). A plot of the Keers and Westcott surface appears in Faulkner (1999). This differs slightly from the original NERC 1975 plot but the differences are not significant. Kjeldson points out that the original NERC report recommended reanalysis of ARFs once more data became available but as of 2010 this had not been done. A summary of recommended ARF values is shown in Table 21-8.

Table 21-8: Areal Reduction Factors (ARF) for Rainfall Depth.

Area	**Duration (hrs)**								
(km^2)	**0.5**	**1**	**2**	**4**	**6**	**12**	**24**	**48**	**96**
1	0.95	0.96	0.97	0.98	0.98	0.98	0.99	0.99	0.99
2	0.94	0.95	0.96	0.97	0.97	0.98	0.98	0.99	0.99
5	0.91	0.93	0.95	0.96	0.96	0.97	0.98	0.98	0.99
10	0.88	0.91	0.93	0.95	0.95	0.97	0.97	0.98	0.98
20	0.85	0.89	0.91	0.93	0.94	0.96	0.97	0.97	0.98
50	0.79	0.84	0.88	0.91	0.92	0.94	0.96	0.97	0.97
100	0.74	0.80	0.85	0.89	0.90	0.93	0.94	0.96	0.97
200	0.68	0.76	0.82	0.86	0.88	0.91	0.93	0.95	0.96
500	0.60	0.69	0.76	0.82	0.85	0.88	0.91	0.93	0.95

2) Climate Change

HIRDS has assessed the impact of future climate change on extreme rainfall using regional climate model simulations of rainfall over New Zealand. From these simulations, amplification factors that can be applied to depth-duration-frequency tables have been estimated for four different emissions scenarios (RCP 2.6, 4.5, 6.0 and 8.5) and four future time slices. These factors allow estimates of future extreme rainfall intensities to be derived directly from the HIRDS procedure based on those calculated from historical rainfall records.

The temperature increase used in design should depend on the design life of the project. The RCP 8.5 scenario should be used for design of permanent infrastructure and for flood hazard mapping as a conservative approach until such time as it is clear that a lower emission pathway is happening. (see also MfE 2008 and 2017)

3) Final Design Storm Rainfall Depth

The final design storm rainfall is then obtained by multiplying the point estimate rainfall (P) by the areal reduction factor (ARF) equation 21-5.

Design Storm Rainfall (mm) = P * ARF Eqn(21-5)

3) Storm profile

For all storm events a standard dimensionless hyetograph has been adopted, based on historical storm analysis, that is triangular in form, with a peak of twice the average intensity occurring at 0.7 duration (time), as illustrated in Figure 21-6. This integrates to the S-shaped cumulative depth hyetograph shown in Figure 21-7.

Figure 21-6: A standard dimensionless hyetograph for rainfall intensity.

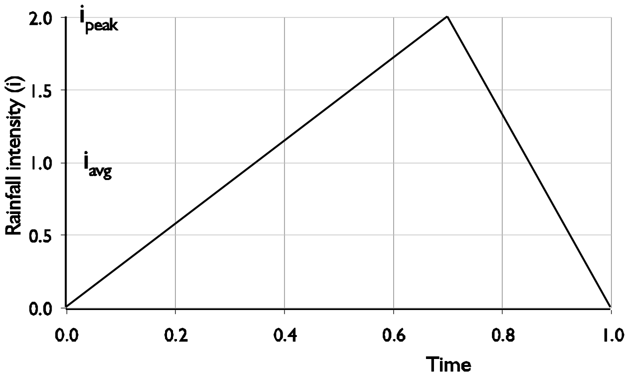
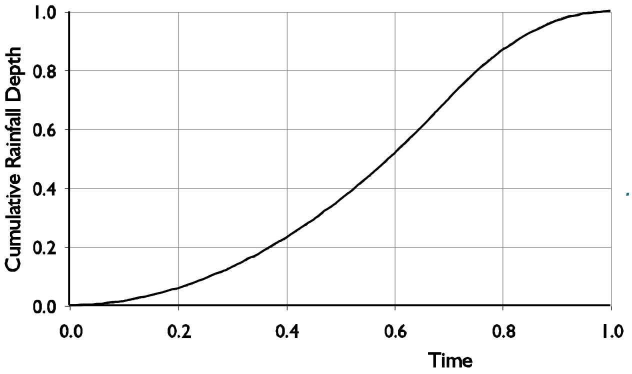


Figure 21-7: A dimensionless cumulative depth hyetograph for rainfall intensity



Rainfall intensity (i) at any time (t) during a storm event of duration (D) can be determined from the following:

$$i_{avg} = RainDepth / D \qquad \text{Eqn (21-6)}$$

$$i_{peak} = 2\, i_{avg} \qquad \text{Eqn (21-7)}$$

For t = 0 to 0.7D

$$i_t = \frac{i_{peak}}{0.7D} t \qquad \text{Eqn (21-8)}$$

For t = 0.7D to D

$$i_t = \frac{i_{peak}}{0.3} (1 - {}^{t}/_{D}) \qquad \text{Eqn (21-9)}$$

21.4.2 Rainfall/Runoff Loss Rates

Infiltration

Computer rainfall/runoff models require an assessment of catchment losses including infiltration and depression storage. Typically the infiltration rate decays with ongoing rain as soil moisture levels increase towards a saturated state. The empirical Horton's equation is often used to simulate this decay using a time based soil specific decay rate parameter ‘k’, an initial infiltration rate ‘f_o’ and an ultimate (end) infiltration rate ‘f_c’. From Horton’s equation (Eqn(21-10)) the infiltration rate ‘f_t’ at time ‘t’ can be determined.

$$f_t = f_c + (f_o - f_c)\, e^{-kt} \qquad \text{Eqn (21-10)}$$

In calibrating a rainfall/runoff model against measured flow refer to Table 21-9, which defines standard soil types, and Table 21-10, which gives typical Christchurch initial and ultimate infiltration rates and typical Horton decay rate derived for the various soil infiltration types described.

Table 21-9: Christchurch standard soil infiltration types

Infiltration Type	***General Soil Description***	***Example Local Soils***
Poor	Poorly drained, low permeability	Taitapu silt loams and Port Hills soils
Moderate	Imperfectly drained, medium permeability	Kaiapoi silt loams
Free	Free draining, high permeability	Waimakariri silt loams

Table 21-10: Christchurch typical and ultimate infiltration rates and Horton decay rates

Infiltration Type	***Initial infiltration rate f_o (mm/hr)***	***Ultimate infiltration rate f_c (mm/hr)***	***Horton decay rate k***	***Approx time to decay to near ultimate (hrs)***
Poor	0 - 5	1.0	1.5E-3	1.5
Moderate	5 - 10	2.5	1E-4	12
Free	10 - 15	5.0	3E-5	36

Note the following:

- The initial infiltration rate ‘f_o’ varies considerably with antecedent wetting and potential storage in upper soil strata which may have ‘freer’ infiltration characteristics than lower strata (eg. topsoil over silt). The lower bound initial rates above typically correspond to wet antecedent catchment conditions which would tend to reduce any upper soil strata storage.
- The ultimate (end) infiltration rate ‘f_c’ is dependent on soil saturation and degree of soil wetting, especially in the deeper soil strata. Determination may require assessment of the properties of deeper strata and also the likelihood and impact of a raised water table during or antecedent to a storm event. This is especially true for longer duration wet winter events.
- The Horton decay rate ‘k’ should be set to a value appropriate to the average catchment soil properties. Note that a value of 1.5E-3 decays to near ultimate in 1.0 to 1.5 hours whereas a decay rate of 3E-5 decays to near ultimate in about 36 hours.
- Sensitivity analyses should be undertaken, particularly where no calibration data is available, to best determine appropriate parameter values and model configuration..
- Consideration should be given to laboratory and field testing to obtain more reliable values.

Application of Horton’s Equation

Horton’s equation is used in two forms known as Standard Horton and Modified Horton.

Standard Horton

Standard Horton’s equation generates an infiltration rate that decays exponentially with time regardless of rainfall rate. *Application:* Valid only where the infiltration rate is less than rainfall rate for the entire storm.

Modified Horton

Modified Horton’s equation stalls the rate of decay such that the cumulative infiltration does not exceed the cumulative rainfall depth. *Application:* Should be used where the initial infiltration rate exceeds the initial rain intensity.

In general it is safer to use modified Horton or to assume wet antecedent conditions with the initial infiltration rate set to not much greater than the ultimate rate.

A more general table of ultimate infiltration rates is included below in Table 21-11

Table 21-11: Soil type ultimate infiltration rates.

USDA Soil Texture Classification	Ultimate infiltration rate (mm/hr)	Infiltration Type
Sand	230	Free
Loamy Sand	60	
Sandy Loam	22	
Loam	13	Moderate
Silt Loam	6.8	
Sandy Clay Loam	3.0	Poor
Clay Loam	2.0	
Silty Clay Loam	2.0	
Sandy Clay	1.2	
Silty Clay	1.0	
Clay	0.6	

21.5 Detention Volume Calculation

Detention volume should be based on detaining longer duration storm events, with the critical duration dependent on the greater receiving catchment. For example all detention facilities within the Heathcote River catchment upstream of the Heathcote/Cashmere Stream confluence, should be sized for a 36 hour 2% AEP design storm event.

In comparison the first flush volume coefficients of Chapter 6 are based on capturing just the runoff from the storm leading edge - typically 25mm depth – which assumes insufficient time for pervious surface contribution. For detention volume determination the critical event that must be allowed for is generally greater than 12 hours by which time most of the surface is likely to be contributing to runoff. The detention volume can be calculated from Equation 21-13.

$$\text{Detention Volume } (m^3) = C_{vol} \text{ x i (mm/hr) x Area (ha) x } 360 \qquad \text{Eqn (21-13)}$$

where ‘C_{vol}’ is from Table 21-13

and ‘i’ is the storm average rainfall intensity for the critical event duration and 2% AEP as per Section 21.4

The volume coefficients vary with surface and sub-surface soil infiltration types. Hence, the underlying ground strata should be checked using either:

- DSIR soil map of Christchurch (Webb et al. 1991)
- City Council borelog information
- On site infiltration testing

Volume coefficient values in Table 21-13 are provided for poor, moderate and free infiltration rates where these are defined in Table 21-9. These are typically greater than those in Table 21-4. Table 6-10 provides coefficients to be used in determining water quality volume or ‘first flush’ (Refer to Chapter 6.4).

Table 21-13: Zone soil infiltration types and Detention Volume Coefficients (C_{vol}) for use in catchments of various soil infiltration types. These coefficients are based on detaining a 36 hour 2% AEP storm event.

District Zone	Infiltration Type	C_{vol}
Residential: RS	Poor	0.51
	Moderate	0.44
	Free	0.44
Residential: RSDT	Poor	0.62
	Moderate	0.58
	Free	0.58
Residential: RNN & RMD	Poor	0.72
	Moderate	0.69
	Free	0.69
Business (industrial/commercial)	Poor	0.91
	Moderate	0.89
	Free	0.89
Residential: RH	Loess	0.60

These coefficients have been derived by subtracting losses from a triangular rain depth hyetograph of peak value 2x mean rain intensity for a 36 hour 50 year event. Losses are based on zone pervious and impervious values combined with excess rainfall based on the typical average infiltration rates for soils of poor, moderate, or free infiltration types along with ponding losses as per Table 21-14. Pervious and impervious area percentages follow Table 21-6.

Table 21-14: District zone average infiltration rates and ponding losses for various soil infiltration types used to derive detention volume coefficients.

Table 21-16: Infiltration and Ponding Losses

District Zone	***Infiltration Type***	***Pervious Infiltration mm/hr***	***Pervious Ponding mm***	***Impervious Infiltration mm/hr***	***Impervious Ponding mm***
Residential:	Poor	2.5	5.0	0	2.5
RS,RSDT,RNN,RMD	Moderate	7.5	5.0	0	2.5
	Free	12.5	5.0	0	2.5
Business	Poor	2.5	2.5	0	2.5
	Moderate	7.5	2.5	0	2.5
	Free	12.5	2.5	0	2.5
Residential RH	Hill	1.5	1.0	0	1.0

21.6 References and further reading

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