

GARDEN ROOF® HYDROLOGY



Project: **CALGARY EXAMPLE - GR15**
CALGARY, AB

Prepared for: City of Calgary

Date: **July 7, 2011**



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STEP 1 of 2: ENTER THE PROJECT INFO

required

PROJECT NAME:

PREPARED FOR:

LOCATION:

OTHER CITY NAME:

RAINFALL TYPE FROM MAP:

GO TO STEP 1A (BELOW MAP)

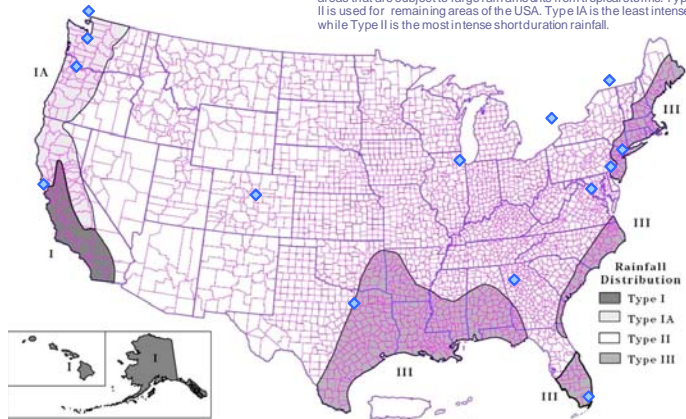
GARDEN ROOF® AREA: SF 90%

'BARE' ROOF AREA: SF 10%

TOTAL ROOF AREA: SF (0.230 ACRES)

NRCS TR55 RAINFALL DISTRIBUTION MAP

Rainfall Types I & IA are for Pacific maritime climate with wet winters & dry summers. Type III is used for the Gulf of Mexico & Atlantic coastal areas that are subject to large rain amounts from tropical storms. Type II is used for remaining areas of the USA. Type IA is the least intense while Type II is the most intense short duration rainfall.



STEP 2 of 2: ENTER GARDEN ROOF SYSTEM INFO

required

LITETOP® MEDIA:

MEDIA DEPTH: INCHES

GARDENDRAIN™:

MOISTURE MAT:

MOISTURE CAPACITY OF VEG: INCHES FOR SEDUMS, 10mm (0.4 inch) PER PENN. STATE UNIV.

The moisture storage capacity of this system is **2.31 inches; the total storage is 1,734 cubic feet (12,973 gallons).**

Analysis A: 24-HR STORMS

Used to compute GR Curve Number, runoff volumes, flow rates, & to size stormwater BMPs req'd by code.

DESIGN STORM:

ROOF SLOPE (as percent):

FLOW PATH LENGTH: FT

ANTECEDENT MOISTURE: INCH

Historic antecedent moisture: #N/A

REFER TO WORKSHEET SERIES 'A'

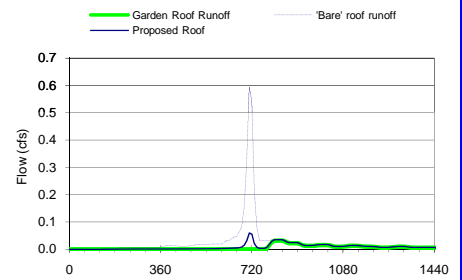
24-HR STORM ANALYSIS RESULTS PREVIEW

Calgary, Ab rainfall type: NRCS Type II

24-hr storms, inch	ENTER PRECIP:
2-YR 2.75	<input type="text" value="2.75"/>
5-YR 4.15	<input type="text" value="4.15"/>
10-YR 5.07	<input type="text" value="5.07"/>
25-YR 6.23	<input type="text" value="6.23"/>
other 3 inch	<input type="text" value="3.00"/>

Calgary Example - Gr15 Roof Curve Number = 73.8

3 inch NRCS Type II - 3.00 INCH STORM HYDROGRAPH



Analysis B: SHORT DURATION STORMS (5 minutes - 120 minutes)

Used to compute the 'C-factor' (runoff coefficient), peak flow rate, and to size pipes & drains.

RECURRENCE: YEAR

DURATION: MINUTES

SEE WORKSHEET B2 FOR DETAILED CALC.

REFER TO WORKSHEET SERIES 'B'

C-FACTOR METHOD:

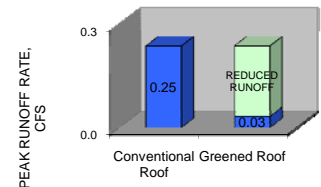
Recommended: Chicago Stormwater Manual

STORM DATA AVAILABLE FOR SF:

User-provided rainfall intensity, inches/hr: USED IN CALC

PEAK FLOW RESULTS PREVIEW

C (composite) = 0.13



Analysis C: ANNUAL & LONG-TERM CONTINUOUS SIMULATION

Used to compute the average annual/monthly runoff & retention¹/ET for the Garden Roof Assembly.

EVAPOTRANSPIRATION CROP FACTOR:

REFER TO WORKSHEET SERIES 'C'

LONG-TERM PERFORMANCE PREVIEW

CALGARY EXAMPLE - GR15: Calgary, AB
AVG ANNUAL PRECIP 19.6 inches

ANNUAL RUNOFF 35%
ANNUAL RETENTION¹ 65%
52% less runoff than a 'bare' roof.

vt_22a

¹Retention = evapotranspiration (ET)

GARDEN ROOF® ASSEMBLY - MOISTURE STORAGE CAPACITY



CALGARY EXAMPLE - GR15 GARDEN ROOF® MEDIA PROPERTIES

A	LITETOP® MEDIA DEPTH	6	INCHES	VANCOUVER EXT (PG)
B	MAX WATER CAPACITY MEDIA	51%		FROM TEST DATA FOR VANCOUVER EXT (PG) MEDIA BLEND
C	MAX WATER CAPACITY	3.09	INCHES	B * A; DIFF. BETWEEN SATURATED & OVEN DRY CONDITIONS
D	WILT POINT	26%		FROM TEST DATA FOR VANCOUVER EXT (PG) MEDIA BLEND
E	AVAIL MEDIA MOISTURE STORAGE	26%		B - D; THIS IS THE AVAILABLE MOISTURE HOLDING CAPACITY

MOISTURE RETENTION CAPACITY OF TOTAL ASSEMBLY

F	MEDIA STORAGE CAPACITY	1.54	INCHES	E * A
G	MOISTURE CAPACITY OF VEG	0.40	INCHES	FOR SEDUMS, 10mm PER PENN. STATE UNIV. RESEARCH
H	GARDENDRAIN™ STORAGE	0.16	INCHES	GR15; FROM TEST DATA, 0.10 gal/sf
I	MOISTURE MAT STORAGE	0.21	INCHES	USED
J	SYSTEM TOTAL STORAGE	2.31	INCHES	F + G + H + I

This is the equivalent depth of water that can be stored over the Garden Roof® area.

The total moisture storage is 1,734 cubic feet (12,973 gallons).

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GARDEN ROOF® ASSEMBLY RUNOFF CURVE NUMBER



THE CALGARY EXAMPLE - GR15 ROOF CONSISTS OF:

GARDEN ROOF® -	9,000 SF
'BARE' ROOF -	1,000 SF
<hr/>	
TOTAL	10,000 SF

A THE GARDEN ROOF CAN HOLD **2.31 INCHES OF MOISTURE** (SYSTEM TOTAL STORAGE - ANTECEDENT RAINFALL)
THE TOTAL MOISTURE STORAGE IS 1,734 CUBIC FEET (12,973 GALLONS).

B THE DESIGN 24-HR STORM IS **3.00 INCHES OF RAINFALL** 3 inch
WHICH IS 2,500 CF (18,703 gallons)

THE GARDEN ROOF RUNOFF IS **0.69 INCHES** (B - A)
C WHICH IS 516 CF (3,859 gallons)

'BARE' ROOF RUNOFF IS **2.77 INCHES BASED ON TR-55 EQUATION 2-2**
D WHICH IS 231 CF (1,726 gallons)

THE TOTAL RUNOFF IS **747 CF (5,585 gallons)** (C + D)
WHICH IS **0.90 INCHES**

WHAT RUNOFF CURVE NUMBER YIELDS 0.90 INCHES OF RUNOFF FROM A 3.00 INCH STORM?

RUNOFF CURVE NUMBER = 73.8 (COMPOSITE GARDEN ROOF® AND 'BARE' AREAS)



¹ LEED for New Construction Version 2.2

LEED SS CREDIT 6.1: Stormwater Design: Quantity Control

STEP 1: Predevelopment Runoff

LEED SS Credit 6.1 requires projects to match or reduce the site runoff.

LEED STORM INFO	One-yr, 24-hr storm	2.00	inch	
	2-yr, 24-hr storm	2.75	inch	
Predev. site impervious area	9,500	sf (95%)	Impervious CN	98
Predev. site pervious area	500	sf (5%)	Pervious CN	74
Predev. site time-of-concentration	6	min	Composite CN	96.8

FROM PROJECT ENGINEER

Predeveloped Site Runoff ² :	Runoff Volume	Peak Rate
One-yr storm	1,375 cf (10,286 gal)	0.60 cfs
2-yr storm	1,992 cf (14,900 gal)	0.87 cfs

² Computed using TR55 graphical method

STEP 2: Determine the LEED SS 6.1 requirement

Is the existing imperviousness less than or equal to 50%? **NO**

LEED requires a 25% decrease in storm runoff rate and volume for the 1- and 2-yr storms:

LEED TARGETS:	Runoff Volume	Peak Rate
One-yr storm	1,031 cf (7,715 gal)	0.45 cfs
2-yr storm	1,494 cf (11,175 gal)	0.65 cfs

STEP 3: Determine the Calgary Example - Gr15 Garden Roof® Runoff

Total roof area: 10,000 sf Garden Roof® portion: 90% Composite CN: 67.2 for one-yr storm
71.6 for 2-yr storm

Developed Site Runoff ² :	Runoff Volume	Peak Rate	Reduction	Does roof achieve LEED 6.1?
One-yr storm	150 cf (1,122 gal)	0.04 cfs	94%	LEED COMPLIANT
2-yr storm	542 cf (4,052 gal)	0.22 cfs	75%	LEED COMPLIANT

² Computed using TR55 graphical method

LEED SS 6.1 CONCLUSION

CALGARY EXAMPLE - GR15 ROOF MEETS LEED 2.2 CREDIT SS 6.1 QUANTITY CONTROL CRITERIA

LEED SS CREDIT 6.2: Stormwater Design: Quality Control

LEED SS Credit 6.2 requires projects to treat 90% of the annual rainfall using acceptable BMPs.

LEED states the size of the storm that must be treated depends on the average annual rainfall.

AVERAGE ANNUAL RAINFALL = 19.6 inches (Arid Watershed)

For this credit, treating 90% of the average annual rainfall is met by treating a storm size 0.50 inch of rainfall

The Calgary Example - Gr15 roof can hold: 2.31 inch of rainfall (from GR moisture storage calc)

LEED SS 6.2 CONCLUSION

CALGARY EXAMPLE - GR15 ROOF MEETS LEED SS CREDIT 6.2 STORMWATER QUALITY CONTROL CRITERIA

TR-55 Worksheet 4: Graphical Peak Discharge Method



Project Calgary example - GR15

Location Calgary, Ab

Condition: **PREDEVELOPED 1-yr** (for Garden Roof[®] LEED calculation)

1. Data

Drainage area	10,000	sf	$A_m =$	0.000359	mi ²
Runoff Curve Number	96.8				
Time of Concentration	6	min	$T_c =$	0.10	hr
Rainfall distribution	II	(I, IA, II, III)			

STORM INFO

2. Frequency, yr	1	
3. Rainfall, P (24 hr)	2.00	
Potential maximum ret., S, in	0.33	From equation 2-4
4. Initial abstraction, I_a , in	0.066	From equation 2-2
5. Compute I_a/P	0.033	
6. Unit peak discharge, q_u , csm/in	1010	Use T_c and I_a/P with Exhibit 4-II
7. Runoff, Q, in	1.65	From equation 2-3
8. Pond & Swamp adjustment factor	1	Per table 4-2; $F_p = 1$ for 0% percent pond & swamp area
9. Peak discharge, Q_p, cfs	0.60	Where $Q_p = q_u A_m Q F_p$

TR-55 Worksheet 4: Graphical Peak Discharge Method



Project Calgary example - GR15

Location Calgary, Ab

Condition: **PREDEVELOPED 2-yr** (for Garden Roof[®] LEED calculation)

1. Data

Drainage area	10,000	sf	$A_m =$	0.000359	mi ²
Runoff Curve Number	96.8				
Time of Concentration	6	min	$T_c =$	0.10	hr
Rainfall distribution	II	(I, IA, II, III)			

STORM INFO

2. Frequency, yr	2	
3. Rainfall, P (24 hr)	2.75	
Potential maximum ret., S, in	0.33	From equation 2-4
4. Initial abstraction, I_a , in	0.066	From equation 2-2
5. Compute I_a/P	0.024	
6. Unit peak discharge, q_u , csm/in	1010	Use T_c and I_a/P with Exhibit 4-II
7. Runoff, Q, in	2.39	From equation 2-3
8. Pond & Swamp adjustment factor	1	Per table 4-2; $F_p = 1$ for 0% percent pond & swamp area
9. Peak discharge, Q_p, cfs	0.87	Where $Q_p = q_u A_m Q F_p$



THE PROPOSED CALGARY EXAMPLE - GR15 ROOF CONSISTS OF:

GARDEN ROOF® -	9,000 SF
'BARE' ROOF -	1,000 SF
TOTAL	10,000 SF

A THE GARDEN ROOF® CAN HOLD .. **2.31 INCHES OF MOISTURE (SEE 'GR STORAGE' CALC.)**

ONE-YEAR STORM CURVE NUMBER CALCULATION

B THE DESIGN 24-HR STORM IS **2.00 INCHES OF RAINFALL**

THE GARDEN ROOF® RUNOFF IS . **0.00 INCHES (B - A)**
 C WHICH IS - CF (gallons)

'BARE' ROOF RUNOFF IS **1.77 INCHES PER TR-55 EQUATION 2-2**
 D WHICH IS **148 CF (1,106 gallons)**

THE TOTAL RUNOFF IS **148 CF (1,106 gallons) (C + D)**
 WHICH IS **0.18 INCHES**

WHAT RUNOFF CURVE NUMBER YIELDS 0.18 INCHES OF RUNOFF FROM A 2.00 INCH STORM?

1-YR STORM CURVE NUMBER = 67.2 (COMPOSITE GARDEN ROOF® AND 'BARE' AREAS)

TWO-YEAR STORM CURVE NUMBER CALCULATION

E THE DESIGN 24-HR STORM IS **2.75 INCHES OF RAINFALL**

THE GARDEN ROOF® RUNOFF IS . **0.44 INCHES (E - A)**
 F WHICH IS **328 CF (2,456 gallons)**

'BARE' ROOF RUNOFF IS **2.52 INCHES PER TR-55 EQUATION 2-2**
 G WHICH IS **210 CF (1,571 gallons)**

THE TOTAL RUNOFF IS **538 CF (4,027 gallons) (F + G)**
 WHICH IS **0.65 INCHES**

WHAT RUNOFF CURVE NUMBER YIELDS 0.65 INCHES OF RUNOFF FROM A 2.75 INCH STORM?

2-YR STORM CURVE NUMBER = 71.6 (COMPOSITE GARDEN ROOF® AND 'BARE' AREAS)

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TR-55 Worksheet 4: Graphical Peak Discharge Method



Project Calgary example - GR15

Location Calgary, Ab

Condition: **DEVELOPED 1-yr** (for Garden Roof[®] LEED calculation)

1. Data

Drainage area	10,000	sf	$A_m =$	0.000359	mi ²
Runoff Curve Number	67.2				
Time of Concentration	6	min	$T_c =$	0.10	hr
Rainfall distribution	II	(I, IA, II, III)			

STORM INFO

2. Frequency, yr	1	
3. Rainfall, P (24 hr)	2.00	
Potential maximum ret., S, in	4.88	From equation 2-4
4. Initial abstraction, I_a , in	0.976	From equation 2-2
5. Compute I_a/P	0.488	
6. Unit peak discharge, q_u , csm/in	552	Use T_c and I_a/P with Exhibit 4-II
7. Runoff, Q, in	0.18	From equation 2-3
8. Pond & Swamp adjustment factor	1	Per table 4-2; $F_p = 1$ for 0% percent pond & swamp area
9. Peak discharge, Q_p, cfs	0.04	Where $Q_p = q_u A_m Q F_p$

TR-55 Worksheet 4: Graphical Peak Discharge Method



Project Calgary example - GR15

Location Calgary, Ab

Condition: **DEVELOPED 2-yr** (for Garden Roof[®] LEED calculation)

1. Data

Drainage area	10,000	sf	$A_m =$	0.000359	mi ²
Runoff Curve Number	71.6				
Time of Concentration	6	min	$T_c =$	0.10	hr
Rainfall distribution	II	(I, IA, II, III)			

STORM INFO

2. Frequency, yr	2	
3. Rainfall, P (24 hr)	2.75	
Potential maximum ret., S, in	3.97	From equation 2-4
4. Initial abstraction, I_a , in	0.794	From equation 2-2
5. Compute I_a/P	0.289	
6. Unit peak discharge, q_u , csm/in	940	Use T_c and I_a/P with Exhibit 4-II
7. Runoff, Q, in	0.65	From equation 2-3
8. Pond & Swamp adjustment factor	1	Per table 4-2; $F_p = 1$ for 0% percent pond & swamp area
9. Peak discharge, Q_p, cfs	0.22	Where $Q_p = q_u A_m Q F_p$

GARDEN ROOF® 24-HR STORM ANALYSES



CALGARY EXAMPLE - GR15 BEFORE GREENING VS. AFTER GREENING

3 INCH NRCS TYPE II - 3.00 INCH STORM HYDROGRAPH

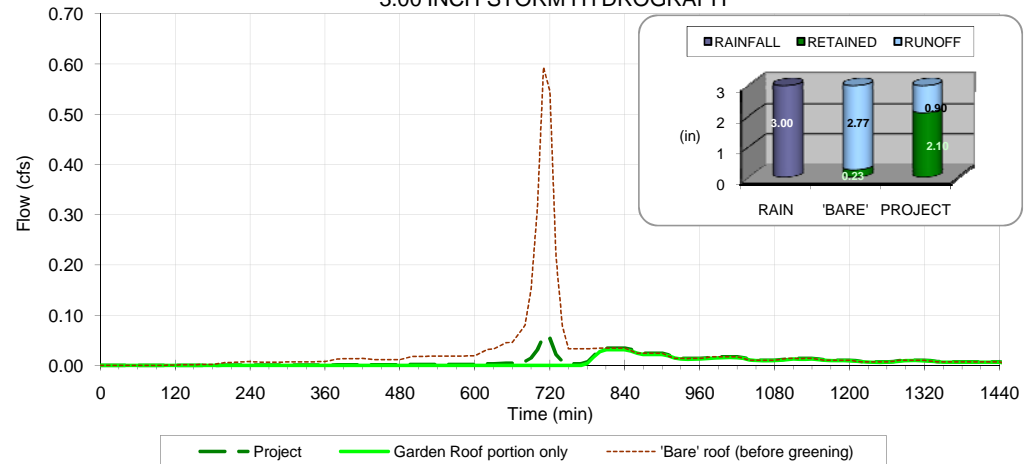
Roof Greening Scenario:	American Hydrotech Garden Roof® Model ¹						NRCS TR-55 model ⁴		Rainfall Retained (in)
	Roof Runoff Rate (cfs)	Stormwater Model Used ²	Time of Peak (min)	Runoff Volume (cf)	Runoff Volume (gal)	Runoff Volume (inches)	Effective Curve Number ³	Peak Runoff Rate ¹ (cfs)	
'Bare' roof" (before greening) (10,000 sf)	0.59	SBUH	710	2,307	17,258	2.77	98.0	1.0	0.23
Calgary Example - Gr15 Roof (10,000 sf)	0.06	WBM/PULS & SBUH	710	747	5,585	0.90	73.8	0.3	2.10
Calgary Example - Gr15 Roof vs 'bare' roof:	REDUCES RATE 90%				REDUCES RUNOFF VOLUME 68%		See note 4	REDUCES TR55 RATE 69%	ROOF RETAINS 9.1 TIMES MORE RAIN

Calgary Example - Gr15 Roof Subareas	Roof Runoff Rate (cfs)	Stormwater Model Used ²	Time of Peak (min)	Runoff Volume (cf)	Runoff Volume (gal)	Runoff Volume (inches)	Effective Curve Number ³	Rainfall Retained (in)
Garden Roof® portion (90%) (9,000 sf)	0.03	WBM/PULS	810	516	3,859	0.69	69.4	2.31
Unvegetated portion (10%) (1,000 sf)	0.06	SBUH	710	231	1,726	2.77	98.0	0.23

Notes:

- American Hydrotech's Garden Roof Model was developed to simulate 24-hr storm runoff for projects incorporating American Hydrotech's Garden Roof Assembly. Calculations are based on tested Garden Roof components. The roof hydrograph, rate, & volume are synthesized from separate Garden Roof and 'bare' roof analyses. Non-roof project areas are not included.
- American Hydrotech's Garden Roof Model uses the Santa Barbara Urban Hydrograph (SBUH) method for 'bare' roof runoff simulation. The Garden Roof surfaces are modeled using a water balance model (WBM) that accounts for the tested site-specific LiteTop media blend & depth, the GardenDrain & moisture mat, site rainfall & antecedent rainfall, and roof dimensions. Excess moisture (that becomes storm runoff) is routed using the PULS method.
- Effective curve numbers will yield the GR assembly runoff volume (based on tested moisture retention properties) from the selected design storm, per TR-55 equation 2-3.
- TR-55 is a widely used set of procedures to calculate storm runoff developed by the U.S. Natural Resources Conservation Service (NRCS). Peak Runoff was computed using the TR-55 Graphical Peak Discharge Method. These computations may be used as an alternative to the Garden Roof Model.

3.00 INCH STORM HYDROGRAPH



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TR-55 Worksheet 4: Graphical Peak Discharge Method



Project Calgary example - GR15

Location Calgary, Ab

Condition: **'Bare' roof (pre- greening)**

1. Data

Drainage area	10,000 sf	$A_m =$	0.000359	mi^2
Runoff Curve Number	98			
Time of Concentration	6 min	$T_c =$	0.10 hr	
Rainfall distribution	II	(I, IA, II, III)		

STORM INFO

2. Frequency, yr	3 inch	
3. Rainfall, P (24 hr)	3.00	
Potential maximum ret., S, in	0.20	From equation 2-4
4. Initial abstraction, I_a , in	0.041	From equation 2-2
5. Compute I_a/P	0.014	
6. Unit peak discharge, q_u , csm/in	1010	Use T_c and I_a/P with Exhibit 4-II
7. Runoff, Q, in	2.77	From equation 2-3
8. Pond & Swamp adjustment factor	1	Per table 4-2; $F_p = 1$ for 0% percent pond & swamp area
9. Peak discharge, Q_p, cfs	1.00	Where $Q_p = q_u A_m Q F_p$

TR-55 Worksheet 4: Graphical Peak Discharge Method



Project Calgary example - GR15

Location Calgary, Ab

Condition: **CALGARY EXAMPLE - GR15 ROOF**

1. Data

Drainage area	10,000 sf	$A_m =$	0.000359	mi^2
Runoff Curve Number	73.8			
Time of Concentration	6 min	$T_c =$	0.10 hr	
Rainfall distribution	II	(I, IA, II, III)		

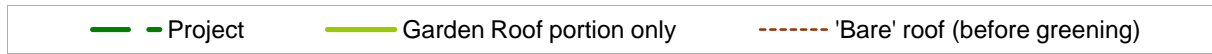
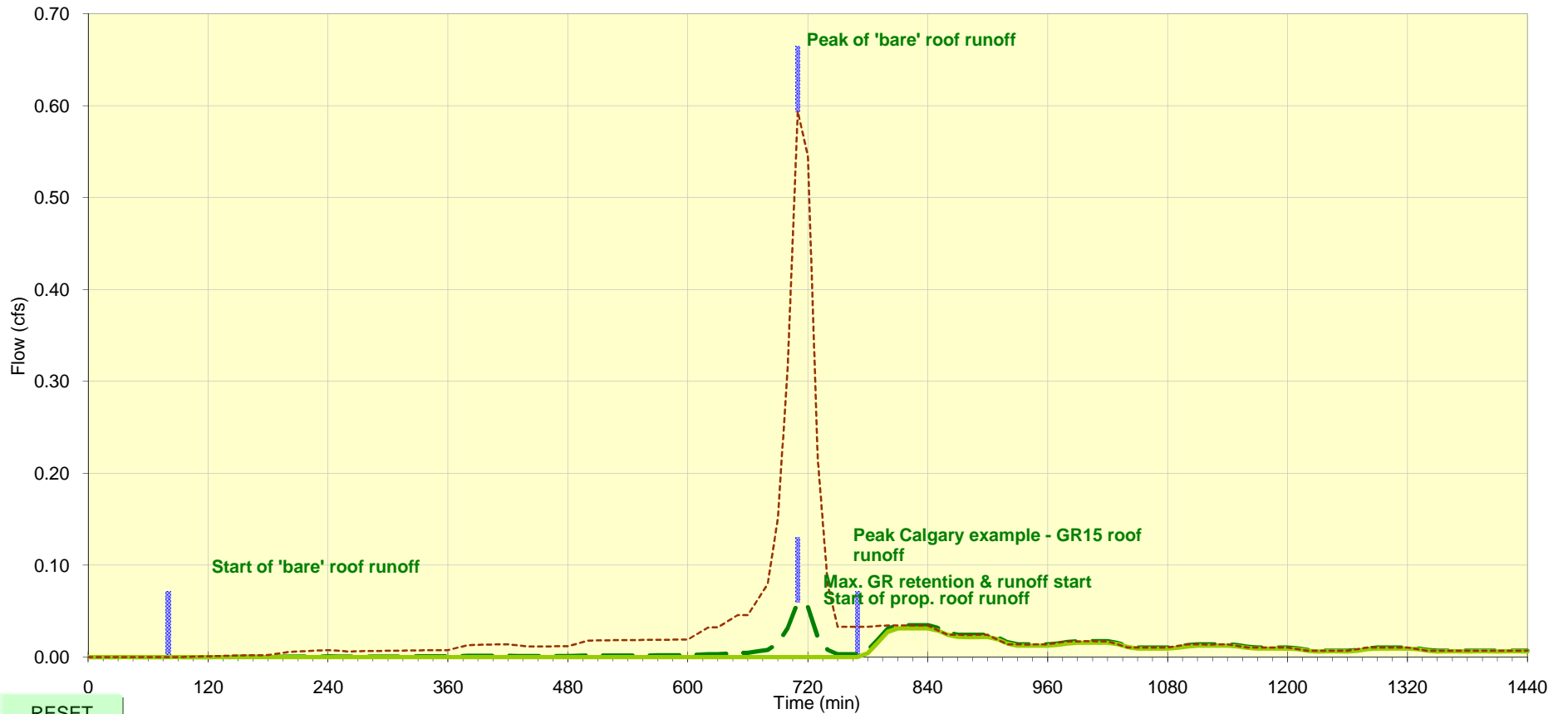
STORM INFO

2. Frequency, yr	3 inch	
3. Rainfall, P (24 hr)	3.00	
Potential maximum ret., S, in	3.56	From equation 2-4
4. Initial abstraction, I_a , in	0.712	From equation 2-2
5. Compute I_a/P	0.237	
6. Unit peak discharge, q_u , csm/in	959	Use T_c and I_a/P with Exhibit 4-II
7. Runoff, Q, in	0.90	From equation 2-3
8. Pond & Swamp adjustment factor	1	Per table 4-2; $F_p = 1$ for 0% percent pond & swamp area
9. Peak discharge, Q_p, cfs	0.31	Where $Q_p = q_u A_m Q F_p$

CALGARY EXAMPLE - GR15 BEFORE GREENING VS. AFTER GREENING



3 INCH NRCS TYPE II - 3.00 INCH STORM HYDROGRAPH



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GARDEN ROOF® PEAK FLOW CALCULATOR



CALGARY EXAMPLE - GR15 INFORMATION

GARDEN ROOF® AREA: 9,000 SF
 TOTAL ROOF AREA: 10,000 SF

DESIGN PEAK-RATE STORM EVENT

RECURRENCE: 2 YEAR
 DURATION: 60 MINUTES

PEAK FLOW CALCULATION (RATIONAL METHOD):

CALGARY EXAMPLE - GR15 ROOF

Q = peak runoff rate (cfs) = C * I * A

Garden Roof® Assembly
 C = runoff coefficient = 0.05 Refer to Worksheet B2 for C-factor derivation

Un-greened portion of roof
 C = runoff coefficient =

TOTAL ROOF $C_{\text{composite}} = 0.13$

I = rain intensity = 1.20 in/hr
 A = area = 0.23 acre

Q = 0.03 cfs (15 gpm) No runoff predicted; minimum C value 0.05 assign

COMPARISON CONVENTIONAL 'BARE' ROOF

Q = C * I * A

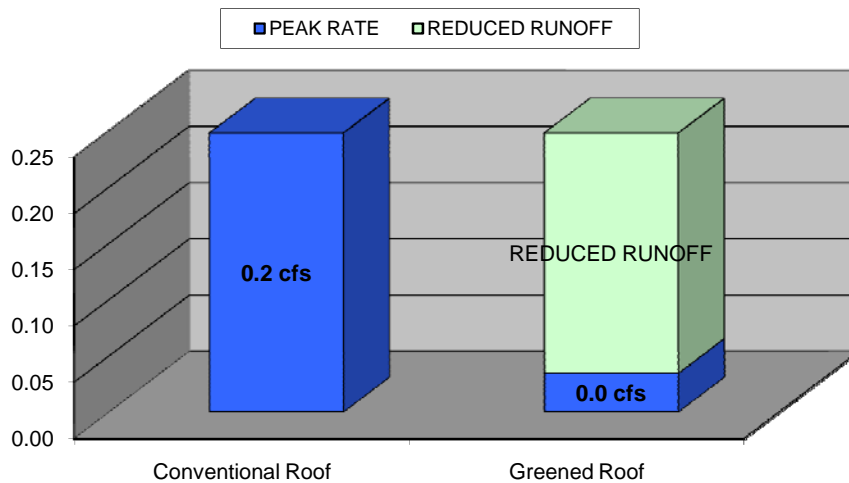
C = runoff coefficient =

I = 1.20 in/hr
 A = 0.23 acre

Q = 0.25 cfs (111 gpm)

Notes:
 cfs = cubic feet per second
 gpm = gallons per minute
 1 acre = 43,560 sf
 1 cfs = 448.8 gpm
 Runoff coef. C is also called the 'C-factor'

ROOF RUNOFF RATE FOR 2-YR 60-MINUTE STORM



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GARDEN ROOF® RUNOFF COEFFICIENT CALCULATION



Surface infiltration rate of Garden Roof® LiteTop® media:
The moisture storage capacity of this system is

79.9 inches/hr FROM LITETOP® MEDIA TEST DATA
2.31 inches; the total storage is 1,734 cubic feet (12,973 gallons).

INTENSITY-DURATION-FREQUENCY DATA*					SURFACE RUNOFF ²		INFILTRATION & SEEPAGE ³					TOTAL DISCHARGE		
Return	Duration	Avg Intensity	Storm volume	Ante-cedent Precip ¹	Surface Runoff rate	surface runoff volume	Garden Roof absorb. Rate	Time to Saturation	retained rainfall	excess rainfall (seepage)	underdrain collection time	Duration that runoff occurs	Total runoff rate ⁴	equiv C runoff coefficient ⁵
	min	inch/hr	inch	inch	inch/hr	inch	inch/hr	min	inch	inch	minutes	minutes	inch/hr	
2-yr							Available storage = 0.83 inches							
	5	1.44	0.12	1.48			1.44	35	0.12		5	5		
	10	1.14	0.19				1.14	44	0.19		5	5		
	15	0.92	0.23				0.92	54	0.23		5	5		
	30	0.66	0.33				0.66	76	0.33		5	5		
	60	0.49	0.49				0.49	102	0.49		5	5		
5-yr							Available storage = 0.93 inches							
	5	2.04	0.17	1.38			2.04	27	0.17		5	5		
	10	1.56	0.26				1.56	36	0.26		5	5		
	15	1.28	0.32				1.28	44	0.32		5	5		
	30	0.94	0.47				0.94	60	0.47		5	5		
	60	0.69	0.69				0.69	81	0.69		5	5		
10-yr							Available storage = 2.30 inches							
	5	2.40	0.20	0.01			2.40	58	0.20		5	5		
	10	1.86	0.31				1.86	74	0.31		5	5		
	15	1.52	0.38				1.52	91	0.38		5	5		
	30	1.12	0.56				1.12	123	0.56		5	5		
	60	0.82	0.82				0.82	168	0.82		5	5		
25-yr							Available storage = 2.30 inches							
	5	2.88	0.24	0.01			2.88	48	0.24		5	5		
	10	2.28	0.38				2.28	61	0.38		5	5		
	15	1.84	0.46				1.84	75	0.46		5	5		
	30	1.34	0.67				1.34	103	0.67		5	5		
	60	0.99	0.99				0.99	139	0.99		5	5		

* Intensity-duration-frequency data for SF

Notes:

- See table (right) for antecedent moisture estimated for the proposed Garden Roof using continuous hydrologic modeling.
- Surface runoff occurs when the rainfall rate exceeds the surface infiltration rate.
- The Garden Roof absorbs rainfall at the lesser of the rainfall rate or the surface infiltration rate. The saturation time is based on the absorption rate and media storage available. Retained rainfall is the difference in the system moisture storage capacity and the antecedent precipitation that is held in the media. Excess rainfall is the difference in the total rainfall and the retained rainfall. Drainage collection time is assumed to be 5 minutes for typical size roof catchments. The duration that runoff occurs begins when seepage occurs and is the sum of the remaining storm duration and the underdrain flow time.
- The total runoff rate, expressed as an equivalent intensity for the Garden Roof area, is computed as the total surface runoff volume and excess rainfall (seepage) amounts divided by the total duration that water is flowing.
- The equivalent Rational Method runoff coefficient 'C', calculated as the ratio of total runoff intensity to rainfall intensity.

ANTECEDENT RAINFALL		Precipitation totals for SF	
recurrence, yr	24-hr	Soil AMC from model	
2	2.40	1.48	
5	2.90	1.38	
10	3.30	0.01	
25	3.60	0.01	

GARDEN ROOF ANNUAL AVG. & LONG-TERM HYDROLOGY



CALGARY EXAMPLE - GR15

SIMULATION PERIOD: 1970 - 1995
LOCATION¹: Calgary, AB
ET¹ CROP FACTOR: P.S.U. - sedum/succulents
GARDEN ROOF[®] AREA: 9,000 sf
TOTAL ROOF AREA: 10,000 sf

PROJECT GARDEN ROOF[®] BENEFIT
AVG ANNUAL PRECIP 19.6 inches
ANNUAL RUNOFF 35% 6,667 cf
ANNUAL RETENTION (ET¹) 65% 9,679 cf
52% less runoff than a 'bare' roof.

¹ Historic climate data from SAN FRANCISCO, CA used for these calculations

¹ ET = evapotranspiration

YEAR	GARDEN ROOF [®] (100% coverage)				'BARE' ROOF (at 100%)		PROJECT ROOF (90% GR)		
	PRECIP (IN)	RUNOFF (IN)	ET ¹ (IN)	RUNOFF/ RAINFALL	RUNOFF ² , IN	ET, IN	RUNOFF (IN)	ET (IN)	RUNOFF/ RAINFALL
1970	18.8	9.3	9.5	50%	16.1	2.7	10.0	8.8	53%
1971	18.7	6.6	12.1	35%	16.0	2.7	7.6	11.1	40%
1972	8.6	0.0	8.6	0%	7.4	1.3	0.7	7.9	9%
1973	31.1	16.2	14.9	52%	26.6	4.5	17.2	13.8	55%
1974	24.9	8.5	16.4	34%	21.3	3.6	9.8	15.1	39%
1975	18.3	5.0	13.3	27%	15.6	2.7	6.1	12.2	33%
1976	8.3	0.0	8.3	0%	7.1	1.2	0.7	7.6	9%
1977	10.9	2.0	8.9	18%	9.3	1.6	2.7	8.2	25%
1978	29.5	12.9	16.7	44%	25.3	4.3	14.1	15.4	48%
1979	18.4	6.4	12.0	35%	15.8	2.7	7.4	11.1	40%
1980	24.8	11.0	13.9	44%	21.2	3.6	12.0	12.8	48%
1981	14.4	3.7	10.7	26%	12.3	2.1	4.6	9.8	32%
1982	34.7	18.1	16.6	52%	29.7	5.0	19.2	15.5	55%
1983	37.3	19.2	18.0	52%	31.9	5.4	20.5	16.8	55%
1984	16.5	6.1	10.5	37%	14.1	2.4	6.9	9.7	42%
1985	17.0	2.6	14.4	15%	14.6	2.5	3.8	13.2	22%
1986	24.5	11.3	13.2	46%	20.9	3.5	12.2	12.2	50%
1987	10.3	1.0	9.2	10%	8.8	1.5	1.8	8.4	18%
1988	14.4	3.0	11.4	21%	12.3	2.1	3.9	10.5	27%
1989	15.0	0.9	14.1	6%	12.8	2.2	2.1	12.9	14%
1990	10.8	0.0	10.8	0%	9.3	1.6	0.9	9.9	9%
1991	13.6	2.9	10.7	21%	11.6	2.0	3.7	9.8	28%
1992	18.0	5.6	12.5	31%	15.4	2.6	6.5	11.5	36%
1993	26.7	13.7	13.0	51%	22.8	3.9	14.7	12.1	55%
1994	14.9	3.0	11.8	20%	12.7	2.2	4.0	10.9	27%
1995	29.5	13.6	15.9	46%	25.2	4.3	14.8	14.7	50%
AVERAGE	19.6	7.0	12.6	30%	16.8	2.8	8.0	11.6	35%
MAXIMUM	37.3	19.2	18.0	52%	31.9	5.4	20.5	16.8	55%
MINIMUM	8.3	0.0	8.3	0%	7.1	1.2	0.7	7.6	9%

YEAR	GARDEN ROOF [®] (100% coverage)				'BARE' ROOF (at 100%)		PROJECT ROOF (90% GR)		
	RAINFALL	RUNOFF	ET ¹ (IN)	RUNOFF/ RAINFALL	RUNOFF ² , IN	ET	RUNOFF	ET	RUNOFF/ RAINFALL
October	1.0	0.1	1.0	7%	0.9	0.2	0.2	0.9	15%
November	2.6	0.7	1.9	27%	2.2	0.4	0.8	1.7	33%
December	3.1	0.9	2.2	29%	2.6	0.4	1.1	2.0	35%
January	4.3	2.5	1.7	60%	3.6	0.6	2.7	1.6	62%
February	3.4	1.5	1.9	44%	2.9	0.5	1.7	1.8	48%
March	3.4	1.2	2.3	34%	2.9	0.5	1.4	2.1	39%
April	1.1	0.1	1.0	11%	0.9	0.2	0.2	0.9	18%
May	0.3	0.0	0.3	0%	0.2	0.0	0.0	0.2	9%
June	0.1	0.0	0.1	0%	0.1	0.0	0.0	0.1	9%
July	0.0	0.0	0.0	0%	0.0	0.0	0.0	0.0	9%
August	0.1	0.0	0.1	0%	0.0	0.0	0.0	0.0	9%
September	0.2	0.0	0.2	0%	0.2	0.0	0.0	0.2	9%

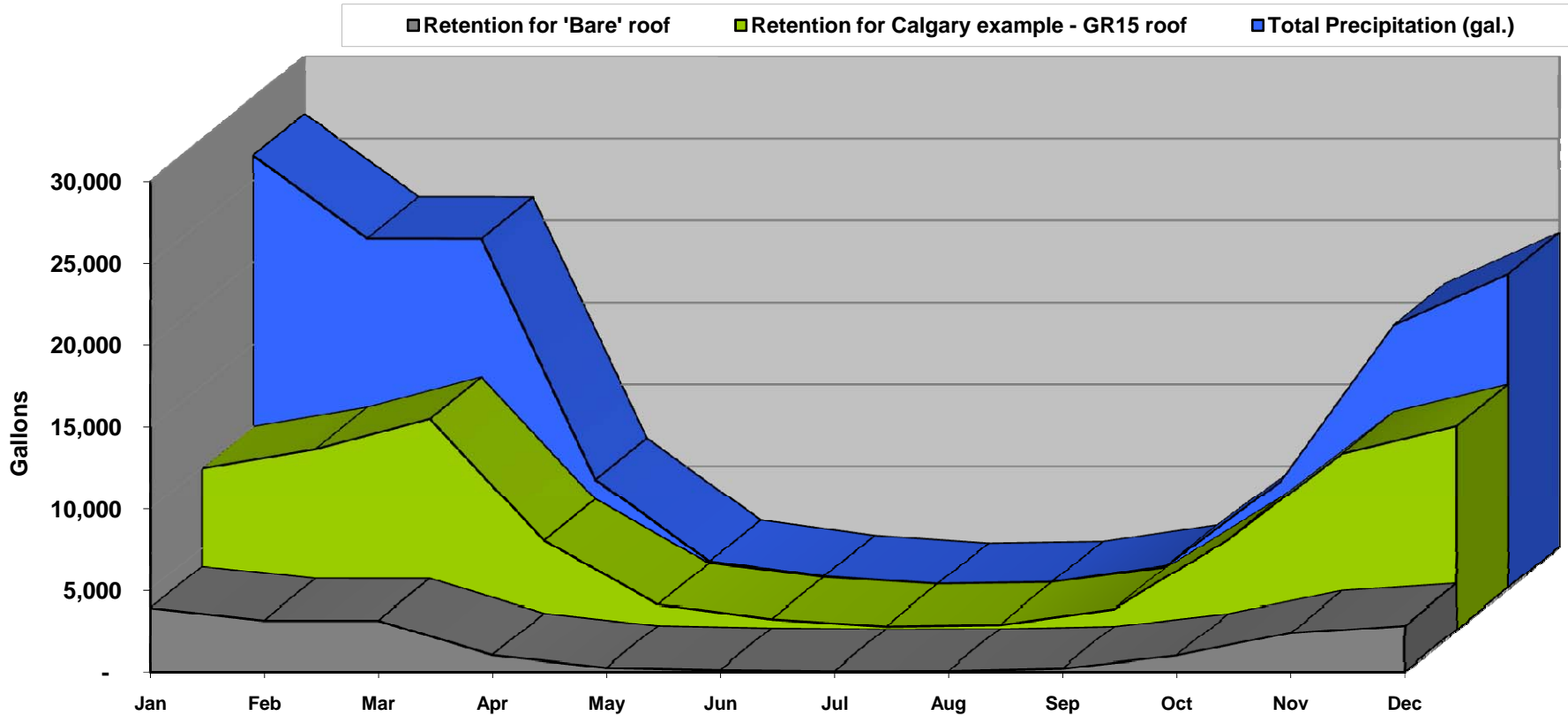
- Note:
 1. ET = evapotranspiration, computed for Garden Roof[®] using the Penman method
 2. 'Bare' roof runoff estimated using the "Simple Method"

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CALGARY EXAMPLE - GR15
 (10,000 sf tot.; GR coverage = 90%)



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LOCATION: Calgary, AB
ET¹ CROP FACTOR: P.S.U. - sedum/succulents
GARDEN ROOF® AREA: 9,000 sf
TOTAL ROOF AREA: 10,000 sf

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