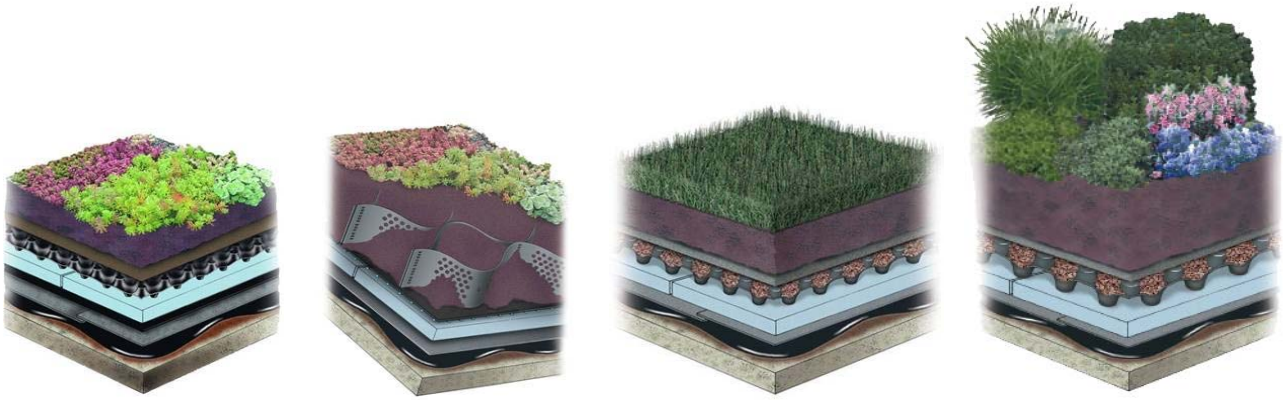
GARDEN ROOF® HYDROLOGY

Project: CALGARY EXAMPLE - GR30

CALGARY, AB

Prepared for: City of Calgary

Date: **July 7, 2011**



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HYDROTECH HYDROLOGY TOOLS

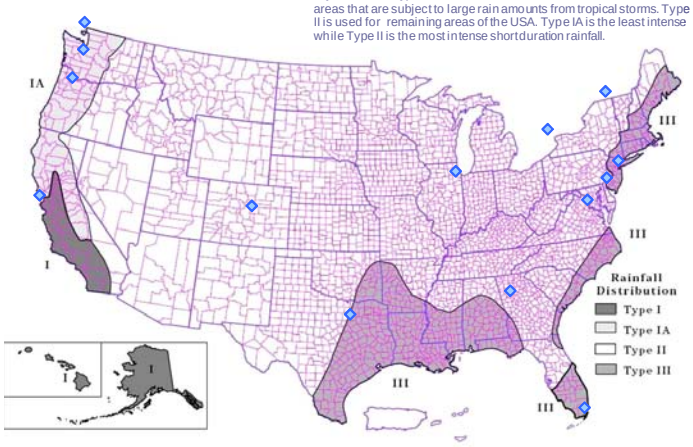
STEP 1 of 2: **ENTER THE PROJECT INFO**

required

PROJECT NAME:	Calgary example - GR30	
PREPARED FOR:	City of Calgary	
LOCATION:	Other	
OTHER CITY NAME:	Calgary, AB	
RAINFALL TYPE FROM MAP:	NRCS Type II	
GO TO STEP 1A (BELOW MAP)		
GARDEN ROOF® AREA:	9,000 SF	90%
'BARE' ROOF AREA:	1,000 SF	10%
TOTAL ROOF AREA:	10,000 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	VANCOUVER INT (PG)	
MEDIA DEPTH	8	INCHES
GARDENDRAIN™	GR30 FILLED	
MOISTURE MAT	USED	
MOISTURE CAPACITY OF VEG	0.4	INCHES FOR SEDUMS, 10mm (0.4 inch) PER PENN. STATE UNIV.

The moisture storage capacity of this system is 2.99 inches; the total storage is 2,240 cubic feet (16,760 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:	3 inch	
ROOF SLOPE (as percent):	2.1%	
FLOW PATH LENGTH:	25	FT
ANTECEDENT MOISTURE:	0.0	INCH
Historic antecedent moisture:	#N/A	

REFER TO WORKSHEET SERIES 'A'

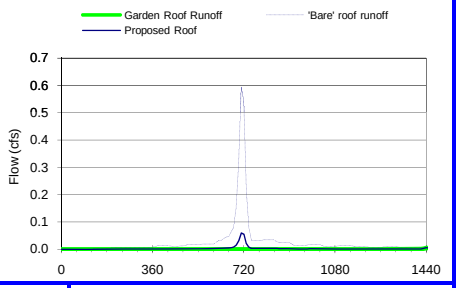
24-HR STORM ANALYSIS RESULTS PREVIEW

Calgary, Ab rainfall type: NRCS Type II

24-hr storms, inch		ENTER PRECIP:
2-YR	2.75	2.75
5-YR	4.15	4.15
10-YR	5.07	5.07
25-YR	6.23	6.23
other 3 inch	3.00	

Calgary Example - Gr30 Roof
Curve Number = 58.5

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:	2	YEAR
DURATION:	60	MINUTES

SEE WORKSHEET B2 FOR DETAILED CALC.

C-FACTOR METHOD: Calculate for specific storm

Recommended: Chicago Stormwater Manual

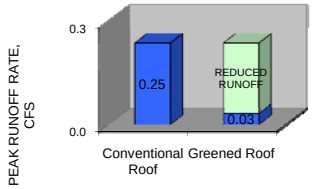
STORM DATA AVAILABLE FOR SF: Enter user value

User-provided rainfall intensity, inches/hr: 1.20 USED IN CALC

REFER TO WORKSHEET SERIES 'B'

PEAK FLOW RESULTS PREVIEW

C (composite) = 0.13



Analysis C: **ANNUAL & LONG-TERM CONTINUOUS SIMULATION**

Used to compute the average annual/monthly runoff & retention[1]/ET for the Garden Roof Assembly.

EVAPOTRANSPIRATION CROP FACTOR: P.S.U. - sedum/succulents

REFER TO WORKSHEET SERIES 'C'

[1]Retention = evapotranspiration (ET)

v1.22a

LONG-TERM PERFORMANCE PREVIEW

CALGARY EXAMPLE - GR30: Calgary, AB

AVG ANNUAL PRECIP	19.6	inches
ANNUAL RUNOFF	32%	
ANNUAL RETENTION[1]	68%	

55% less runoff than a 'bare' roof.

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GARDEN ROOF® ASSEMBLY - MOISTURE STORAGE CAPACITY

CALGARY EXAMPLE - GR30 GARDEN ROOF® MEDIA PROPERTIES

A	LITETOP® MEDIA DEPTH	8	INCHES	VANCOUVER INT (PG)
B	MAX WATER CAPACITY MEDIA	52%		FROM TEST DATA FOR VANCOUVER INT (PG) MEDIA BLEND
C	MAX WATER CAPACITY	4.18	INCHES	B * A; DIFF. BETWEEN SATURATED & OVEN DRY CONDITIONS
D	WILT POINT	26%		FROM TEST DATA FOR VANCOUVER INT (PG) MEDIA BLEND
E	AVAIL MEDIA MOISTURE STORAGE	26%		B - D; THIS IS THE AVAILABLE MOISTURE HOLDING CAPCITY

MOISTURE RETENTION CAPACITY OF TOTAL ASSEMBLY

F	MEDIA STORAGE CAPACITY	*2.09*	INCHES	E * A
G	MOISTURE CAPACITY OF VEG	*0.40*	INCHES	FOR SEDUMS, 10mm PER PENN. STATE UNIV. RESEARCH
H	GARDENDRAIN™ STORAGE	*0.29*	INCHES	GR30 FILLED; FROM TEST DATA, 0.18 gal/sf
I	MOISTURE MAT STORAGE	*0.21*	INCHES	USED
J	**SYSTEM TOTAL STORAGE**	**2.99**	**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 2,240 cubic feet (16,760 gallons).

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GARDEN ROOF® ASSEMBLY RUNOFF CURVE NUMBER

THE CALGARY EXAMPLE - GR30 ROOF CONSISTS OF:

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

A THE GARDEN ROOF CAN HOLD ..... **2.99** INCHES OF MOISTURE (SYSTEM TOTAL STORAGE - ANTECEDENT RAINFALL)
THE TOTAL MOISTURE STORAGE IS 2,240 CUBIC FEET (16,760 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 ..... **0.01** INCHES (B - A)
C WHICH IS 10 CF (73 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 ..... 240 CF (1,799 gallons) (C + D)
WHICH IS 0.29 INCHES

WHAT RUNOFF CURVE NUMBER YIELDS 0.29 INCHES OF RUNOFF FROM A 3.00 INCH STORM?

RUNOFF CURVE NUMBER = 58.5 (COMPOSITE GARDEN ROOF® AND 'BARE' AREAS)

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LEED[1] CREDIT STORM ANALYSES

[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	FROM PROJECT ENGINEER
Predev. site time-of-concentration	6 min	Composite CN	**96.8**	

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 - Gr30 Garden Roof® Runoff**

Total roof area: 10,000 sf Garden Roof® portion: 90% Composite CN: 67.2 for one-yr storm; 60.1 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	208 cf (1,559 gal)	0.05 cfs	94%	LEED COMPLIANT

[2] Computed using TR55 graphical method

LEED SS 6.1 CONCLUSION

CALGARY EXAMPLE - GR30 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 siz 0.50 inch of rainfall

The Calgary Example - Gr30 roof can hold: 2.99 inch of rainfall (from GR moisture storage calc)

LEED SS 6.2 CONCLUSION

CALGARY EXAMPLE - GR30 ROOF MEETS LEED SS CREDIT 6.2 STORMWATER QUALITY CONTROL CRITERIA

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TR-55 Worksheet 4: Graphical Peak Discharge Method

Project Calgary example - GR30

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 $Q_p = q_u A_m Q F_p$

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TR-55 Worksheet 4: Graphical Peak Discharge Method

Project Calgary example - GR30

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 $Q_p = q_u A_m Q F_p$

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GARDEN ROOF® ASSEMBLY: CURVE NUMBERS FOR LEED

THE PROPOSED CALGARY EXAMPLE - GR30 ROOF CONSISTS OF:

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

A THE GARDEN ROOF® CAN HOLD .. **2.99** 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 . **0.00** INCHES (E - A)
F WHICH IS - CF (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 ..... 210 CF (1,571 gallons) (F + G)
WHICH IS 0.25 INCHES

WHAT RUNOFF CURVE NUMBER YIELDS 0.25 INCHES OF RUNOFF FROM A 2.75 INCH STORM?

2-YR STORM CURVE NUMBER = 60.1 (COMPOSITE GARDEN ROOF® AND 'BARE' AREAS)

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TR-55 Worksheet 4: Graphical Peak Discharge Method

Project Calgary example - GR30

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 $Q_p = q_u A_m Q F_p$

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TR-55 Worksheet 4: Graphical Peak Discharge Method

Project Calgary example - GR30

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	60.1				
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	6.63	From equation 2-4
4. Initial abstraction, I_a, in	1.326	From equation 2-2
5. Compute I_a/P	0.482	
6. Unit peak discharge, q_u, csm/in	574	Use T_c and I_a/P with Exhibit 4-II
7. Runoff, Q, in	0.25	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**	**0.05**	Where $Q_p = q_u A_m Q F_p$

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GARDEN ROOF® 24-HR STORM ANALYSES

CALGARY EXAMPLE - GR30 BEFORE GREENING VS. AFTER GREENING

3 INCH NRCS TYPE II - 3.00 INCH STORM HYDROGRAPH

		American Hydrotech Garden Roof® Model[1]						NRCS TR-55 model[4]		
Roof Greening Scenario:		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[4] (cfs)	Rainfall Retained (in)
'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 - Gr30 Roof	(10,000 sf)	0.06	WBM/PULS & SBUH	710	240	1,799	0.29	58.5	0.1	2.71
Calgary Example - Gr30 Roof vs 'bare' roof:		**REDUCES RATE 90%**			**REDUCES RUNOFF VOLUME 90%**			See note 4	**REDUCES TR55 RATE 94%**	**ROOF RETAINS 11.7 TIMES MORE RAIN**

Calgary Example - Gr30 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)	0.00	WBM/PULS	1440	10	73	0.01	43.6	2.99
Unvegetated portion (10%) (1,000 sf)	0.06	SBUH	710	231	1,726	2.77	98.0	0.23

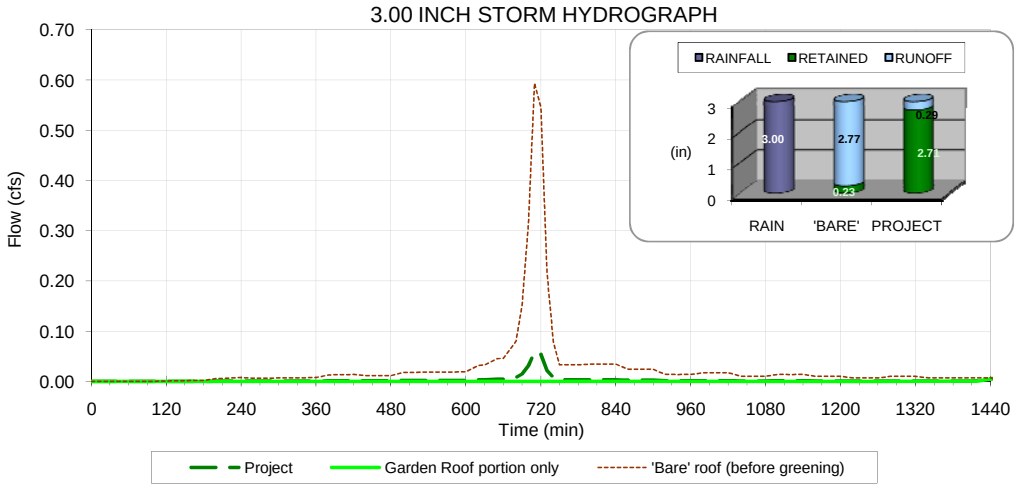
Notes:

1. 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.

2. 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.

3. 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.

4. 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.



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TR-55 Worksheet 4: Graphical Peak Discharge Method

Project Calgary example - GR30

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 $Q_p = q_u A_m Q F_p$

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TR-55 Worksheet 4: Graphical Peak Discharge Method

Project Calgary example - GR30

Location Calgary, Ab

Condition: **CALGARY EXAMPLE - GR30 ROOF**

1. Data

Drainage area	10,000	sf	A_m =	0.000359	mi^2
Runoff Curve Number	58.5				
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	7.09	From equation 2-4
4. Initial abstraction, I_a, in	1.418	From equation 2-2
5. Compute I_a/P	0.473	
6. Unit peak discharge, q_u, csm/in	608	Use T_c and I_a/P with Exhibit 4-II
7. Runoff, Q, in	0.29	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**	**0.06**	Where $Q_p = q_u A_m Q F_p$

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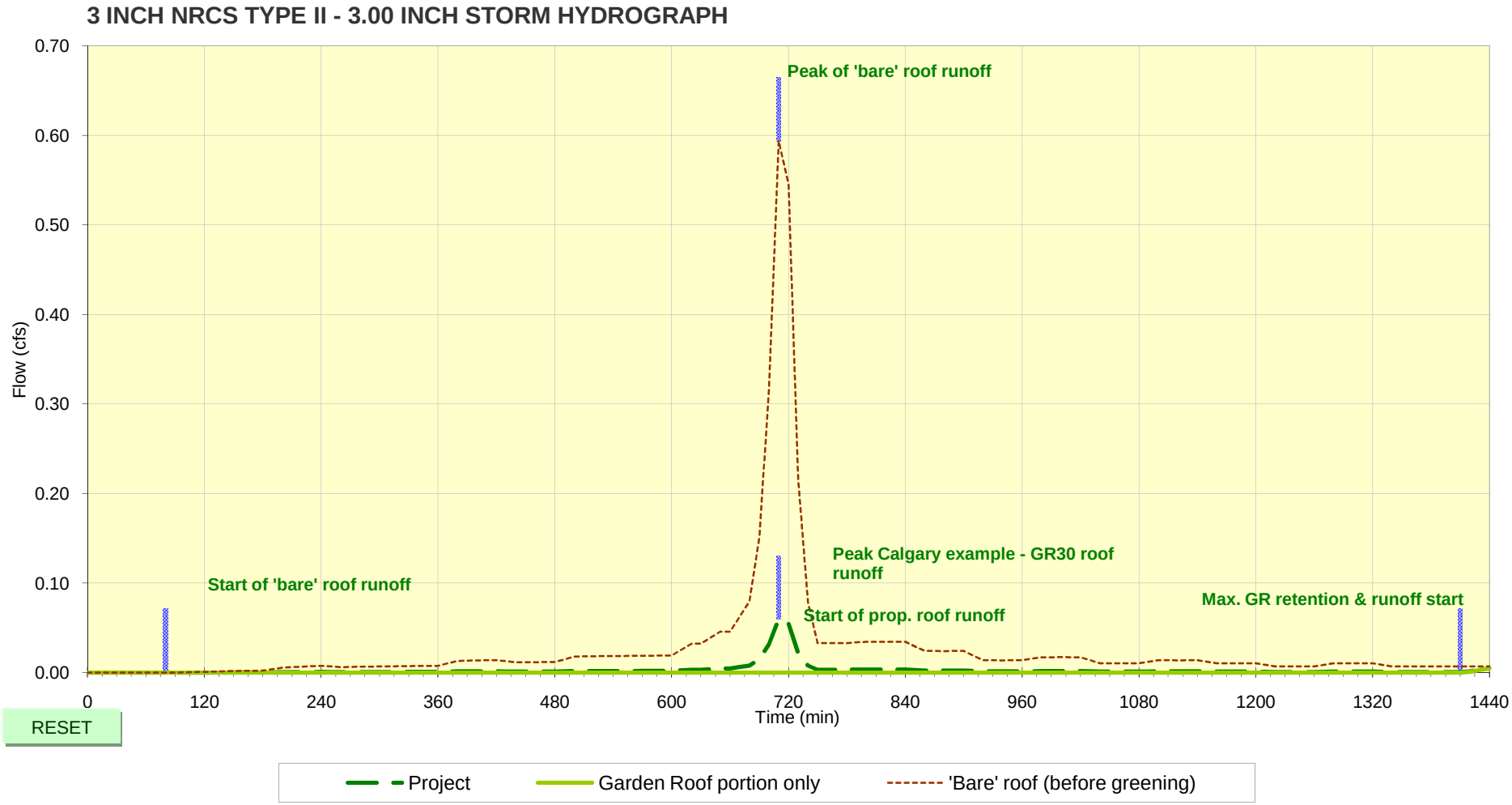
CALGARY EXAMPLE - GR30 BEFORE GREENING VS. AFTER GREENING



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GARDEN ROOF® PEAK FLOW CALCULATOR

CALGARY EXAMPLE - GR30 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 - GR30 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 = 0.80

TOTAL ROOF $C_{composite}$ = **0.13**

I = rain intensity = 1.20 in/hr No runoff predicted; minimum C value 0.05 assigr

A = area = 0.23 acre

Q = 0.03 cfs (15 gpm)

COMPARISON CONVENTIONAL 'BARE' ROOF

Q = C * I * A

C = runoff coefficient = 0.90

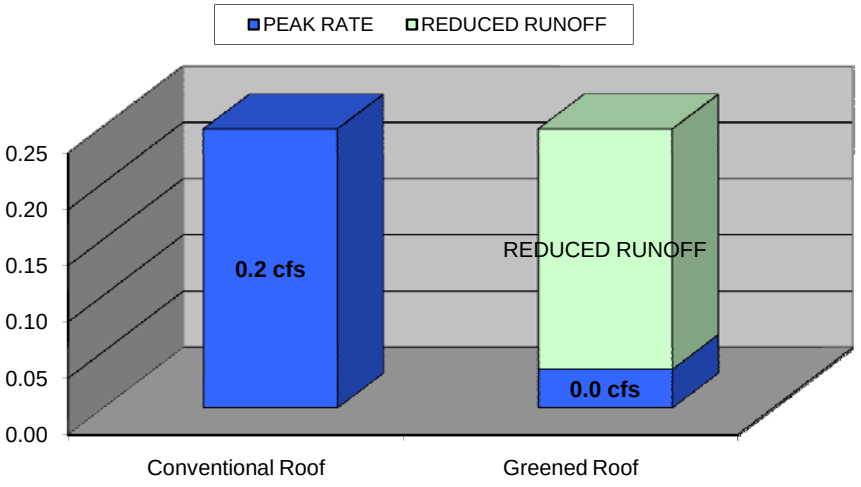
I = 1.20 in/hr

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: 17 inches/hr *FROM LITETOP® MEDIA TEST DATA*

The moisture storage capacity of this system is 2.99 inches; the total storage is 2,240 cubic feet (16,760 gallons).

INTENSITY-DURATION-FREQUENCY DATA*					SURFACE RUNOFF[2]		INFILTRATION & SEEPAGE[3]						TOTAL DISCHARGE	
Return	Duration min	Avg Intensity inch/hr	Storm volume inch	Ante-cedent Precip[1] inch	Surface Runoff rate inch/hr	surface runoff volume inch	Garden Roof absorb. Rate inch/hr	Time to Saturation min	retained rainfall inch	excess rainfall (seepage) inch	underdrain collection time minutes	Duration that runoff occurs minutes	Total runoff rate[4] inch/hr	equiv C runoff coefficient[5]
2-yr				1.90			Available storage = 1.09 inches							
	5	1.44	0.12				1.44	45	0.12		5	5		
	10	1.14	0.19				1.14	57	0.19		5	5		
	15	0.92	0.23				0.92	71	0.23		5	5		
	30	0.66	0.33				0.66	99	0.33		5	5		
	60	0.49	0.49				0.49	133	0.49		5	5		
5-yr				1.83			Available storage = 1.16 inches							
	5	2.04	0.17				2.04	34	0.17		5	5		
	10	1.56	0.26				1.56	45	0.26		5	5		
	15	1.28	0.32				1.28	54	0.32		5	5		
	30	0.94	0.47				0.94	74	0.47		5	5		
	60	0.69	0.69				0.69	101	0.69		5	5		
10-yr				0.01			Available storage = 2.98 inches							
	5	2.40	0.20				2.40	74	0.20		5	5		
	10	1.86	0.31				1.86	96	0.31		5	5		
	15	1.52	0.38				1.52	117	0.38		5	5		
	30	1.12	0.56				1.12	159	0.56		5	5		
	60	0.82	0.82				0.82	218	0.82		5	5		
25-yr				0.01			Available storage = 2.98 inches							
	5	2.88	0.24				2.88	62	0.24		5	5		
	10	2.28	0.38				2.28	78	0.38		5	5		
	15	1.84	0.46				1.84	97	0.46		5	5		
	30	1.34	0.67				1.34	133	0.67		5	5		
	60	0.99	0.99				0.99	180	0.99		5	5		

* Intensity-duration-frequency data for SF

Notes:
1. See table (right) for antecedent moisture estimated for the proposed Garden Roof using continuous hydrologic modeling.
2. Surface runoff occurs when the rainfall rate exceeds the surface infiltration rate.
3. The Garden Roof absorbs rainfall at the lesser of the rainfall rate or the surface infiltration rate. The saturation time is based on the absorbtion 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.
4. 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.
5. The equivalent Rational Method runoff coefficient 'C', calcuated as the ratio of total runoff intensity to rainfall intensity.

ANTECEDENT RAINFALL Precipitation totals for SF

REF: 24-hr precipitation from NOAA ATLAS 2, Volume XI

	Precipitation, inches	
recurrence, yr	24-hr	Soil AMC from model
2	2.40	1.90
5	2.90	1.83
10	3.30	0.01
25	3.60	0.01

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GARDEN ROOF ANNUAL AVG. & LONG-TERM HYDROLOGY

CALGARY EXAMPLE - GR30

SIMULATION PERIOD: 1970 - 1995
LOCATION*: Calgary, AB
ET[1] CROP FACTOR: P.S.U. - sedum/succulents
GARDEN ROOF® AREA: 9,000 sf
TOTAL ROOF AREA: 10,000 sf

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

PROJECT GARDEN ROOF® BENEFIT

AVG ANNUAL PRECIP	19.6	inches
ANNUAL RUNOFF	32%	6,220 cf
ANNUAL RETENTION (ET[1])	68%	10,127 cf

55% less runoff than a 'bare' roof.

[1] ET = evapotranspiration

RESULTS BY YEAR

		GARDEN ROOF® (100% coverage)			'BARE' ROOF (at 100%)		PROJECT ROOF (90% GR)		
YEAR	PRECIP (IN)	RUNOFF (IN)	ET[1] (IN)	RUNOFF/ RAINFALL	RUNOFF[2], IN	ET, IN	RUNOFF (IN)	ET (IN)	RUNOFF/ RAINFALL
1970	18.8	8.6	10.1	46%	16.1	2.7	9.4	9.4	50%
1971	18.7	6.0	12.7	32%	16.0	2.7	7.0	11.7	37%
1972	8.6	0.0	8.6	0%	7.4	1.3	0.7	7.9	9%
1973	31.1	15.5	15.5	50%	26.6	4.5	16.6	14.4	54%
1974	24.9	7.8	17.1	31%	21.3	3.6	9.2	15.7	37%
1975	18.3	4.3	14.0	24%	15.6	2.7	5.5	12.8	30%
1976	8.3	0.0	8.3	0%	7.1	1.2	0.7	7.6	9%
1977	10.9	1.3	9.6	12%	9.3	1.6	2.1	8.8	20%
1978	29.5	12.2	17.3	41%	25.3	4.3	13.5	16.0	46%
1979	18.4	5.8	12.7	31%	15.8	2.7	6.8	11.7	37%
1980	24.8	10.3	14.5	41%	21.2	3.6	11.4	13.4	46%
1981	14.4	3.0	11.3	21%	12.3	2.1	4.0	10.4	28%
1982	34.7	17.4	17.3	50%	29.7	5.0	18.6	16.1	54%
1983	37.3	18.6	18.7	50%	31.9	5.4	19.9	17.4	53%
1984	16.5	5.4	11.1	33%	14.1	2.4	6.3	10.3	38%
1985	17.0	2.0	15.1	11%	14.6	2.5	3.2	13.8	19%
1986	24.5	10.6	13.9	43%	20.9	3.5	11.6	12.9	47%
1987	10.3	0.4	9.9	4%	8.8	1.5	1.2	9.0	12%
1988	14.4	2.3	12.1	16%	12.3	2.1	3.3	11.1	23%
1989	15.0	0.2	14.8	1%	12.8	2.2	1.5	13.5	10%
1990	10.8	0.0	10.8	0%	9.3	1.6	0.9	9.9	9%
1991	13.6	2.2	11.4	16%	11.6	2.0	3.1	10.4	23%
1992	18.0	4.9	13.2	27%	15.4	2.6	5.9	12.1	33%
1993	26.7	13.1	13.6	49%	22.8	3.9	14.0	12.7	53%
1994	14.9	2.4	12.5	16%	12.7	2.2	3.4	11.5	23%
1995	29.5	13.0	16.5	44%	25.2	4.3	14.2	15.3	48%
AVERAGE	**19.6**	**6.4**	**13.2**	**27%**	**16.8**	**2.8**	**7.5**	**12.2**	**32%**
MAXIMUM	37.3	18.6	18.7	50%	31.9	5.4	19.9	17.4	54%
MINIMUM	8.3	0.0	8.3	0%	7.1	1.2	0.7	7.6	9%

AVERAGE MONTHLY RESULTS (ARRANGED AS 'WATER YEAR')

		GARDEN ROOF® (100% coverage)			'BARE' ROOF (at 100%)		PROJECT ROOF (90% GR)		
		(average monthly values in inches)							
YEAR	RAINFALL	RUNOFF	ET[1] (IN)	RUNOFF/ RAINFALL	RUNOFF[2], IN	ET	RUNOFF	ET	RUNOFF/ RAINFALL
October	1.0	0.1	1.0	5%	0.9	0.2	0.1	0.9	13%
November	2.6	0.5	2.1	20%	2.2	0.4	0.7	1.9	26%
December	3.1	0.7	2.3	24%	2.6	0.4	0.9	2.2	30%
January	4.3	2.4	1.8	57%	3.6	0.6	2.5	1.7	60%
February	3.4	1.4	2.0	42%	2.9	0.5	1.6	1.9	46%
March	3.4	1.2	2.3	34%	2.9	0.5	1.3	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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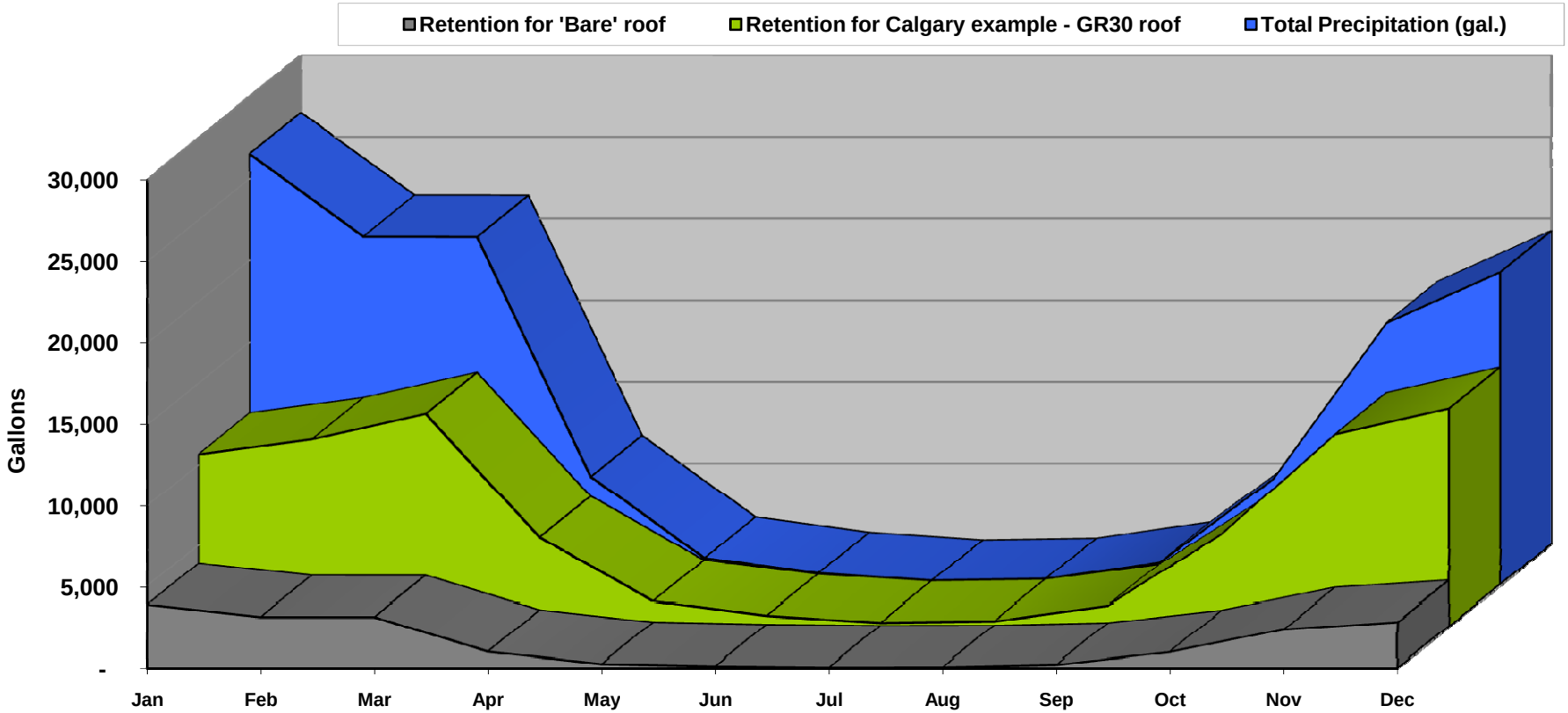
CALGARY EXAMPLE - GR30
(10,000 sf tot.; GR coverage = 90%)



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