

**APPENDIX C**  
**RUNOFF VOLUME CALCULATIONS**



**Pennoni Associates Inc.**

Consulting Engineers

PROJECT: Longwood Gardens Nursery Greenhouse

SUBJECT: Stormwater BMP Stage-Storage

JOB NO.: BCCC18001

SHEET: 1 OF 2

BY: MEM

CHK'D: CRP

DATE: 6/7/2018

**Bio-Retention Basin 1**

**Stone/Soil Storage**

<b>Rock Aggregate</b>	
Invert Elev. (ft)	419.40
Rock Depth (ft)	1.00
Surface Area (sf)	9,814.00
Aggregate Porosity	0.4

<b>Soil Mixture</b>	
Invert Elev. (ft)	420.40
Soil Depth (ft)	2.00
Surface Area (sf)	9,814.00
Soil Porosity	0.1

Stage	Basin Depth	Aggregate Storage	Soil Storage	Total Storage
<i>ft. MSL</i>	<i>ft.</i>	<i>cf</i>	<i>cf</i>	<i>cf</i>
419.40	0.00	0.00	0.00	0.00
419.90	0.50	1,962.80	0.00	1,962.80
420.40	1.00	1,962.80	0.00	3,925.60
420.90	1.50	0.00	490.70	4,416.30
421.40	2.00	0.00	490.70	4,907.00
421.90	2.50	0.00	490.70	5,397.70
422.40	3.00	0.00	490.70	5,888.40

**Total Subsurface Storage Volume = 5,888 cf**

**Surface Storage**

ELEV	AREA (SF)	AVG. AREA (SF)	DEPTH (FT)	VOL (CF)	SUM VOL (CF)
422.4	0.00				0
		4,907.00	0.6	2,944	2,944
423.00	9,814.00	10,951.00	1.0	10,951	13,895
424.00	12,088.00	13,060.00	1.0	13,060	26,955
425.00	14,032.00				

Grate Elevation: 423.40

**Total Surface Storage Volume = 10,367 cf**

**Total Storage Volume:**

Total Storage Volume = Subsurface Storage Volume + Surface Storage Volume

**Total Storage Volume = 16,256 cf**

**Bio-Retention Basin 1**

Cover Type/Condition	Soil Type	Area (s.f.)	Area (Ac.)	CN	S	I <sub>a</sub> (0.2*S)	Q	Runoff
							Runoff <sup>1</sup> (in)	Volume <sup>2</sup> (ft <sup>3</sup> )
Lawn, good condition	A	-	-	39	15.64	3.13	0.06	-
Lawn, good condition	B	-	-	61	6.39	1.28	0.87	-
Lawn, good condition	D	-	-	80	2.50	0.50	2.13	-
Meadow, good condition	A	-	-	30	23.33	4.67	0.00	-
Meadow, good condition	B	87,658.00	2.01	58	7.24	1.45	0.72	5,226
Meadow, good condition	D	-	-	78	2.82	0.56	1.97	-
Permeable Paver	B	-	-	70	4.29	0.86	1.40	-
Permeable Paver	C	-	-	79	2.66	0.53	2.05	-
Green Roof	*	-	-	86	1.63	0.33	2.65	-
Impervious	*	63,682.00	1.46	98	0.20	0.04	3.87	20,563
<b>TOTAL</b>		<b>151,340.00</b>	<b>3.47</b>					<b>25,789</b>

Total Infiltration Volume Provided (cf)	Total Runoff Volume to Facility (cf)	Excess Runoff Volume (cf)	Effective Runoff Volume (cf)	Infiltration Facilities Surface Area (sf)	Drainage Area Loading Ratio (8:1 max) <sup>3</sup>	Impervious Loading Ratio (5:1 max) <sup>4</sup>
16,256	25,789	9,533	16,256	9,814	15	6

1. Runoff (in) =  $Q = (P - 0.2S)^2 / (P + 0.8S)$  where 4.11 in

**Infiltration Facilities Surface Area equals surface area at Riser Elevation.**

2. Runoff Volume (CF) =  $Q \times \text{Area} \times 1/12$

P = 2-year Rainfall (in)  
 S = (1000 / CN) - 10  
 Q = Runoff (in)

Area = Land Use Area (sq. ft.)

3. A Maximum Total Loading Ratio of **8:1** relating **total** drainage area to infiltration area

4. Recommended Maximum Impervious Loading Ratio of **3:1** relating impervious drainage area to infiltration area for Karst Areas  
 Maximum Impervious Loading Ratio of **5:1** relating impervious drainage area to infiltration area.  
 Impervious area includes permeable pavement area and impervious area.

**Pennoni Associates Inc.**

Consulting Engineers

PROJECT: Longwood Gardens Nursery Greenhouse

SUBJECT: Stormwater BMP Stage-Storage

JOB NO.: BCCCI18001

SHEET: 1 OF 2

BY: MEM

CHK'D: CRP

DATE:

6/7/2018

**Bio-Retention Basin 2**

**Stone/Soil Storage**

<b>Rock Aggregate</b>	
Invert Elev. (ft)	433.80
Rock Depth (ft)	2.00
Surface Area (sf)	5,442.00
Aggregate Porosity	0.4

<b>Soil Mixture</b>	
Invert Elev. (ft)	435.80
Soil Depth (ft)	2.00
Surface Area (sf)	5,442.00
Soil Porosity	0.1

Stage	Basin Depth	Aggregate Storage	Soil Storage	Total Storage
<i>ft. MSL</i>	<i>ft.</i>	<i>cf</i>	<i>cf</i>	<i>cf</i>
433.80	0.00	0.00	0.00	0.00
434.30	0.50	1,088.40	0.00	1,088.40
434.80	1.00	1,088.40	0.00	2,176.80
435.30	1.50	1,088.40	0.00	3,265.20
435.80	2.00	1,088.40	0.00	4,353.60
436.30	2.50	0.00	272.10	4,625.70
436.80	3.00	0.00	272.10	4,897.80
437.30	3.50	0.00	272.10	5,169.90
437.80	4.00	0.00	272.10	5,442.00

**Total Subsurface Storage Volume = 5,442 cf**

**Surface Storage**

ELEV	AREA (SF)	AVG. AREA (SF)	DEPTH (FT)	VOL (CF)	SUM VOL (CF)
437.8	0.00				0
		512.00	0.2	102	102
438.00	1,024.00				102
		3,233.00	1.0	3,233	3,335
439.00	5,442.00				3,335
		6,442.50	1.0	6,443	9,778
440.00	7,443.00				9,778
		8,226.00	1.0	8,226	18,004
441.00	9,009.00				18,004
		4,504.50	4.0	18,018	

Grate  
Elevation: 438.80

**Total Surface Storage Volume = 5,626 cf**

**Total Storage Volume:**

Total Storage Volume = Subsurface Storage Volume + Surface Storage Volume

**Total Storage Volume = 11,068 cf**

**Bio-Retention Basin 2**

Cover Type/Condition	Soil Type	Area (s.f.)	Area (Ac.)	CN	S	I <sub>a</sub> (0.2*S)	Q	Runoff
							Runoff <sup>1</sup> (in)	Volume <sup>2</sup> (ft <sup>3</sup> )
Lawn, good condition	A	-	-	39	15.64	3.13	0.06	-
Lawn, good condition	B	16,671.00	0.38	61	6.39	1.28	0.87	1,207
Lawn, good condition	D	-	-	80	2.50	0.50	2.13	-
Meadow, good condition	A	-	-	30	23.33	4.67	0.00	-
Meadow, good condition	B	47,270.00	1.09	58	7.24	1.45	0.72	2,818
Meadow, good condition	D	-	-	78	2.82	0.56	1.97	-
Permeable Paver	B	-	-	70	4.29	0.86	1.40	-
Permeable Paver	C	-	-	79	2.66	0.53	2.05	-
Green Roof	*	-	-	86	1.63	0.33	2.65	-
Impervious	*	45,734.00	1.05	98	0.20	0.04	3.87	14,768
<b>TOTAL</b>		<b>109,675.00</b>	<b>2.52</b>					<b>18,793</b>

Total Infiltration Volume Provided (cf)	Total Runoff Volume to Facility (cf)	Excess Runoff Volume (cf)	Effective Runoff Volume (cf)	Infiltration Facilities Surface Area (sf)	Drainage Area Loading Ratio (8:1 max) <sup>3</sup>	Impervious Loading Ratio (5:1 max) <sup>4</sup>
11,068	18,793	7,725	11,068	5,442	20	8

1. Runoff (in) =  $Q = (P - 0.2S)^2 / (P + 0.8S)$  where 4.11 in

**Infiltration Facilities Surface Area equals surface area at Riser Elevation.**

2. Runoff Volume (CF) =  $Q \times \text{Area} \times 1/12$

P = 2-year Rainfall (in)  
 S = (1000 / CN) - 10  
 Q = Runoff (in)

Area = Land Use Area (sq. ft.)

3. A Maximum Total Loading Ratio of **8:1** relating **total** drainage area to infiltration area

4. Recommended Maximum Impervious Loading Ratio of **3:1** relating impervious drainage area to infiltration area for Karst Areas  
 Maximum Impervious Loading Ratio of **5:1** relating impervious drainage area to infiltration area.  
 Impervious area includes permeable pavement area and impervious area.

JOB NO.:	BCCCC18001	DATE:	
SHEET:	2 OF 2	DATE:	
BY:	MEM	DATE:	6/7/2018
CHK'D:	CRP		

PROJECT:	Longwood Gardens Nursery Greenhouse
SUBJECT:	Stormwater BMP Stage-Storage

**Bio-Retention Basin 2**

Cover Type/Condition	Soil Type	Area (s.f.)	Area (Ac.)	CN	S	I <sub>a</sub> (0.2*S)	Q	Runoff
							Runoff <sup>1</sup> (in)	Volume <sup>2</sup> (ft <sup>3</sup> )
Lawn, good condition	A	-	-	39	15.64	3.13	0.06	-
Lawn, good condition	B	16,671.00	0.38	61	6.39	1.28	0.87	1,207
Lawn, good condition	D	-	-	80	2.50	0.50	2.13	-
Meadow, good condition	A	-	-	30	23.33	4.67	0.00	-
Meadow, good condition	B	47,270.00	1.09	58	7.24	1.45	0.72	2,818
Meadow, good condition	D	-	-	78	2.82	0.56	1.97	-
Permeable Paver	B	-	-	70	4.29	0.86	1.40	-
Permeable Paver	C	-	-	79	2.66	0.53	2.05	-
Green Roof	*	-	-	86	1.63	0.33	2.65	-
Impervious	*	45,734.00	1.05	98	0.20	0.04	3.87	14,768
<b>TOTAL</b>		<b>109,675.00</b>	<b>2.52</b>					<b>18,793</b>

Total Infiltration Volume Provided (cf)	Total Runoff Volume to Facility (cf)	Excess Runoff Volume (cf)	Effective Runoff Volume (cf)	Infiltration Facilities Surface Area (sf)	Drainage Area Loading Ratio (8:1 max) <sup>3</sup>	Impervious Loading Ratio (5:1 max) <sup>4</sup>
11,068	18,793	7,725	7,725	5,442	20	8

1. Runoff (in) =  $Q = (P - 0.2S)^2 / (P + 0.8S)$  where 4.11 in **Infiltration Facilities Surface Area equals surface area at Riser Elevation.**

2. Runoff Volume (CF) =  $Q \times \text{Area} \times 1/12$

P = 2-year Rainfall (in)  
 S = (1000 / CN) - 10  
 Q = Runoff (in)

Area = Land Use Area (sq. ft.)

3. A Maximum Total Loading Ratio of **8:1** relating **total** drainage area to infiltration area

4. Recommended Maximum Impervious Loading Ratio of **3:1** relating impervious drainage area to infiltration area for Karst Areas  
 Maximum Impervious Loading Ratio of **5:1** relating impervious drainage area to infiltration area.  
 Impervious area includes permeable pavement area and impervious area.

# Pennoni Associates Inc.

Consulting Engineers

JOB NO.:	BCCCI18001
SHEET 1 OF 3	DATE
BY: CRP	06/07/18
CHK'D:	

PROJECT:	Longwood Gardens Nursery Greenhouse
SUBJECT:	Stage-Storage Curve - Subsurface Basin

## Subsurface Infiltration Basin #3 - Section 1

PIPE	
Dia.(ft.):	2.5
* Length (feet):	100
U.S. IE:	423.50
D.S. IE:	423.50
Slope (ft/ft):	0.000
No. Pipes	27

BASIN	
IE	423.00
Length	105
Width	122
Aggregate Porosity	40%

No.	Stage	Basin Depth	PIPE STORAGE							AGGREGATE		TOTAL		Stage
			D.S. Control Section		Length from D.S.control section, l	U.S. Control Section		aver. area	volume	Ends	Around Pipe	Total		
			depth, d	area, a		depth, d	area, a							
#	ft. MSL	ft.	ft.	sq. ft.	ft.	ft.	sq. ft.	sq. ft.	cf.	cf	cf	cf	AF	ft. MSL
1	423.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0	0	0	0.000000		423.00
2	423.50	0.50	0.00	0.00	0	0.00	0.00	0.00	0	122	2,440	2,562	0.058815	423.50
3	424.00	1.00	0.50	0.70	100	0.50	0.70	0.70	1,887	244	4,125	6,256	0.143623	424.00
4	424.50	1.50	1.00	1.83	100	1.00	1.83	1.83	4,951	366	5,340	10,656	0.244637	424.50
5	425.00	2.00	1.50	3.08	100	1.50	3.08	3.08	8,303	488	6,439	15,230	0.349628	425.00
6	425.50	2.50	2.00	4.21	100	2.00	4.21	4.21	11,367	610	7,653	19,630	0.450641	425.50
7	426.00	3.00	2.50	4.91	100	2.50	4.91	4.91	13,254	732	9,339	23,324	0.535449	426.00
8	426.50	3.50	2.50	4.91	100	2.50	4.91	4.91	13,254	854	11,779	25,886	0.594264	426.50
9	427.00	4.00	2.50	4.91	100	2.50	4.91	4.91	13,254	976	14,219	28,448	0.653080	427.00

1st Stage Orifice Inv. 425.60

**Total Storage Volume = 20,214 cf**



# Pennoni Associates Inc.

Consulting Engineers

PROJECT: Longwood Gardens Nursery Greenhouse

SUBJECT: Stage-Storage Curve - Subsurface Basin

JOB NO.: BCCCI18001

SHEET 2 OF 3 DATE

BY: CRP 06/07/18

CHK'D:

## Subsurface Infiltration Basin #3 - Section 2

PIPE	
Dia.(ft.):	2.5
* Length (feet):	45
U.S. IE:	423.50
D.S. IE:	423.50
Slope (ft/ft):	0.000
No. Pipes	10

BASIN	
IE	423.00
Length	50
Width	45
Aggregate Porosity	40%

No.	Stage	Basin Depth	PIPE STORAGE							AGGREGATE		TOTAL		Stage
			D.S. Control Section		Length from D.S. control section, l	U.S. Control Section		aver. area	volume	Ends	Around Pipe	Total		
			depth, d	area, a		depth, d	area, a							
#	ft. MSL	ft.	ft.	sq. ft.	ft.	ft.	sq. ft.	sq. ft.	cf.	cf	cf	cf	AF	ft. MSL
1	423.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0	0	0	0	0.000000	423.00
2	423.50	0.50	0.00	0.00	0	0.00	0.00	0.00	0	45	405	450	0.010331	423.50
3	424.00	1.00	0.50	0.70	45	0.50	0.70	0.70	315	90	684	1,089	0.024993	424.00
4	424.50	1.50	1.00	1.83	45	1.00	1.83	1.83	825	135	885	1,845	0.042357	424.50
5	425.00	2.00	1.50	3.08	45	1.50	3.08	3.08	1,384	180	1,066	2,630	0.060383	425.00
6	425.50	2.50	2.00	4.21	45	2.00	4.21	4.21	1,894	225	1,267	3,387	0.077747	425.50
7	426.00	3.00	2.50	4.91	45	2.50	4.91	4.91	2,209	270	1,546	4,025	0.092410	426.00
8	426.50	3.50	2.50	4.91	45	2.50	4.91	4.91	2,209	315	1,951	4,475	0.102740	426.50
9	427.00	4.00	2.50	4.91	45	2.50	4.91	4.91	2,209	360	2,356	4,925	0.113071	427.00

1st Stage Orifice Inv. 425.60

**Total Storage Volume = 3,489 cf**

**Subsurface Infiltration Basin #3 - Section 1**

Cover Type/Condition	Soil Type	Area (s.f.)	Area (Ac.)	CN	S	I <sub>a</sub> (0.2*S)	Q Runoff <sup>1</sup> (in)	Runoff Volume <sup>2</sup> (ft <sup>3</sup> )
Lawn, good condition	B	-	-	61	6.39	1.28	0.87	-
Lawn, good condition	D	-	-	74	3.51	0.70	1.68	-
Meadow, good condition	B	-	-	58	7.24	1.45	0.72	-
Meadow, good condition	D	-	-	71	4.08	0.82	1.47	-
Woods, good condition	B	-	-	55	8.18	1.64	0.57	-
Woods, good condition	C	-	-	70	4.29	0.86	1.40	-
Permeable Paver	B	-	-	70	4.29	0.86	1.40	-
Permeable Paver	C	-	-	79	2.66	0.53	2.05	-
Green Roof	*	-	-	86	1.63	0.33	2.65	-
Impervious	*	63,790	1.46	98	0.20	0.04	3.87	20,598
<b>TOTAL</b>		<b>63,790</b>	<b>1.46</b>					<b>20,598</b>

Storage Volume Provided (cf)	Excess Runoff Volume (cf)	Effective Runoff Volume (cf)	Infiltration Basin Surface Area (sf)	Drainage Area Loading Ratio (8:1 max) <sup>4</sup>	Impervious Loading Ratio (5:1 max) <sup>5</sup>
23,703	-	20,598	12,810	5	5

1. Runoff (in) =  $Q = (P - 0.2S)^2 / (P + 0.8S)$  where  
4.11 in

2. Runoff Volume (CF) =  $Q \times \text{Area} \times 1/12$   
 P = 2-year Rainfall (in)  
 S = (1000 / CN) - 10  
 Q = Runoff (in)  
 Area = Land Use Area (sq. ft.)

3. Infiltration Facility Surface Area includes Infiltration Basin Surface Area and Permeable Pavement Surface Area and Bio-Retention Area #14

4. A Maximum Total Loading Ratio of **8:1** relating **total** drainage area to infiltration area

5. Recommended Maximum Impervious Loading Ratio of **3:1** relating impervious drainage area to infiltration area for Karst Areas  
 Maximum Impervious Loading Ratio of **5:1** relating impervious drainage area to infiltration area.  
 Impervious area includes permeable pavement area and impervious area.

# Pennoni Associates Inc.

Consulting Engineers

JOB NO.:	BCCCI18001
SHEET 1 OF 2	DATE
BY: CRP	06/07/18
CHK'D:	

PROJECT:	Longwood Gardens Greenhouse Nursery
SUBJECT:	Stage-Storage Curve - Subsurface Basin

## Subsurface Infiltration/Detention Basin #4

PIPE	
Dia.(ft.):	2
* Length (feet):	75
U.S. IE:	440.50
D.S. IE:	440.50
Slope (ft/ft):	0.000
No. Pipes	14

BASIN	
IE	440.00
Length	80
Width	54
Aggregate Porosity	40%

No.	Stage	Basin Depth	PIPE STORAGE							AGGREGATE		TOTAL		Stage
			D.S. Control Section		Length from D.S.control section, l	U.S. Control Section		aver. area	volume	Ends	Around Pipe	Total		
			depth, d	area,a		depth, d	area,a							
#	ft. MSL	ft.	ft.	sq. ft.	ft.	ft.	sq. ft.	sq. ft.	cf.	cf	cf	cf	AF	ft. MSL
1	440.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0	0	0	0	0.000000	440.00
2	440.50	0.50	0.00	0.00	0	0.00	0.00	0.00	0	54	810	864	0.019835	440.50
3	441.00	1.00	0.50	0.61	75	0.50	0.61	0.61	645	108	1,362	2,115	0.048552	441.00
4	441.50	1.50	1.00	1.57	75	1.00	1.57	1.57	1,649	162	1,770	3,582	0.082222	441.50
5	442.00	2.00	1.50	2.53	75	1.50	2.53	2.53	2,654	216	2,178	5,048	0.115892	442.00
6	442.50	2.50	2.00	3.14	75	2.00	3.14	3.14	3,299	270	2,731	6,299	0.144610	442.50
7	443.00	3.00	2.00	3.14	75	2.00	3.14	3.14	3,299	324	3,541	7,163	0.164445	443.00
8	443.50	3.50	2.00	3.14	75	2.00	3.14	3.14	3,299	378	4,351	8,027	0.184279	443.50
9	444.00	4.00	2.00	3.14	75	2.00	3.14	3.14	3,299	432	5,161	8,891	0.204114	444.00

1st Stage Orifice Inv. 442.25

**Total Storage Volume = 5,372 cf**

JOB NO.:	BCCCI18001
SHEET2 OF 2	DATE
BY: CRP	06/07/18
CHK'D:	

PROJECT:	Longwood Gardens Greenhouse Nursery
SUBJECT:	Stage-Storage Curve - Subsurface Basin

**Subsurface Infiltration/Detention Basin #4**

Cover Type/Condition	Soil Type	Area (s.f.)	Area (Ac.)	CN	S	I <sub>a</sub> (0.2*S)	Q Runoff <sup>1</sup> (in)	Runoff Volume <sup>2</sup> (ft <sup>3</sup> )
Lawn, good condition	B	-	-	61	6.39	1.28	0.87	-
Lawn, good condition	D	-	-	74	3.51	0.70	1.68	-
Meadow, good condition	B	-	-	58	7.24	1.45	0.72	-
Meadow, good condition	D	-	-	71	4.08	0.82	1.47	-
Woods, good condition	B	-	-	55	8.18	1.64	0.57	-
Woods, good condition	C	-	-	70	4.29	0.86	1.40	-
Permeable Paver	B	-	-	70	4.29	0.86	1.40	-
Permeable Paver	C	-	-	79	2.66	0.53	2.05	-
Green Roof	*	-	-	86	1.63	0.33	2.65	-
Impervious	*	14,580	0.33	98	0.20	0.04	3.87	4,708
<b>TOTAL</b>		14,580	0.33					4,708

Storage Volume Provided (cf)	Excess Runoff Volume (cf)	Effective Runoff Volume (cf)	Infiltration Basin Surface Area (sf)	Drainage Area Loading Ratio (8:1 max) <sup>4</sup>	Impervious Loading Ratio (5:1 max) <sup>5</sup>
5,372	-	4,708	4,320	3	3

1. Runoff (in) =  $Q = (P - 0.2S)^2 / (P + 0.8S)$  where  
4.11 in

2. Runoff Volume (CF) =  $Q \times \text{Area} \times 1/12$   
 P = 2-year Rainfall (in)  
 S = (1000 / CN) - 10  
 Q = Runoff (in)  
 Area = Land Use Area (sq. ft.)

3. Infiltration Facility Surface Area includes Infiltration Basin Surface Area and Permeable Pavement Surface Area and Bio-Retention Area #14.

4. A Maximum Total Loading Ratio of **8:1** relating **total** drainage area to infiltration area

5. Recommended Maximum Impervious Loading Ratio of **3:1** relating impervious drainage area to infiltration area for Karst Areas  
 Maximum Impervious Loading Ratio of **5:1** relating impervious drainage area to infiltration area.  
 Impervious area includes permeable pavement area and impervious area.