PA Design Guide #10
Design Guidelines for Silage Leachate and Runoff

Criteria:

This design guide covers the collection, storage and treatment of leachate and high flow runoff. Leachate and high flow runoff is known to come from raw materials storage areas including but is not limited to feed silos, silage bunkers, and bedding materials. The primary focus is on silage leachate and other contaminates mixing with storm water.

The quantity and concentration of the leachate and high flow runoff varies significantly with storm event size, seasonality, bunker management, and silage quality.

Source control to reduce leachate volume and solids movement is critical to the effectiveness of downstream BMP's. Harvest at optimum moistures to reduce leachate volume. Cover and wrap silage to reduce generation of percolate. Ensure that ground water and surface water do not enter the site. Seal cracks and prevent uncontrolled flows into the feed storage area. Practice good bunk management. Clean and sweep waste feed off of concrete pad and dispose properly.

Direct the leachate and high flow runoff from within the feed storage area to a settling facility or slow the runoff flow to facilitate settling of the solids prior to entering any liquid storage or vegetated buffer. Use low-flow collection devices, dilution, storage or other acceptable methods to collect/control leachate. Higher flows resulting from rainfall events shall go to an established vegetated buffer provided the following conditions are met:

- Leachate and associated low flow has been controlled and collected sufficiently to prevent burning of vegetation in the vegetated buffer. The amount of leachate and associated low flow collection will be monitored and adjusted to prevent any vegetated buffer kill zones from developing.
- Size a settling area volume as per the bunk size in Table 1.
- Provide screens or other devices to retain solids in the settling area or the collection apron for proper solids disposal.
- The high flow runoff collection, transfer, and distribution system shall be designed to contol the 2yr – 24hr rain event volume at CN=88 and when routing control the 2yr-60min peak flow.
- Provide a vegetated buffer as per the bunk size in Table 1.
- The flow length through the vegetated buffer shall be a minimum of 50'. Maintain an additional minimum setback distance of 50' from surface water, wells, wetlands, sinkholes, etc. as measured from the bottom of the vegetated buffer.
- Divert uncontaminated surface runoff or sub-surface water away from collection devises and the vegetated buffer locations.
- Maintain the vegetated buffer in vigorous sod or equal. Exclude livestock access to the vegetated buffer except for flash grazing.
- Distribute flow evenly over the top edge of the vegetated buffer or irrigate over vegetated buffer.
- Manage high flow runoff from the storage and collection site to prevent erosion up to the 10yr -24 hour event.

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For sites that do not meet the above listed criteria, refer to the Pennsylvania NRCS conservation practice standard for Waste Storage Facility (313), Vegetated Treatment Area (635) and/or a Constructed wetland (656).

Additional BMPs or enhanced BMPs shall be used for sites located in sensitive areas.

CAFO projects shall meet any additional CAFO requirements.

Environmental resource concerns are significantly reduced from sites with small feed storage areas and/or those located great distances from a receiving water body and when high flow runoff is not expected to cause an erosion issue; size and layout of BMPs may reflect reduced environmental resource concerns.

Leachate shall not be conveyed to a covered or under-the-barn waste storage structure, as silage leachate may generate excessive manure gas production. Adhere to safety procedures when agitating and discharging a waste storage structure that contains silage leachate.

References

Tyson, J. T., Graves, R. E., Horizontal Silos. H76. College of Agricultural Sciences, Coop. Ext., Pennsylvania State University, University Park. 6pp.

Clarke, S. P., Stone, R. P., 1995. How to Handle Seepage from Farm Silos. Ontario Ministry of Agriculture. #04-031. 9pp.

Larson, R., Holly, M., Silage-Runoff-Characterization. University of Wisconsin, #67602. 2013.

Cropper, J. B., DuPoldt, C. A., 1995. Silage Leachate & Water Quality. NRCS USDA. Environmental Quality Technical Note N5. 17pp.

Westmoreland Conservation District, 2013, Bio-retention in Clay Soils, page 7

Wright, P. E., Vanderstappen, P. J. 1994. Base Flow Silage Leachate Control. NRCS USDA. ASAE 94-2560. 9pp.

Table 1 Silage Leachate and Runoff

Bunker size < ½ acre

Settling Volume = resulting volume from the creation of the screened device.

Vegetated Buffer = 1/4 of DA

Bunker Size =1/2 acre up to 1 acre

Settling Volume = 2% of DA in CF*

Vegetated Buffer = 1/3 of DA

Bunker Size over 1 acre

Settling volume= 5% of DA in CF*

Vegetated Buffer = 1/2 of DA

Note: DA = The collected drainage area from the feed storage site, entrance aprons, and access areas, measured in square feet.

(*5% of DA in CF (cubic feet) is the same as 15 minute duration at the peak inflow rate resulting from 2-year, 24-hour rainfall event.)

Design Note #10 Commentary

Water quality issues with bunker silos include both silage leachate as well as high flow runoff. Feed storage areas such as bunker silos, trench silos, and access areas are considered production areas. It is generally understood that low flow leachate from feed storage areas not only kills vegetation but has also been directly related to fish kills. Water quality issues directly related to high flow runoff is not as obvious; however the high flow runoff from these areas can still pose a resource concern. Based on several studies (one just released by University of Wisconsin- Madison in 2013) evidence shows that nutrients levels vary significantly due to rainfall event size, duration, intensity, season of year, bunker condition (management), moisture content, and amount of silage material in relation to exposed clean concrete or exposed plastic cover. Releasing the high flow runoff directly to a stream is not acceptable and must be addressed in some manner to lower the risk of water quality problems.

If resource concerns are identified, use low-flow collection devices, dilution, storage, distribution systems, or other acceptable methods to control leachate and runoff flow from production areas.

100 % collection of leachate - This applies to all, but the very smallest sites that are located in a conservative location and no evidence of past leachate discharge. An estimated volume of 1 cu ft. /ton depending on moisture content, type of silo structure, and crop being ensiled is a good estimate of leachate volume over the leaching period, which is generally 10-30 days after ensiling. Some references suggest lower volumes of leachate when the silage is harvested at a moisture content lower than 70%. (The moisture content of the silage may vary greatly from year to year depending on weather conditions). When the ensiled material is opened (cover removed) for use as feed, there may be an increase in percolate from the storage area which shall be collected and treated as leachate. Examples of collection devises are shown in the reference written by Wright.

Sizing of settling area/volume - Improved water quality will also be addressed by having a settling area for solids and a well-designed low flow silage leachate collection system in place. It is apparent that large sites involve not only more actual bunk storage area, but also more paved access area resulting in the need to collect more waste feed solids and warranting a larger settling basin. Protection for the smallest bunker silos will be achievable with just the collection swale and retention as a result of the screening devises along with good bunk management. This is reflected in the staggered volume requirements found in Table 1

Example of Calculating Required Settling Volume –

Bunker size = 40,000 sq. ft.

The settling volume (cu. Ft.) = 2% of the DA (sq. ft.) = 0.02 x 40,000 sq. ft. = 800 cu. ft.

Collection of High Flow - Runoff from the area up to the 2yr 24hr event that is not collected as leachate will be transferred for distribution to a vegetated buffer to finish removal of any minor contaminants.

When the high flow runoff must be transferred for distribution, the system will be sized to handle a 2yr-24hr event for volume with CN = 88 and the 2 yr-60min peak with no CN factor; routing is acceptable.

Vegetated Buffer - The water quality properties of high flow storm runoff have great variability from site to site. For many years the New York State Technical Guide has guidance directing that vegetated buffers to be 1/3 the DA and favoring a narrow but long geometry for their suggested site layouts. Table 1 directs a sliding scale for sizing the vegetated buffers. This PA Design guide allows flexibility to use more conservative wider and shorter layouts, so long as the flow length is a minimum of 50 feet plus 50' setback. This guide also allows the use of a long and narrow vegetated buffer, such as 15' flat bottom by 190' for a ¼ acre pad. See Table 1 for the various vegetated buffer sizing requirements. Vegetated buffers are not to be confused with a Vegetated Treatment Area meeting Standard 635.

Distribution over the site – The term "sheet flow" has now been replaced with "even flow over the top edge of the vegetated buffer". Distribution may also be done over the entire area using one or more sprinkler guns.

Distance to stream-Changes have now been made to require the high flows to enter the top of the vegetated buffer with at least 50' of flow length required within the vegetated buffer and another 50' of vegetated setback before entering surface water, wetlands, sinkholes, etc.. The nutrient load of this runoff would be very low due to low-flow leachate collection, solids settling, good bunk management, and flow thru a vegetated buffer.

Level of protection for sensitive sites- Sites that do not have a sufficient vegetated buffer or setback distance require containing up to the 2yr-24hour event with a CN of 88. Adjusting the volume runoff with a CN of 88 is supported by the recent Larson report that demonstrated runoff from these sites does not mimic parking lots with a CN of 98. A typical 2yr-24hr event rainfall (NRCS rainfall tables or NOOA 14) adjusted to a CN-88 (NRCS NEH Part 630, Ch. 10 10A-41) results in net runoff depth range of 1.8 to 2.4 inches (depending on location). Treating this depth of runoff will effectively control over 90% of the annual volume. This conclusion is supported by the Westmoreland reference showing that an average Pa site having more than 143 rain days per year shows that only 2 days exceed 1.5 inches. In addition, treating runoff from 1" of precipitation will control 91% of the runoff events. The dilution effect due to heavy rainfall will be significant for the large storms not controlled.

Computation of peak runoff for the routing requirements - Recognizing the many other aspects of these requirements work to attenuate runoff volume, peak and water quality, these guidelines use the 2 year-60 min (no CN factor applied) rainfall frequency data for the routing requirements for the high flow runoff. The 2 yr-60min frequency data can be found in the NOAA Atlas 14 Point Precipitation Frequency Estimates, http://hdsc.nws.noaa.gov/hdsc/pfds/pfds_map_pr.html . Alternate computation methods can be used at the engineer's discretion.

Flood Routing Example - Storage volumes for sites requiring collection of the 2yr-24hour event can be reduced by using a simplified routing method found in Part 650-Engineering Field Handbook, Chap. 11, page 11-55a, Table A (attached) or equal.

Example for a location in Lebanon County with a bunker silo and concrete areas = 40,000 sf. Site located 65' from stream bank.

Downstream area for vegetated buffer lacks the minimum distance of 100'. Thus, there is the need to control 2yr-24hr event and store/pump/route to a suitable vegetated buffer or storage. 2yr-24hr rainfall is 3.04" and runoff is 1.86" with CN=88. See attached NOAA Atlas 14 and CN=88 chart.

Volume Runoff = 40,000 sf x 1.86"/12 = 6,200 cf

Routing using 11-55b EFH Table A (attached)

Select pump Qo, assume 115 gpm, thus Qo = 115gpm / 448.8 gpm/cfs = 0.26cfs

Qi = DA x (2yr-60 min runoff depth) x converted to cfs = 40,000 sf x 1.35" / (12 x 3600) = 1.25cfs

Qo / Qi = 0.26/1.25 = 0.21

From EFH 11-55b table A read Vs / Vr = 0.47

Vs = 0.47 x Vr = 0.47 (6,200 cf) = 2,914 cf

2,914 cf is the required storage when routed with 115 gpm pump…..a portion of which can possibly come from the required settling volume.

The use of 2yr-24hr for the Vr, CN=88, and 2yr-60min for Qi are specific benchmark parameters selected based on hydraulic engineering experiences and recent case studies.

Overview - These changes will bring the Standard more in line with appropriate BMPs based on recent experiences and the June 2013 tour of bunk silos in Lancaster County. These changes now allow more options and flexibility with silage leachate BMPs. Reduced size and simpler layouts of BMPs may result. This can be the case for some small sites or sites located great distances from areas of concern.

WHL, PJV, GRW 1/31/2014

Rainfall data from NOAA 14 for example design.

NOAA Atlas 14, Volume 2, Version 3
Location name: Lebanon, Pennsylvania, US*
Coordinates: 40.2550, -76.4044
Elevation: 882ft*
* source: Google Maps

POINT PRECIPITATION FREQUENCY ESTIMATES

G.M. Bonnin, D. Martin, B. Lin, T. Parzybok, M.Yekta, and D. Riley
NOAA, National Weather Service, Silver Spring, Maryland

PF_tabular | PF_graphical | Maps_&_aerials

PF tabular

PDS-based point precipitation frequency estimates with 90% confidence intervals (in inches)[1]

Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	0.328 (0.297-0.362)	0.390 (0.353-0.432)	0.458 (0.415-0.507)	0.510 (0.460-0.563)	0.568 (0.511-0.627)	0.610 (0.547-0.672)	0.652 (0.582-0.718)	0.689 (0.612-0.760)	0.734 (0.648-0.810)	0.769 (0.674-0.850)
10-min	0.523 (0.474-0.578)	0.623 (0.565-0.690)	0.733 (0.664-0.812)	0.812 (0.733-0.896)	0.902 (0.810-0.994)	0.967 (0.867-1.07)	1.03 (0.920-1.14)	1.09 (0.965-1.20)	1.16 (1.02-1.28)	1.21 (1.06-1.33)
15-min	0.652 (0.591-0.721)	0.781 (0.708-0.865)	0.925 (0.837-1.02)	1.03 (0.925-1.13)	1.14 (1.03-1.26)	1.22 (1.10-1.35)	1.30 (1.16-1.43)	1.37 (1.22-1.51)	1.46 (1.28-1.61)	1.51 (1.33-1.67)
30-min	0.892 (0.808-0.986)	1.08 (0.976-1.19)	1.31 (1.19-1.45)	1.48 (1.34-1.63)	1.68 (1.51-1.86)	1.84 (1.65-2.02)	1.99 (1.77-2.19)	2.12 (1.89-2.34)	2.30 (2.03-2.54)	2.44 (2.14-2.69)
60-min	1.11 (1.01-1.23)	1.35 (1.22-1.49)	1.68 (1.52-1.86)	1.92 (1.74-2.12)	2.24 (2.01-2.47)	2.48 (2.22-2.73)	2.73 (2.43-3.00)	2.97 (2.64-3.28)	3.29 (2.91-3.63)	3.54 (3.11-3.92)
2-hr	1.31 (1.19-1.46)	1.59 (1.44-1.76)	2.00 (1.81-2.22)	2.33 (2.10-2.58)	2.79 (2.50-3.07)	3.16 (2.82-3.48)	3.56 (3.16-3.92)	3.97 (3.50-4.38)	4.57 (3.98-5.04)	5.05 (4.37-5.58)
3-hr	1.43 (1.30-1.59)	1.74 (1.57-1.93)	2.19 (1.98-2.43)	2.55 (2.30-2.83)	3.05 (2.73-3.37)	3.46 (3.08-3.83)	3.90 (3.45-4.31)	4.36 (3.83-4.82)	5.02 (4.36-5.55)	5.56 (4.78-6.16)
6-hr	1.77 (1.60-1.99)	2.15 (1.94-2.40)	2.70 (2.43-3.02)	3.16 (2.82-3.52)	3.82 (3.40-4.24)	4.38 (3.87-4.85)	4.99 (4.37-5.52)	5.64 (4.90-6.24)	6.61 (5.66-7.31)	7.42 (6.28-8.22)
12-hr	2.18 (1.96-2.45)	2.63 (2.37-2.97)	3.33 (2.99-3.75)	3.92 (3.50-4.40)	4.81 (4.26-5.37)	5.57 (4.89-6.20)	6.43 (5.59-7.14)	7.37 (6.33-8.17)	8.80 (7.42-9.74)	10.0 (8.34-11.1)
24-hr	2.52 (2.31-2.78)	3.04 (2.79-3.36)	3.86 (3.53-4.26)	4.57 (4.16-5.02)	5.63 (5.09-6.17)	6.56 (5.89-7.18)	7.60 (6.75-8.29)	8.76 (7.70-9.54)	10.5 (9.10-11.4)	12.1 (10.3-13.1)
2-day	2.93 (2.69-3.23)	3.54 (3.25-3.91)	4.49 (4.12-4.95)	5.29 (4.83-5.83)	6.48 (5.87-7.11)	7.50 (6.75-8.21)	8.62 (7.70-9.42)	9.85 (8.71-10.8)	11.7 (10.2-12.8)	13.3 (11.4-14.5)
3-day	3.10 (2.85-3.41)	3.74 (3.44-4.12)	4.74 (4.35-5.21)	5.58 (5.10-6.12)	6.82 (6.20-7.46)	7.88 (7.12-8.61)	9.06 (8.12-9.87)	10.4 (9.19-11.3)	12.3 (10.7-13.4)	13.9 (12.0-15.2)
4-day	3.27 (3.01-3.59)	3.95 (3.64-4.33)	4.99 (4.58-5.46)	5.86 (5.37-6.41)	7.16 (6.52-7.81)	8.27 (7.49-9.01)	9.50 (8.54-10.3)	10.9 (9.67-11.8)	12.9 (11.3-14.0)	14.6 (12.7-15.9)
7-day	3.85 (3.56-4.21)	4.63 (4.28-5.06)	5.78 (5.34-6.31)	6.76 (6.23-7.36)	8.20 (7.51-8.91)	9.44 (8.60-10.2)	10.8 (9.77-11.7)	12.3 (11.0-13.3)	14.5 (12.8-15.7)	16.4 (14.3-17.8)
10-day	4.42 (4.11-4.78)	5.29 (4.93-5.73)	6.63 (6.07-7.06)	7.56 (7.01-8.16)	9.04 (8.34-9.74)	10.3 (9.43-11.0)	11.6 (10.6-12.5)	13.0 (11.8-14.0)	15.1 (13.5-16.2)	16.7 (14.9-18.1)
20-day	6.02 (5.66-6.41)	7.14 (6.72-7.62)	8.57 (8.05-9.14)	9.72 (9.11-10.3)	11.3 (10.6-12.0)	12.6 (11.7-13.4)	13.9 (12.9-14.8)	15.3 (14.1-16.3)	17.2 (15.8-18.3)	18.7 (17.1-20.0)
30-day	7.47 (7.05-7.92)	8.82 (8.32-9.36)	10.4 (9.79-11.0)	11.6 (11.0-12.3)	13.3 (12.5-14.1)	14.7 (13.7-15.5)	16.0 (15.0-17.0)	17.4 (16.2-18.5)	19.3 (17.8-20.5)	20.8 (19.1-22.1)
45-day	9.41 (8.94-9.92)	11.1 (10.5-11.7)	12.8 (12.2-13.5)	14.2 (13.4-14.9)	15.9 (15.1-16.8)	17.3 (16.3-18.2)	18.6 (17.5-19.6)	19.9 (18.7-20.9)	21.5 (20.2-22.7)	22.8 (21.3-24.1)
60-day	11.3 (10.7-11.8)	13.2 (12.6-13.9)	15.2 (14.4-15.9)	16.6 (15.8-17.5)	18.5 (17.6-19.5)	20.0 (18.9-21.0)	21.3 (20.2-22.4)	22.6 (21.4-23.8)	24.3 (22.9-25.6)	25.5 (24.0-26.9)

[1] Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS).

Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values.

Please refer to NOAA Atlas 14 document for more information.

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PF graphical

Use this table to adjust Design Storm Rainfall depth for runoff volume computation

-Enter Rainfall depth on left side and move to column under appropriate tenths. (Interpolate if needed) Use value show. See Design Note # 10 example problem.

Curve **88**

Reference: NRCS-National Engineering Handbook, Part 630-Hydrology
Ch. 10- Estimation of Direct Runoff from Storm Events, Page 10A-41

Runoff for inches of rainfall—Curve no. 88

Inches	Tenths 0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0	0.00	0.00	0.00	0.00	0.01	0.03	0.06	0.10	0.15	0.20
1	0.25	0.31	0.38	0.44	0.51	0.58	0.66	0.73	0.81	0.89
2	0.97	1.05	1.13	1.21	1.30	1.38	1.47	1.56	1.64	1.73
3	1.82	1.91	2.00	2.09	2.18	2.27	2.36	2.45	2.55	2.64
4	2.73	2.82	2.92	3.01	3.11	3.20	3.29	3.39	3.48	3.58
5	3.67	3.77	3.86	3.96	4.05	4.15	4.24	4.34	4.44	4.53
6	4.63	4.73	4.82	4.92	5.02	5.11	5.21	5.31	5.40	5.50
7	5.60	5.69	5.79	5.89	5.99	6.08	6.18	6.28	6.38	6.47
8	6.57	6.67	6.77	6.87	6.96	7.06	7.16	7.26	7.36	7.45
9	7.55	7.65	7.75	7.85	7.94	8.04	8.14	8.24	8.34	8.44
10	8.53	8.63	8.73	8.83	8.93	9.03	9.13	9.22	9.32	9.42
11	9.52	9.62	9.72	9.82	9.92	10.01	10.11	10.21	10.31	10.41
12	10.51	10.61	10.71	10.81	10.91	11.00	11.10	11.20	11.30	11.40
13	11.50	11.60	11.70	11.80	11.90	11.99	12.09	12.19	12.29	12.39
14	12.49	12.59	12.69	12.79	12.89	12.99	13.09	13.19	13.28	13.38
15	13.48	13.58	13.68	13.78	13.88	13.98	14.08	14.18	14.28	14.38
16	14.48	14.58	14.67	14.77	14.87	14.97	15.07	15.17	15.27	15.37
17	15.47	15.57	15.67	15.77	15.87	15.97	16.07	16.17	16.27	16.37
18	16.46	16.56	16.66	16.76	16.86	16.96	17.06	17.16	17.26	17.36
19	17.46	17.56	17.66	17.76	17.86	17.96	18.06	18.16	18.26	18.36
20	18.46	18.56	18.65	18.75	18.85	18.95	19.05	19.15	19.25	19.35
21	19.45	19.55	19.65	19.75	19.85	19.95	20.05	20.15	20.25	20.35
22	20.45	20.55	20.65	20.75	20.85	20.95	21.05	21.15	21.25	21.35
23	21.44	21.54	21.64	21.74	21.84	21.94	22.04	22.14	22.24	22.34
24	22.44	22.54	22.64	22.74	22.84	22.94	23.04	23.14	23.24	23.34
25	23.44	23.54	23.64	23.74	23.84	23.94	24.04	24.14	24.24	24.34
26	24.44	24.54	24.64	24.74	24.84	24.94	25.03	25.13	25.23	25.33
27	25.43	25.53	25.63	25.73	25.83	25.93	26.03	26.13	26.23	26.33
28	26.43	26.53	26.63	26.73	26.83	26.93	27.03	27.13	27.23	27.33
29	27.43	27.53	27.63	27.73	27.83	27.93	28.03	28.13	28.23	28.33
30	28.43	28.53	28.63	28.73	28.83	28.93	29.03	29.13	29.23	29.33
31	29.43	29.53	29.63	29.73	29.82	29.92	30.02	30.12	30.22	30.32
32	30.42	30.52	30.62	30.72	30.82	30.92	31.02	31.12	31.22	31.32
33	31.42	31.52	31.62	31.72	31.82	31.92	32.02	32.12	32.22	32.32
34	32.42	32.52	32.62	32.72	32.82	32.92	33.02	33.12	33.22	33.32
35	33.42	33.52	33.62	33.72	33.82	33.92	34.02	34.12	34.22	34.32
36	34.42	34.52	34.62	34.72	34.82	34.92	35.02	35.12	35.22	35.32
37	35.42	35.52	35.62	35.72	35.82	35.92	36.02	36.12	36.22	36.32
38	36.42	36.52	36.62	36.71	36.81	36.91	37.01	37.11	37.21	37.31
39	37.41	37.51	37.61	37.71	37.81	37.91	38.01	38.11	38.21	38.31
40	38.41	38.51	38.61	38.71	38.81	38.91	39.01	39.11	39.21	39.31

For 3.04" use 1.86" by interpolation

Note: Runoff value determined by equation $Q = \frac{(P - 0.2S)^2}{P + 0.8S}$

Table A is one method to flood route one event with a storage combined with pump. It is valid for peak flows over 0.47 ft3/s/acre. In this example the 2yr/60 min peak converts to 1.36 ft3/s/acre which is > 0.47 ft3/s/acre. Reference: Title 210-NEH, Part 650, EFH, Ch 11 Ponds and Reservoirs, Pgs. 11-55 a to c

Table A

Using 0.21 the ratio of Vs/Vr = 0.47 from Table A

Vs/Vr	0.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
0.0	1.00	.99	.98	.96	.95	.94	.92	.91	.90	.88
0.1	.87	.85	.84	.82	.81	.79	.78	.76	.75	.74
0.2	.70	.67	.64	.61	.58	.56	.54	.52	.50	.48
0.3	.47	.45	.44	.42	.41	.40	.39	.38	.37	.36
0.4	.35	.32	.30	.28	.26	.24	.23	.21	.20	.19
0.5	.18	.17	.16	.15	.14	.13	.12	.12	.11	.11
0.6	.10	.10	.09	.09	.08	.08	.07	.07	.07	.07
0.7	.06	.06	.06	.06	.05	.05	.05	.05	.04	.04
0.8	.04	.04	.04	.04	.04	.03	.03	.03	.03	.03

Table A: Values of Qo/Qi for pipe flow structures with a discharge over 0.47 $ft^3/s/acre$ (300 csm).

Example #1:

Given: Vs = 5.9 acre-feet or 0.94 in.
Vr = 21.1 acre-feet or 3.4 in.
Qi = 360 ft^3/s
D.A. = 75 acres

Find: Qo

Solution: Find the point for Vs of 0.94 in. and Vr of 3.4 in. in figure 1. Since the point is below the line, use Table A.

$\frac{Vs}{Vr} = \frac{0.94}{3.4} = 0.28$ (Vs and Vr must be in same units)

$\frac{Qo}{Qi} = 0.50$ (From Table A)

$Qo = 0.50 \times Qi = 0.50 \times 360\ ft^3/s = 180\ ft^3/s$

Description of Terms:
Vs = Volume of temporary storage, acre-feet or in.
Vr = Volume of runoff, acre-feet or in.
Qo = Required principal spillway discharge, ft^3/s (Table A)
Qi = Peak flow from design storm, ft^3/s

PRECIPITATION: Annual Rain Volume

Average Precipitation Amounts by Year, Allegheny County, PA	
(year)	*(inches)*
2011	48.3
2010	38.8
2009	31.1
2008	36.1
2007	40.0
2006	36.9
2005	34.0
2004	50.4 *
	39.5"

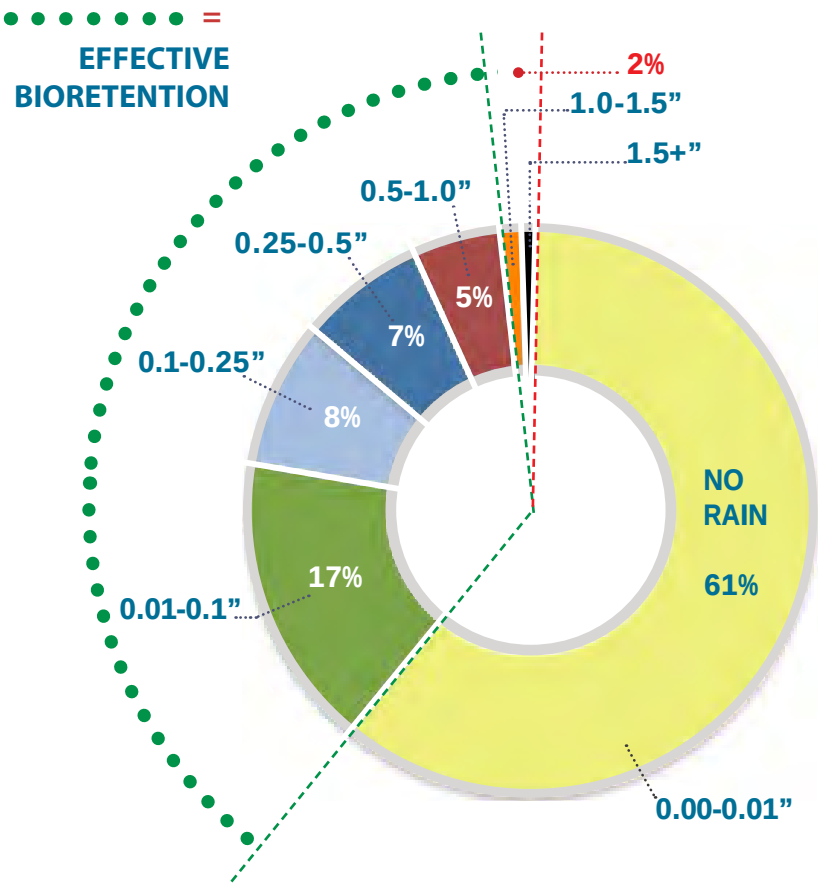
* Hurricane Ivan, in September 2004, accounted for an atypical 7-10" of rain over three days.

The average annual rainfall in Allegheny County, Pennsylvania from 2004 to 2011 was **39.5".**

Meteorology and landscape characteristics, like physiography, influence where rain and snow end up falling on the ground. It's not unusual for a person to drive through a downpour in one area only to travel on dry roads two or five miles away. Large regional landscapes affect rain and snow fall—both amounts increase by a modest percentage as Great Lakes-driven weather moves eastward from Allegheny County towards the Appalachian Mountains.

3 Rivers Wet Weather's Calibrated Radar Rainfall Data was summarized by Landbase Systems on the Precipitation charts in this section.

PRECIPITATION: All Days in a Year



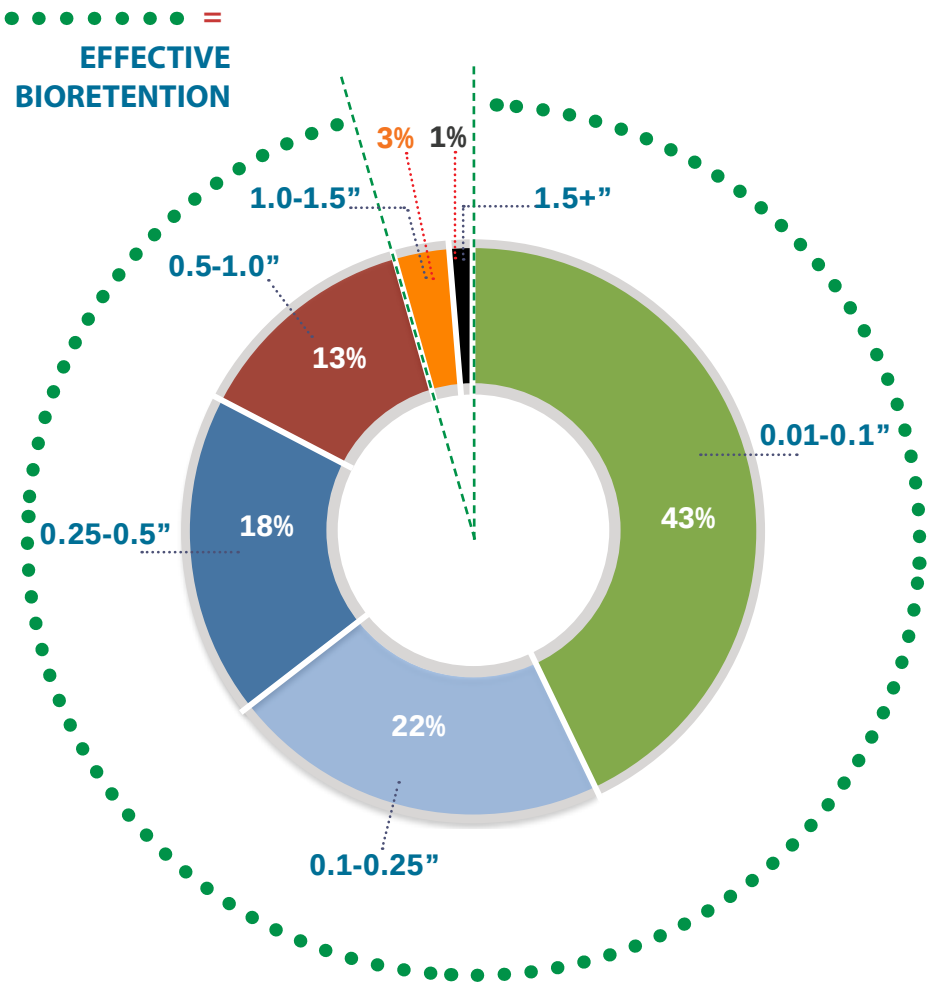
ALL DAYS in an AVERAGE YEAR — RAIN & NO RAIN

One can see from the graphic to the left that 61% of days in a year in this region of Southwest Pennsylvania has virtually no rain (0.0-0.1”); 78% of days has less than 1/10” of precipitation; and, 5% of all days receives between 0.5” to 1.0”—1/3 of annual precipitation.

Design criteria for bioretention as specified in this Primer calls for managing 1” of runoff in 24 hours. (Though when properly designed and maintained, they can efficiently handle greater volumes). Intercepting up to 1” of precipitation represents an average of 91% of annual rainfall (or about 36” per year).

Precipitation Ranges *(inches)*	Average # Days per Year	Percent of ALL Days per Year	Percent of Annual Precipitation
0.0 - 0.01	223	61%	<1%
0.01 - 0.10	61	17%	7%
0.10 - 0.25	31	8%	13%
0.25 - 0.50	26	7%	24%
0.50 - 1.0	18	5%	31%
1.0 - 1.5	4	1%	13%
1.50+	2	1%	12%
	365	**100%**	**100%**

PRECIPITATION: Rain Days in a Year



RAIN DAYS in an AVERAGE YEAR

The graphic to the left illustrates that the vast majority of annual precipitation we receive in Southwest Pennsylvania (39.5" average) is well below 1". In fact, 83% of all annual precipitation is 1/2" per day or less.

96% of all precipitation days fall into the design criteria for bioretention cells to manage 1" of stormwater in a 24-hour period—as specified in this Primer. Well-designed and well-maintained rain gardens with underdrains can readily manage inflows from larger, far more infrequent storms.

Precipitation Ranges *(inches)*	Average # Days per Year	Percent of RAIN Days per Year	Percent of Annual Precipitation
0.01 - 0.1	61	43%	7%
0.1 - 0.25	31	22%	13%
0.25 - 0.50	26	18%	24%
0.50 - 1.0	18	13%	31%
1.0 - 1.5	5	3%	13%
1.50+	2	1%	12%
	143	**100%**	**100%**

IF we control runoff from the small rain events less than 1/2", then we can control most of the runoff most of the time. Most non-point source pollution would be reduced most of the time too! By capturing and retaining the first 1/4" of runoff, we would solve many of the combined sewer overflows in the region.