

HYDROLOGIC AND HYDRAULIC STUDY FOR THE SANDY RUN WATERSHED

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By

Michel Boufadel, Ph.D., Graduate Director, Department of Civil and Environmental
Engineering, Temple University

I- INTRODUCTION

This report provides a narrative for the hydrologic and hydraulic study conducted by Temple University for FEMA for the Sandyrun Watershed. The report has two major sections: The Hydrologic Model and the Hydraulic Model.

The Sandyrun Watershed lies in the upper Delaware River Basin in Pennsylvania and discharges into the Wissahickon Creek located to the North of City of Philadelphia. The watershed is located in Montgomery County. The watershed area is 13.84 square miles (Fig. 1).

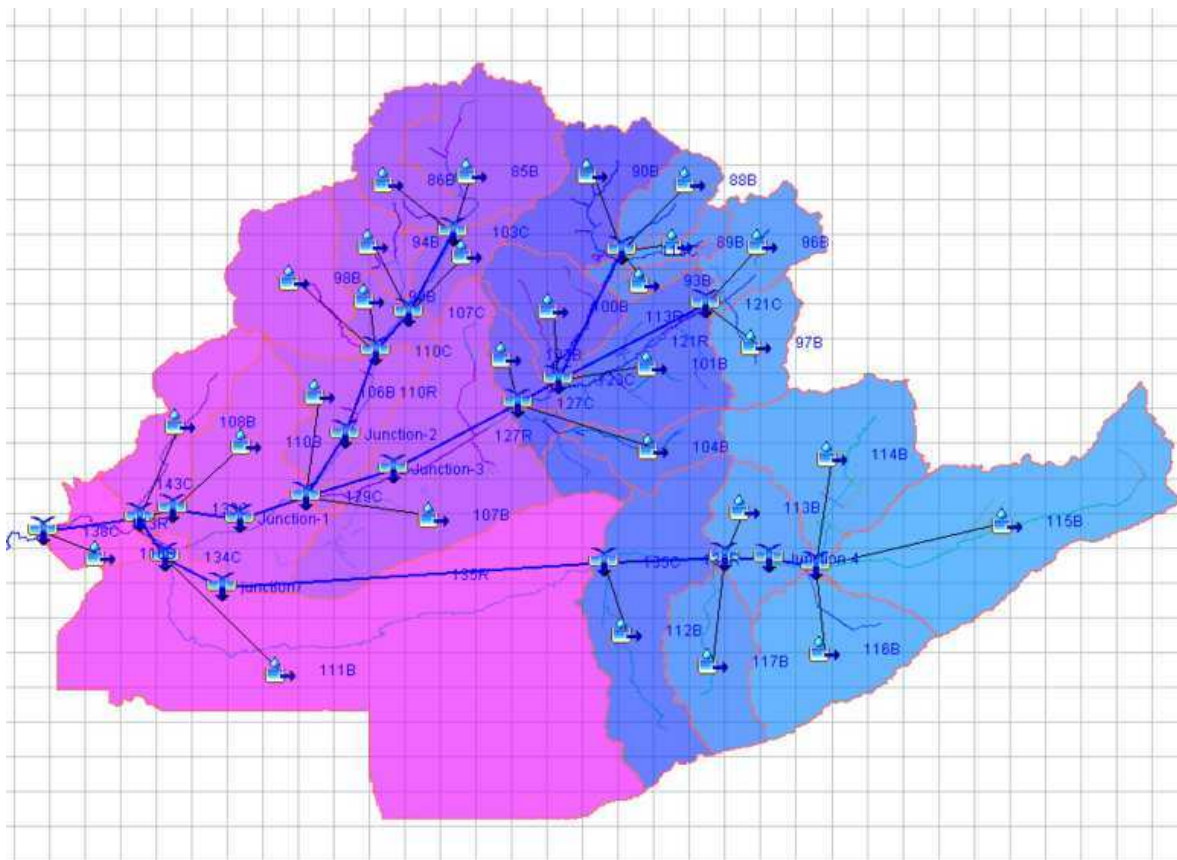


Figure 1: The Sandyrun watershed. For hydrologic modeling purposes, the watershed was considered as consisting of 28 primary subbasins (e.g., 111B).

The topography of the Sandyrun Watershed is characterized by gently rolling hills in the headwaters, and moderately sloping valley in the central part of the watershed, and tidal

flats draining to the Wissahickon Creek. The elevations over the whole watershed range from 402 feet to less than 150 feet (National Geodetic Vertical Datum).

The climate of the region is characterized by warm summers and cold winters with moderate intermediate seasons. Winter temperatures rarely drop below 0°F, and summer temperatures do not often rise above 100°F. The mean annual temperature is 54°F.

II- THE HYDROLOGIC MODEL

For hydrologic modeling, the U.S. Army Corps of Engineers' (COE) software HEC-HMS was used. The watershed was treated as consisting of 28 subbasins, whose areas range from 0.1 to 3.1 mile² with an average of 0.5 mile². A curve number was computed for each subbasin based on Land Use Land Cover (LULC) data and soil type data. The outflows from the subbasins were assumed to pass through Junctions. The junctions are designated by the symbols C in Figure 1 (e.g., junction 134C). They were connected to each other and to the outlet of the watershed by reaches (designated by the symbol R in Figure 1, e.g., 110R).

Basin	Area (mile ²)	CN	Percent Impervious	Time lag (minute)
100B	0.3306	81	30	26.4
101B	0.5125	81.69	16	26.5
102B	0.1312	85.2	30	22.3
104B	0.2	80.66	15	23.6
106B	0.3814	81	20	31.4
107B	1.0484	82.73	10	33.8
108B	0.3718	83.83	25	31.8
110B	0.6765	90.00	30	27.2
111B	3.1098	85.00	30	62.7
112B	0.7662	89.00	30	32.3
113B	0.2991	87.60	30	17.8
114B	0.6523	88.30	30	33.7
115B	1.1069	82.65	0	48.4
116B	0.5426	86.96	20	21.3
117B	0.3687	86.93	35	24.7
118B	0.1789	77.14	5	17.5
85B	0.5069	84.5	30	29.8
86B	0.2420	81.73	0	27.7
88B	0.1843	85.27	15	22.3
89B	0.0770	81.67	0	20.4
90B	0.3836	81.33	20	24.9
93B	0.0664	80.28	15	23.7
94B	0.1943	82.16	5	26.5
95B	0.1681	81.02	5	21.1
96B	0.2591	83.52	35	20.9
97B	0.2331	80.96	20	18.4

98B	0.4635	86.40	30	31.8
99B	0.1208	84.10	30	13.9

Watershed properties (slope, land use, etc...) were used to estimate the parameters. The Curve numbers were computed based on the landuse data obtained from the Delaware Valley Regional Planning Commission DVRPC (www.dvrpc.org) at the 1/2,000 resolution based the year 2000 aerial imagery and the soil type data obtained from the Pennsylvania Spatial Data Access, PASDA, (<http://www.pasda.psu.edu/>) at the resolution 1/24,000, which is the highest available from the National Resources Conservation Center. The percent impervious was obtained from OrthoPhotos, and it was usually less than 30% of the area of the corresponding basin. This value could be considered high. However, due to the highly efficient stormwater drainage network in the watershed and the small size of the subbasins, it is expected that a large portion of the rainfall (i.e. 30%) run off of the subbasin prior to considerable infiltration takes place on that volume.

Water flow between basins and through the reaches was modeled using the Kinematic Wave method, whose parameters for the corresponding streams are reported in Table 2. For each subbasin, the hydrologic parameters to compute were the initial infiltration volume (Ia), the lag times of the SCS hydrographs, and the storage characteristics of the floodplains. A nominal value of 0.2S was used for the parameter Ia, where S is the total potential loss volume. The lag time was obtained based on the curve number and the slope of the subbasin using the SCS method. The storage was modeled using the Modified Puls Method which is a type of River Routing with storage. It views the reach under study as made up of a number of subreaches. This number is obtained as the integer approximation for the ratio of the reach length by the product of the wave celerity and the simulation time step. One subreach indicates a simple reservoir, and a high number of subreaches indicates translation without storage, approaching therefore the behavior of a kinematic wave. The storage-outflow values were obtained by running HEC-RAS for the four design storms (10 year, 50 year, 100 year and 500 year) and computing the flow and storage at these locations. A curve was fitted at these four points to obtain storage-outflow at different flow values. Appendix II-A reports the storage-outflow values.

Reach ID	Length (feet)	Width (feet)	Slope (ft/ft)	Manning's n
107R	1642.7	15	0.0109	0.03
110R	5108.06	20	0.0034	0.03
113R	5569.52	20	0.0051	0.03
121R	5569.12	20	0.0129	0.03
127R	7972.58	30	0.002	0.03
129R	6657.6	40	0.0022	0.03
134R	609.26	40	0.00011	0.03

135R	15637.9	40	0.0017	0.03
139R	6670.83	20	0.0122	0.03
140R	3077.66	20	0.0011	0.03
143R	3320.95	40	0.0009	0.03

Design Storms

The SCS Type II storms of return periods 10, 50, 100, and 500 were used as the design storms, per FEMA. The total amounts of rainfall were obtained from the NOAA website <http://hdsc.nws.noaa.gov/hdsc/pfds/> at the location (Lat=40.14; Long=-75.1), (Willow Grove). The upper 95% confidence level gave the following volumes in inches, 5.22 (five point twenty two), 7.30 (seven point thirty), 8.32 (eight point thirty two), 11.07 (eleven point zero seven), for the 10, 50, 100, and 500 year storms. The temporal distribution of rainfall pulses for the design storms for the area are of the SCS Type II, whose maximum occurs at the twelfth hour after the beginning of rainfall. The rainfall of the SCS storms was started arbitrarily at midnight on **June 01, 2007**. The peak flows and volumes of the design storms at various locations in the Sandyrun watershed are reported in tables in Appendix II-B. The peak flows at the Junctions are obtained by getting the peak flows of the combined hydrographs at the junctions. Note that the increase of the peak flow with the return period was larger than the increase in total rainfall. For example, the total rainfall for the 100 year storm was around 1.5 times larger than that of the 10 year storm, but the peak flows ratio was around 2.0. This could be due to the diminishing relative effects of rainfall loss and/or nonlinearity in the response of the watershed.

III- THE HYDRAULIC MODEL

The hydraulic study was conducted for the Whole Watershed. Within the Watershed, the stream reaches were obtained based on a combination of aerial survey and land topography. A Shape file was created in GIS for the stream reaches. The streams were named (numbered) arbitrarily, in part, because many of them did not have names, and it was thought that such a numbering eliminates the need to refer to nested tributaries.

Shape files for the banks and flowpaths were generated by creating lines at 10 and 20 feet from the stream centerlines, respectively. The Manning's coefficient for the streams was obtained by assigning a value for 23 categories based on the landuse data (obtained from DVRPC).

Table 3 Values of Manning's coefficient, "n", for 23 landuse categories	
Vacant	0.030
Wooded	0.100
Residential: Multi-Family	0.050
Recreation	0.030

Community Services	0.050
Parking: Multi-Family	0.020
Commercial	0.050
Parking: Commercial	0.020
Residential: Single-Family Detached	0.050
Parking: Light Manufacturing	0.020
Agriculture	0.030
Parking: Community Services	0.020
Parking: Transportation	0.020
Utility	0.030
Manufacturing: Light Industrial	0.020
Water	0.030
Parking: Recreation	0.010
Residential: Mobile Home	0.050
Parking: Row Home	0.020
Residential: Row Home	0.050
Transportation	0.020
Mining	0.030
Parking: Utility	0.020

The landuse shape file was then overlaid on the stream network, and the corresponding Manning's coefficient was automatically obtained using HEC-GEORAS. Because the landuse shape file was georeferenced with an accuracy of 100 feet at some locations, the Manning's values were not always representing the physics of the problem. This was corrected when observed, but no systematic check on the "n" values was conducted.

The drainage area for each reach was obtained from the software WMS using the shape files of the streams and the DEM of the watershed. The drainage areas are reported in Tables in Appendix III.

To obtain the floodplains in any particular stream, one needs to use the peak flow in that particular stream and run HEC-RAS (River Analysis System) in the steady-state mode. The peak flow Q_i in each stream "i" was obtained according to the formula:

$$Q_i = \frac{A_i}{A_b} Q_b + Q_{upstream} \quad (1)$$

Where Q_b is the peak flow from the subbasin in which stream "i" is located,
 A_i is the area draining into stream i,
and A_b is the drainage area of the subbasin.

The term $Q_{upstream}$ indicates peak flow rate from an upstream subbasin that is routed through reach "i". The peak flows based on Equation (1) are reported in Tables in Appendix III.

Although it has been the standard approach by FEMA to model the hydraulics in streams that drain 1.0 mi^2 and more, we modeled streams that drain 0.1 mi^2 and above. The lower

limit is important for Pennsylvania where a stream encroachment study is needed for streams draining more than 100 acres (0.15 mi²). All structures (bridges, culverts) in streams draining 0.50 mi² or more were included and modeled. The number of these structures was 47. South of the Turnpike we surveyed and included structures in streams draining less than 0.5 mi². But at all other areas draining less than 0.5 mi² such structures were not included. This implies that the results from these areas (where no structures were modeled) are indicative of the probability of flooding and not the exact extent of flooding (or lack of). Photographs of the structures that were surveyed are reported under the GIS folder. The photographs could be retrieved based on the coordinates of the structures.

The peak flows in each reach are reported in Appendix III where there the names of the reaches (numbers) match the GIS files. All the streams were treated as disconnected and their downstream slopes were used as the boundary conditions, as per the requirements of FEMA. However, it is worth noting that within each subbasin, the peak flows of most streams are coincident within 15 minutes. The profiles of the streams are reported in Appendix III where the stream naming was made to match known stream names (Sandy Run, Tributary 1 to Rapp Run, etc.). The backwater limits are also shown. The actual files for these profiles are in the folder Reach Profiles under the RAS folder, and they are RASLOT files.

END OF MAIN DOCUMENT

APPENDICES:

There is no Appendix I, but the numbering of Appendices is intended to match the corresponding Section in the document: II) Hydrology and III) Hydraulics.

APPENDIX II-A: STORAGE OUTFLOW RELATION

Reach 130 Modified Puls Applied Using Two equal length subreaches	
Discharge(cfs)	Volume(Acre-foot)
3924	70.481
5500	101.05
7000	130.71
8500	160.81
10000	191.27
11500	222.03
13000	253.07
14500	284.35
16000	315.85
17500	347.54
19000	379.42
20500	411.47
22000	443.68
23500	476.04

Reach 148 Modified Puls applied Using Two Two equal length subreaches	
Discharge(cfs)	Volume(Acre-foot)
3987.7	188.73
5564.7	339.86
6000	347.17
7500	372.37
9000	397.57
10500	422.77
12000	447.97

13500	473.17
15000	498.37
16500	523.57
18000	548.77
19500	573.97
21000	599.17

Reach 27 Modified Puls was Applied Using one Subreach	
Discharge(cfs)	Volume(Acre-foot)
3193	38.72
5000	50.406
7500	63.979
10000	75.773
12500	86.399
15000	96.177
17500	105.3
20000	113.91
22500	122.08
25000	129.88
27500	137.37

Reach 56 Modified Puls Applied Using one Subreach	
Discharge(cfs)	Volume(Acre-foot)
6732.1	758.6
7000	1213.1
10000	1376
12500	1511.8
15000	1647.5
17500	1783.3
20000	1919
22500	2054.8
25000	2190.5
27500	2326.3
30000	2462
32500	2597.8

Reach 57 Modified Puls Applied Using one Subreach	
Discharge(cfs)	Volume(Acre-foot)
6732.1	153.81
9000	188.32
11500	223.41
14000	256.24
16500	287.34
19000	317.03
21500	345.56
24000	373.1
26500	399.79
29000	425.72
31500	450.98
34000	475.64
36500	499.75
39000	523.38
41500	546.54
44000	569.29
46500	591.65
49000	613.65
51500	635.31
54000	656.65

Reach 58 Modified Puls Applied Using Two Equal Lengths Subreaches	
Discharge(cfs)	Volume(Acre-foot)
6524.3	192.04
9000	241.32
11500	287.19
14000	330.24
16500	371.1
19000	410.19
21500	447.82
24000	484.2
26500	519.49
29000	553.83
31500	587.32

34000	620.04
100000	1333.7
166000	1911.4
232000	2424.2
298000	2895.8
364000	3337.8
430000	3756.9
496000	4157.8

APPENDIX II-B: RESULTS OF THE DESIGN STORMS

Table II-B1: HEC-HMS Results of the SCS 10-year storm				
Location	Peak Discharge(CFS)	Time of Peak	Volume(AC-FT)	Drainage Area(Mi2)
100B	540.9	01Jun2007, 23:18	66.8	0.3306
101B	805.3	01Jun2007, 23:19	97.3	0.5125
102B	258.5	01Jun2007, 23:14	28.5	0.1312
103C	1168.1	01Jun2007, 23:21	155.4	0.7489
103R	1167.4	01Jun2007, 23:23	155.3	0.7489
104B	330.1	01Jun2007, 23:16	36.9	0.2
106B	533	01Jun2007, 23:24	72.9	0.3814
107B	1397.1	01Jun2007, 23:26	197.4	1.0484
107C	1709.5	01Jun2007, 23:20	219.8	1.1113
107R	1708.5	01Jun2007, 23:22	219.7	1.1113
108B	555.8	01Jun2007, 23:24	77.2	0.3718
110B	1265.2	01Jun2007, 23:19	165.9	0.6765
110C	2586.6	01Jun2007, 23:21	355.4	1.6956
110R	2581.4	01Jun2007, 23:27	353.7	1.6956
111B	2957.2	01Jun2007, 23:56	682.7	3.1098
112B	1264.8	01Jun2007, 23:24	189	0.7662
113B	708.7	01Jun2007, 23:10	71.3	0.2991
113C	1219.1	01Jun2007, 23:16	137.1	0.7113
113R	1215.2	01Jun2007, 23:24	136.8	0.7113
114B	1042	01Jun2007, 23:25	160.4	0.6523
115B	1094.9	01Jun2007, 23:42	196.5	1.1069
116B	1110.2	01Jun2007, 23:13	117.5	0.5426
117B	706.1	01Jun2007, 23:16	84.1	0.3687
118B	308.8	01Jun2007, 23:10	28.1	0.1789
121C	982.9	01Jun2007, 23:12	100.6	0.4922
121R	978.8	01Jun2007, 23:18	100.2	0.4922

123C	3481.5	01Jun2007, 23:20	401.2	2.0466
127C	3359.1	01Jun2007, 23:31	466.2	2.3778
127R	3354.5	01Jun2007, 23:43	459.9	2.3778
129C	3951.1	02Jun2007, 00:08	1073.2	5.5032
129R	3949.5	02Jun2007, 00:17	1063.1	5.5032
133C	3904.1	02Jun2007, 00:30	1224.6	6.1797
134C	6298.3	02Jun2007, 00:14	1470.8	6.8456
134R	6296.6	02Jun2007, 00:16	1468	6.8456
135C	4410	01Jun2007, 23:31	813.7	3.7358
135R	4404.5	01Jun2007, 23:54	792.2	3.7358
138C	10248.4	02Jun2007, 00:23	2785.5	13.576
139C	3269.6	01Jun2007, 23:30	627.3	2.9696
139R	3267.7	01Jun2007, 23:36	624.7	2.9696
140C	2775.3	01Jun2007, 23:22	474.4	2.3018
140R	2595.6	01Jun2007, 23:38	471.9	2.3018
143C	10219	02Jun2007, 00:18	2769.8	13.3971
143R	10217.9	02Jun2007, 00:23	2757.4	13.3971
85B	821.1	01Jun2007, 23:21	113.4	0.5069
86B	347.6	01Jun2007, 23:20	41.9	0.242
88B	350.4	01Jun2007, 23:14	37.8	0.1843
89B	135.2	01Jun2007, 23:13	13.3	0.077
90B	633	01Jun2007, 23:17	73.9	0.3836
93B	108.3	01Jun2007, 23:16	12.1	0.0664
94B	296.7	01Jun2007, 23:19	35.1	0.1943
95B	289.1	01Jun2007, 23:13	29.4	0.1681
96B	524.1	01Jun2007, 23:13	56	0.2591
97B	462.4	01Jun2007, 23:11	44.6	0.2331
98B	743.5	01Jun2007, 23:23	108.7	0.4635
99B	310	01Jun2007, 23:06	26.9	0.1208
Junction-1	3949.5	02Jun2007, 00:17	1063.1	5.5032
Junction-2	2581.4	01Jun2007, 23:27	353.7	1.6956
Junction-3	3354.5	01Jun2007, 23:43	459.9	2.3778
Junction-4	2596.7	01Jun2007, 23:32	474	2.3018
junction7	4404.5	01Jun2007, 23:54	792.2	3.7358
Reach 130	3003.2	01Jun2007, 23:33	400.7	2.0466
Reach148	2294	02Jun2007, 00:16	455.9	2.3778
Reach27	2596.7	01Jun2007, 23:32	474	2.3018
Reach56	1038.6	02Jun2007, 00:05	346.9	1.6956
Reach57	3731.7	02Jun2007, 00:32	1058.7	5.5032
Reach58	3712.4	02Jun2007, 00:21	788.1	3.7358

Table II-B2: HEC-HMS Results of the SCS 50-year storm				
Location	Peak Discharge(CFS)	Time of Peak	Volume(AC-FT)	Drainage Area(Mi2)
100B	821.6	01Jun2007, 23:18	101.3	0.3306
101B	1242.7	01Jun2007, 23:18	150.4	0.5125
102B	383.4	01Jun2007, 23:14	42.6	0.1312
103C	1762.4	01Jun2007, 23:21	233.9	0.7489

103R	1761	01Jun2007, 23:22	233.8	0.7489
104B	513.4	01Jun2007, 23:16	57.4	0.2
106B	822.2	01Jun2007, 23:23	112.4	0.3814
107B	2158.9	01Jun2007, 23:26	306.3	1.0484
107C	2614.1	01Jun2007, 23:20	335.5	1.1113
107R	2612.5	01Jun2007, 23:21	335.4	1.1113
108B	836.2	01Jun2007, 23:23	116.5	0.3718
110B	1823.1	01Jun2007, 23:19	239.5	0.6765
110C	3900.7	01Jun2007, 23:20	533.5	1.6956
110R	3898.5	01Jun2007, 23:26	531.4	1.6956
111B	4388.6	01Jun2007, 23:55	1012.5	3.1098
112B	1823.5	01Jun2007, 23:24	272	0.7662
113B	1029.2	01Jun2007, 23:10	103.6	0.2991
113C	1871.2	01Jun2007, 23:15	211.1	0.7113
113R	1867.1	01Jun2007, 23:22	210.7	0.7113
114B	1503.8	01Jun2007, 23:25	230.9	0.6523
115B	1719.9	01Jun2007, 23:41	310.2	1.1069
116B	1644.1	01Jun2007, 23:13	175.7	0.5426
117B	1034.2	01Jun2007, 23:16	123.9	0.3687
118B	503.2	01Jun2007, 23:10	45.6	0.1789
121C	1485	01Jun2007, 23:12	152.2	0.4922
121R	1482.1	01Jun2007, 23:17	151.8	0.4922
123C	5334.3	01Jun2007, 23:19	614.2	2.0466
127C	5116.9	01Jun2007, 23:31	713.5	2.3778
127R	5109.2	01Jun2007, 23:41	705.8	2.3778
129C	6117.8	02Jun2007, 00:05	1640.6	5.5032
129R	6116.2	02Jun2007, 00:13	1628	5.5032
133C	6061.5	02Jun2007, 00:25	1861.2	6.1797
134C	9655	02Jun2007, 00:10	2189.5	6.8456
134R	9653.5	02Jun2007, 00:11	2186	6.8456
135C	6787.7	01Jun2007, 23:32	1209.9	3.7358
135R	6772.4	01Jun2007, 23:51	1182.9	3.7358
138C	15828.8	02Jun2007, 00:17	4193.9	13.576
139C	5130.8	01Jun2007, 23:29	941.1	2.9696
139R	5126.7	01Jun2007, 23:34	937.9	2.9696
140C	4164.2	01Jun2007, 23:22	716.8	2.3018
140R	4027.7	01Jun2007, 23:34	713.7	2.3018
143C	15780.4	02Jun2007, 00:14	4163.6	13.3971
143R	15778.1	02Jun2007, 00:17	4148.3	13.3971
85B	1214.7	01Jun2007, 23:21	167.3	0.5069
86B	549.3	01Jun2007, 23:20	66.7	0.242
88B	527.2	01Jun2007, 23:14	57.3	0.1843
89B	213.2	01Jun2007, 23:13	21.2	0.077
90B	972.9	01Jun2007, 23:17	113.7	0.3836
93B	168.9	01Jun2007, 23:16	18.9	0.0664
94B	463.4	01Jun2007, 23:18	55.1	0.1943
95B	455.6	01Jun2007, 23:13	46.6	0.1681
96B	779.8	01Jun2007, 23:13	83.5	0.2591

97B	711	01Jun2007, 23:11	68.7	0.2331
98B	1086.3	01Jun2007, 23:23	158.4	0.4635
99B	458.3	01Jun2007, 23:06	39.7	0.1208
Junction-1	6116.2	02Jun2007, 00:13	1628	5.5032
Junction-2	3898.5	01Jun2007, 23:26	531.4	1.6956
Junction-3	5109.2	01Jun2007, 23:41	705.8	2.3778
Junction-4	4033	01Jun2007, 23:29	716.3	2.3018
junction7	6772.4	01Jun2007, 23:51	1182.9	3.7358
Reach 130	4567.7	01Jun2007, 23:33	613.5	2.0466
Reach148	3538.4	02Jun2007, 00:13	700.1	2.3778
Reach27	4033	01Jun2007, 23:29	716.3	2.3018
Reach56	1575.8	02Jun2007, 00:02	521.9	1.6956
Reach57	5792.4	02Jun2007, 00:27	1621.6	5.5032
Reach58	5638.5	02Jun2007, 00:15	1177	3.7358

Table II-B3: HEC-HMS Results of the SCS 100-year storm

Location	Peak Discharge(CFS)	Time of Peak	Volume(AC-FT)	Drainage Area(Mi2)
100B	960.1	01Jun2007, 23:18	118.6	0.3306
101B	1458.5	01Jun2007, 23:18	177	0.5125
102B	444.6	01Jun2007, 23:14	49.5	0.1312
103C	2055.3	01Jun2007, 23:21	273.1	0.7489
103R	2054.4	01Jun2007, 23:22	273	0.7489
104B	604.2	01Jun2007, 23:15	67.7	0.2
106B	965.1	01Jun2007, 23:23	132.1	0.3814
107B	2533.9	01Jun2007, 23:26	360.8	1.0484
107C	3060.7	01Jun2007, 23:20	393.4	1.1113
107R	3059.4	01Jun2007, 23:21	393.2	1.1113
108B	974	01Jun2007, 23:23	136.1	0.3718
110B	2096.4	01Jun2007, 23:19	275.9	0.6765
110C	4550.5	01Jun2007, 23:20	622.3	1.6956
110R	4548	01Jun2007, 23:25	620.1	1.6956
111B	5092.6	01Jun2007, 23:55	1176.3	3.1098
112B	2098.1	01Jun2007, 23:24	312.9	0.7662
113B	1186.6	01Jun2007, 23:10	119.5	0.2991
113C	2192.3	01Jun2007, 23:15	248.1	0.7113
113R	2186.7	01Jun2007, 23:22	247.7	0.7113
114B	1730.8	01Jun2007, 23:25	265.8	0.6523
115B	2028.3	01Jun2007, 23:41	367.3	1.1069
116B	1904.8	01Jun2007, 23:13	204.6	0.5426
117B	1194.6	01Jun2007, 23:16	143.5	0.3687
118B	600.3	01Jun2007, 23:10	54.6	0.1789
121C	1732	01Jun2007, 23:12	178	0.4922
121R	1725.9	01Jun2007, 23:17	177.6	0.4922
123C	6244.1	01Jun2007, 23:19	720.8	2.0466

127C	5974.6	01Jun2007, 23:31	837.3	2.3778
127R	5963.8	01Jun2007, 23:40	829	2.3778
129C	7025.8	02Jun2007, 00:03	1924.6	5.5032
129R	7024.1	02Jun2007, 00:11	1910.8	5.5032
133C	7017.4	02Jun2007, 00:23	2179.4	6.1797
134C	11429.7	02Jun2007, 00:08	2547.3	6.8456
134R	11427.2	02Jun2007, 00:10	2543.4	6.8456
135C	8047	01Jun2007, 23:30	1406.6	3.7358
135R	8015.9	01Jun2007, 23:49	1377.7	3.7358
138C	18616.2	02Jun2007, 00:15	4896.8	13.576
139C	6070.4	01Jun2007, 23:27	1097.3	2.9696
139R	6068.3	01Jun2007, 23:32	1093.7	2.9696
140C	4847.8	01Jun2007, 23:22	837.6	2.3018
140R	4720.4	01Jun2007, 23:33	834.2	2.3018
143C	18560.1	02Jun2007, 00:11	4858.9	13.3971
143R	18555	02Jun2007, 00:15	4842.2	13.3971
85B	1408.6	01Jun2007, 23:21	194	0.5069
86B	648.9	01Jun2007, 23:20	79.1	0.242
88B	613.7	01Jun2007, 23:14	67	0.1843
89B	251.8	01Jun2007, 23:12	25.2	0.077
90B	1140.6	01Jun2007, 23:17	133.6	0.3836
93B	198.9	01Jun2007, 23:16	22.4	0.0664
94B	545.7	01Jun2007, 23:18	65.2	0.1943
95B	537.8	01Jun2007, 23:13	55.2	0.1681
96B	905.3	01Jun2007, 23:13	97.2	0.2591
97B	833.6	01Jun2007, 23:10	80.8	0.2331
98B	1255.1	01Jun2007, 23:23	183	0.4635
99B	531.4	01Jun2007, 23:06	46.1	0.1208
Junction-1	7024.1	02Jun2007, 00:11	1910.8	5.5032
Junction-2	4548	01Jun2007, 23:25	620.1	1.6956
Junction-3	5963.8	01Jun2007, 23:40	829	2.3778
Junction-4	4722.4	01Jun2007, 23:28	837	2.3018
junction7	8015.9	01Jun2007, 23:49	1377.7	3.7358
Reach 130	5331.6	01Jun2007, 23:33	720.1	2.0466
Reach148	4026.9	02Jun2007, 00:18	822.5	2.3778
Reach27	4722.4	01Jun2007, 23:28	837	2.3018
Reach56	1842.3	02Jun2007, 00:02	609.2	1.6956
Reach57	6704.3	02Jun2007, 00:27	1903.5	5.5032
Reach58	6667.4	02Jun2007, 00:11	1371	3.7358

Table II-B4: HEC-HMS Results of the SCS 500-year storm				
Location	Peak Discharge(CFS)	Time of Peak	Volume(AC-FT)	Drainage Area(Mi2)
100B	1333.4	01Jun2007, 23:18	165.6	0.3306
101B	2039.5	01Jun2007, 23:18	249.7	0.5125
102B	608.8	01Jun2007, 23:14	68.4	0.1312
103C	2844.6	01Jun2007, 23:21	380	0.7489
103R	2843.5	01Jun2007, 23:22	379.8	0.7489

104B	848.9	01Jun2007, 23:15	96	0.2
106B	1350.3	01Jun2007, 23:23	186.2	0.3814
107B	3543.3	01Jun2007, 23:25	509.7	1.0484
107C	4264.8	01Jun2007, 23:19	551.4	1.1113
107R	4261.5	01Jun2007, 23:20	551.2	1.1113
108B	1344.5	01Jun2007, 23:23	189.4	0.3718
110B	2831.3	01Jun2007, 23:18	374.2	0.6765
110C	6300	01Jun2007, 23:20	864.4	1.6956
110R	6296.3	01Jun2007, 23:24	862	1.6956
111B	6987.8	01Jun2007, 23:55	1621.5	3.1098
112B	2838.1	01Jun2007, 23:24	423.9	0.7662
113B	1610.1	01Jun2007, 23:10	162.8	0.2991
113C	3056.5	01Jun2007, 23:15	349.2	0.7113
113R	3050	01Jun2007, 23:21	348.7	0.7113
114B	2343	01Jun2007, 23:25	360.2	0.6523
115B	2858.1	01Jun2007, 23:41	523.6	1.1069
116B	2603.7	01Jun2007, 23:13	282.9	0.5426
117B	1625	01Jun2007, 23:16	196.9	0.3687
118B	863.4	01Jun2007, 23:10	79.3	0.1789
121C	2397.4	01Jun2007, 23:11	248.3	0.4922
121R	2393.4	01Jun2007, 23:16	247.7	0.4922
123C	8699.1	01Jun2007, 23:19	1011.7	2.0466
127C	8277.9	01Jun2007, 23:30	1175.2	2.3778
127R	8265	01Jun2007, 23:39	1165.5	2.3778
129C	9367.3	01Jun2007, 23:49	2700.1	5.5032
129R	9356.2	01Jun2007, 23:56	2683.6	5.5032
133C	9654.1	02Jun2007, 00:10	3048.1	6.1797
134C	16679.4	02Jun2007, 00:02	3519.6	6.8456
134R	16674	02Jun2007, 00:03	3514.9	6.8456
135C	11327.8	01Jun2007, 23:28	1942	3.7358
135R	11307.7	01Jun2007, 23:44	1907.1	3.7358
138C	26839.4	02Jun2007, 00:06	6811.6	13.576
139C	8571.9	01Jun2007, 23:25	1522.2	2.9696
139R	8566	01Jun2007, 23:29	1518	2.9696
140C	6688.5	01Jun2007, 23:22	1166.7	2.3018
140R	6572.5	01Jun2007, 23:32	1162.4	2.3018
143C	26750.5	02Jun2007, 00:03	6752.3	13.3971
143R	26739.3	02Jun2007, 00:06	6732.3	13.3971
85B	1931.5	01Jun2007, 23:21	266.8	0.5069
86B	917.4	01Jun2007, 23:19	113.2	0.242
88B	845.9	01Jun2007, 23:14	93.5	0.1843
89B	355.6	01Jun2007, 23:12	36	0.077
90B	1592.2	01Jun2007, 23:16	188	0.3836
93B	279.9	01Jun2007, 23:15	31.7	0.0664
94B	767.1	01Jun2007, 23:18	92.7	0.1943
95B	759.3	01Jun2007, 23:13	78.9	0.1681
96B	1242.5	01Jun2007, 23:13	134.5	0.2591
97B	1164.7	01Jun2007, 23:10	113.8	0.2331

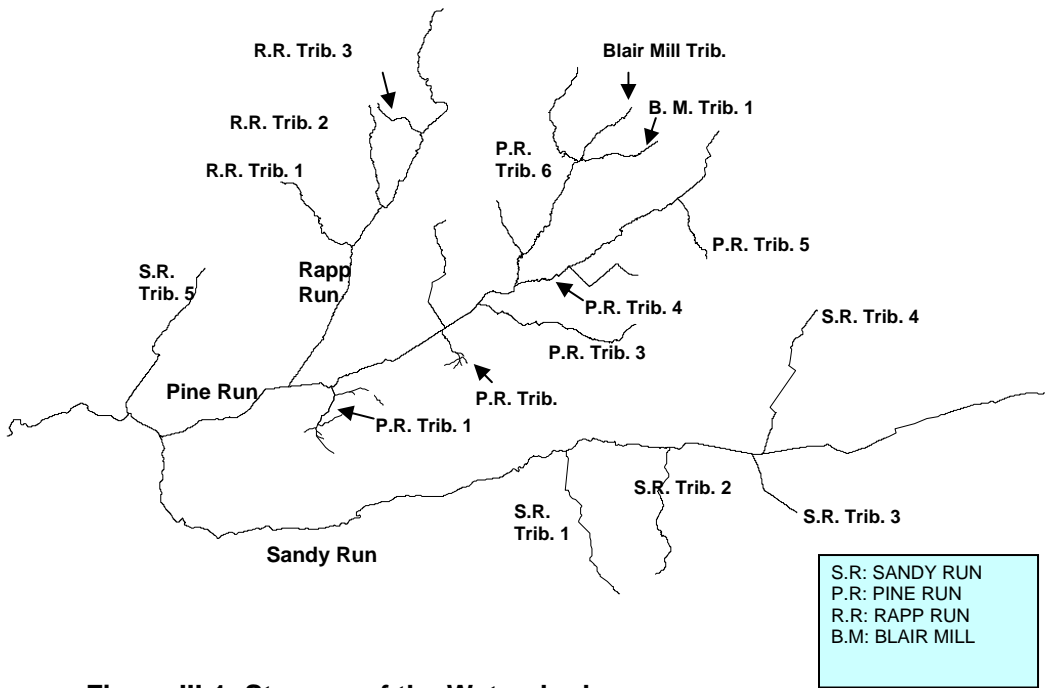
98B	1710.2	01Jun2007, 23:23	249.8	0.4635
99B	728.1	01Jun2007, 23:06	63.4	0.1208
Junction-1	9356.2	01Jun2007, 23:56	2683.6	5.5032
Junction-2	6296.3	01Jun2007, 23:24	862	1.6956
Junction-3	8265	01Jun2007, 23:39	1165.5	2.3778
Junction-4	6580	01Jun2007, 23:27	1165.9	2.3018
junction7	11307.7	01Jun2007, 23:44	1907.1	3.7358
Reach 130	7378.2	01Jun2007, 23:32	1010.8	2.0466
Reach148	4996.1	02Jun2007, 00:20	1156.7	2.3778
Reach27	6580	01Jun2007, 23:27	1165.9	2.3018
Reach56	2563.7	02Jun2007, 00:00	847.5	1.6956
Reach57	9094.9	02Jun2007, 00:15	2673.9	5.5032
Reach58	9820.5	02Jun2007, 00:03	1898.1	3.7358

APPENDIX III: Hydraulics

Table III-A: Peak Flows and Drainage Areas for Reaches in the Watershed. The naming of the reaches herein matches with the GIS file. The naming based on known streams is reported in Figure III-1 below.					
Reach	10 yr	50 yr	100 yr	500 yr	Area, mi ²
R1	138.15	214.86	252.86	355.26	0.083706
R2	0.0001	0.0002	0.0003	0.0004	0.00284
R3	0.0001	0.0002	0.0003	0.0004	0.00284
R4	0.0001	0.0002	0.0003	0.0004	0.0463
R5	0.0001	0.0002	0.0003	0.0004	0.049
R6	410.7	631.27	740.1	1033.1	0.2489
R7	0.0001	0.0002	0.0003	0.0004	0.054
R8	2.48	3.85	4.53	6.37	0.0015
R9	87.52	135.1	158.51	221.66	0.0557
R10	0.0001	0.0002	0.0003	0.0004	0.00215
R11	0.0001	0.0002	0.0003	0.0004	0.00244
R12	2136.9	3223.7	3759.1	5201.1	1.7593
R13	743.5	1086.3	1255.1	1710.2	0.463
R14	0.0001	0.0002	0.0003	0.0004	0.0244
R15	0.0001	0.0002	0.0003	0.0004	0.0028
R16	902.54	1302.54	1499.2	2029.43	0.565
R17	10248.4	15828.8	18616.2	26839.4	13.8346
R18	468.25	728.26	857.06	1204.2	0.3024
R19	347.6	549.3	648.9	917.4	0.24142
R20	251.96	393.52	463.41	651.42	0.165
R21	0.0001	0.0002	0.0003	0.0004	0.003744
R22	0.0001	0.0002	0.0003	0.0004	0.0218
R23	708.2	1020.99	1147.74	1589.1	0.4251

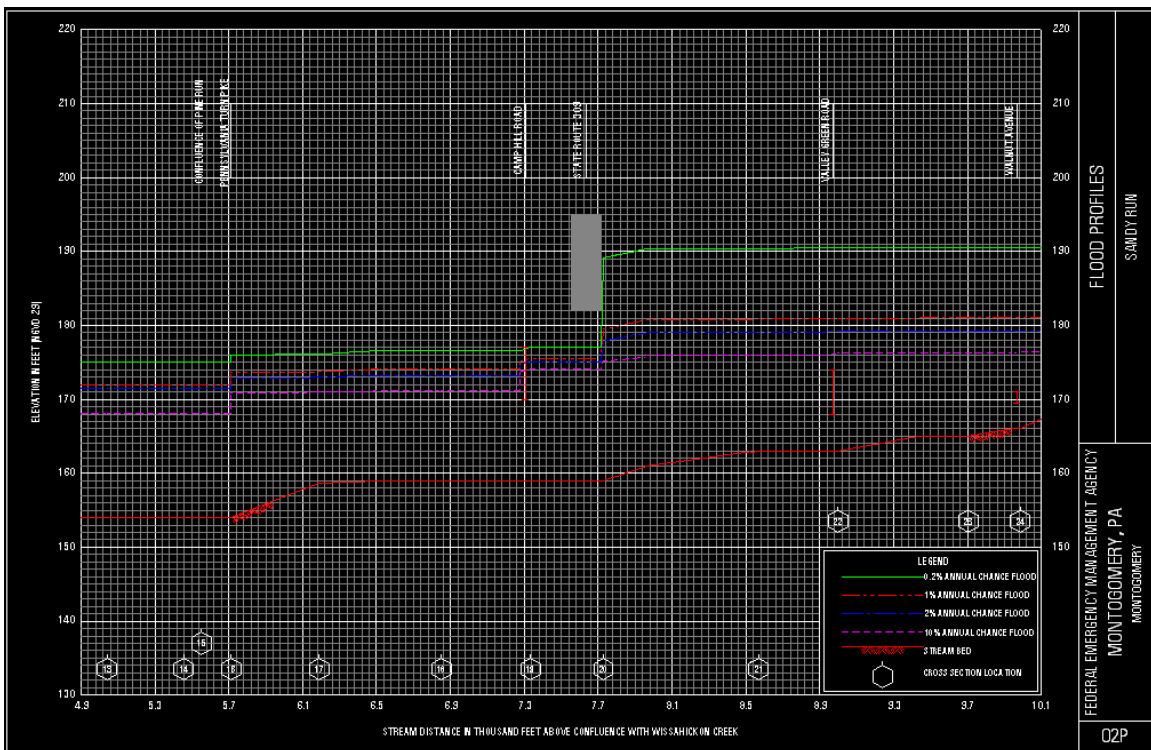
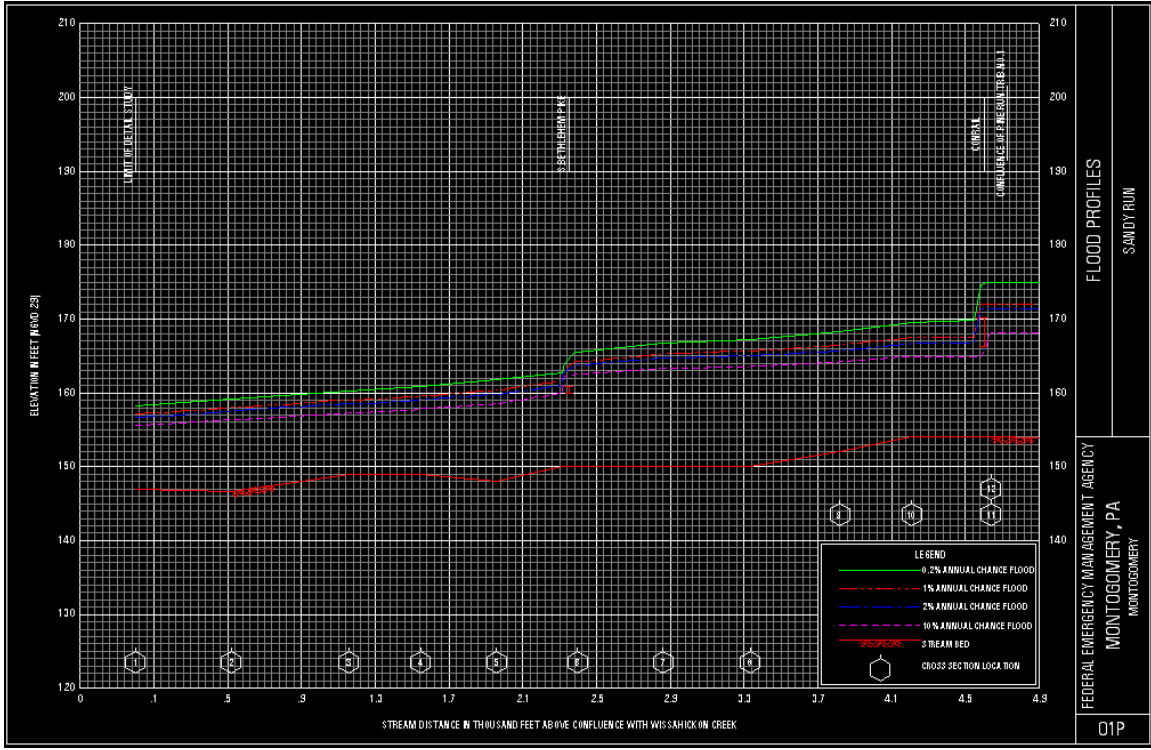
R24	0.0001	0.0002	0.0003	0.0004	0.057
R25	0.0001	0.0002	0.0003	0.0004	0.0037
R26	315.5	484.9	568.52	793.61	0.1912
R27	1094.9	1719.9	2028.3	2858.1	1.107
R30	135.2	213.2	251.8	355.6	0.1952
R31	158.42	243.48	285.45	398.47	0.096
R32	275.08	422.79	495.67	691.92	0.1667
R33	350.4	527.2	613.7	845.9	0.1952
R34	633	972.9	1140.6	1592.2	0.38355
R35	485.6	740.4	865.5	1201.5	0.26194
R36	0.0001	0.0002	0.0003	0.0004	0.001435
R37	1118.6	1713.3	2006.1	2793.7	0.7334
R38	555.8	836.2	974	1344.5	0.37177
R39	1259.66	1915.5	2234.54	3104.7	0.7717
R42	3261.7	4951.1	5776.2	7987	2.199
R43	0.0001	0.0002	0.0003	0.0004	0.0039
R44	524.1	805.5	944.35	1318.26	0.3178
R45	330.1	513.4	604.2	848.9	0.201
R46	3.63	5.65	6.65	9.34	0.0022
R47	316.73	492.6	579.73	814.52	0.1919
R48	311.94	485.16	570.97	802.21	0.189
R50	821.1	1214.7	1408.6	1931.5	0.5068
R51	1456.5	2216.6	2592.2	3602.8	0.916
R52	1709.5	2614.1	3060.7	4264.8	1.116
R53	2018.5	3070.8	3590.8	4989.6	1.2312
R54	2666.65	4030	4702.36	6512.26	1.844
R55	152.97	235.11	275.64	384.77	0.14
R56	1571.6	2398	2807.4	3914	2.0768
R57	3904.1	6061.5	7017.4	9654.1	6.351
R58	6296.6	9653.5	11427.2	16674	6.82794
R60	0.0001	0.0002	0.0003	0.0004	0.055
R61	1042	1503.8	1730.8	2343	0.6485
R62	0.0001	0.0002	0.0003	0.0004	0.025
R64	1215.2	1867.1	2186.7	3050	0.7409
R65	0.0001	0.0002	0.0003	0.0004	0.0249
R66	503.6	782.89	921.2	1293.94	0.3498
R67	337.06	493.7	570.25	775.7	0.176
R68	0.0001	0.0002	0.0003	0.0004	0.0176
R69	3304.3	5056.9	5907	8182.6	2.6
R70	4410	6787.7	8047	11327.8	3.304
R71	706.1	1034.2	1194.6	1625	0.37513
R72	296.7	463.4	545.7	767.1	0.19384
R73	2653.37	4009.52	4678.32	6478.63	1.7474
R74	0.0001	0.0002	0.0003	0.0004	0.0464
R75	0.0001	0.0002	0.0003	0.0004	0.0188
R94	95.95	148.3	174	243.34	0.072
R97	0.0001	0.0002	0.0003	0.0004	0.001492
R99	0.0001	0.0002	0.0003	0.0004	0.000875

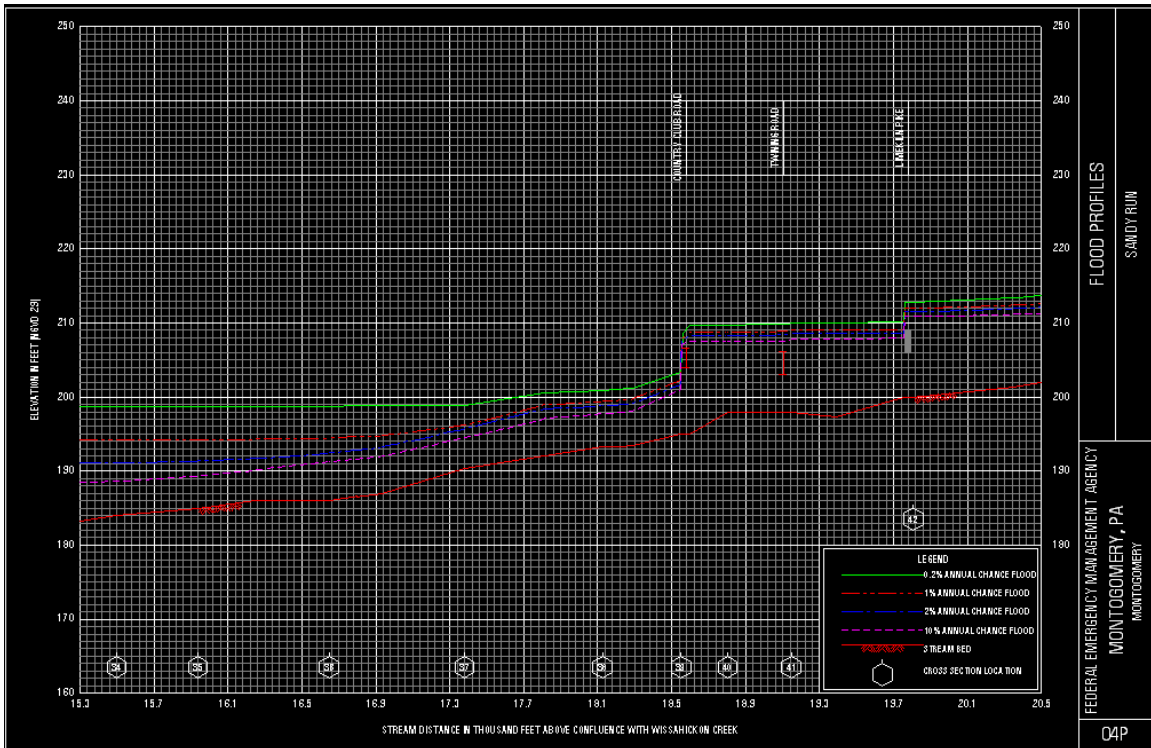
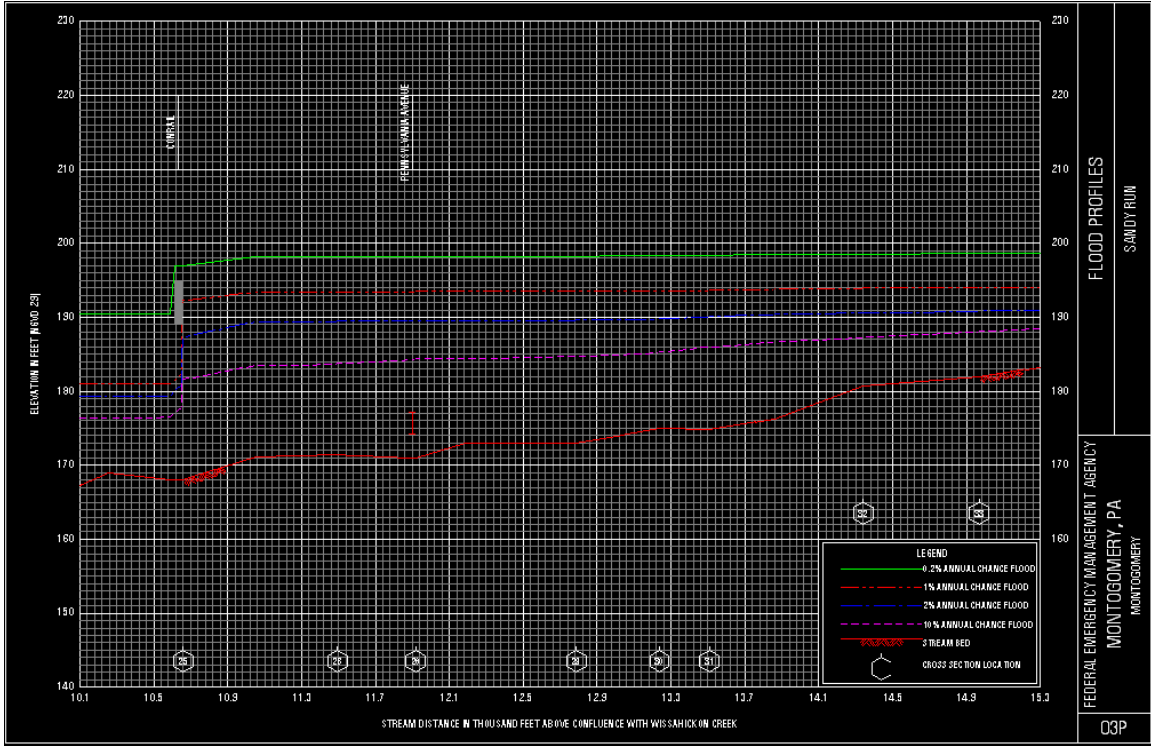
R100	0.0001	0.0002	0.0003	0.0004	0.000301
R103	0.0001	0.0002	0.0003	0.0004	0.0029
R104	1110.2	1644.1	1904.8	2603.7	0.5425
R106	1172.13	1780.44	2076.1	2883.04	0.7255
R107	0.0001	0.0002	0.0003	0.0004	0.0357
R108	0.0001	0.0002	0.0003	0.0004	0.000531
R109	0.0001	0.0002	0.0003	0.0004	0.0958
R110	0.0001	0.0002	0.0003	0.0004	0.0183
R111	1116.04	1693.88	1974.46	2740.97	0.67708
R112	28.9	44.62	52.36	73.22	0.0184
R113	112.66	173.86	204.05	285.33	0.0717
R114	315.99	487.62	572.3	800.28	0.1693
R116	87.52	135.1	158.51	221.66	0.0557
R117	203.33	313.77	368.25	514.95	0.0637
R118	115.8	178.8	209.74	293.29	0.0737
R119	205.22	317.12	372.21	520.48	0.154
R122	199.6	303.19	354.3	492.06	0.13
R123	0.0001	0.0002	0.0003	0.0004	0.0795
R124	137.24	211.78	248.56	347.57	0.08734
R125	978.8	1482.1	1725.9	2393.4	0.5032
R126	0.0001	0.0002	0.0003	0.0004	0.004218
R127	438.8	674.7	791.04	1105.24	0.2212
R128	888.4	1344.8	1569.41	2174.57	0.2311
R129	343.87	511.64	593.98	815.23	0.1699
R131	82.1	122.16	141.82	194.65	0.04059
R132	462.4	711	833.6	1164.7	0.222573
R133	544.5	833.16	975.42	1359.35	0.23309
R134	23.6	36.3	42.56	59.46	0.000688
R135	0.0001	0.0002	0.0003	0.0004	0.0528
R136	0.0001	0.0002	0.0003	0.0004	0.062
R137	0.0001	0.0002	0.0003	0.0004	0.0002
R143	269.99	417.2	489.67	684.73	0.2026
R144	433.77	642.37	744.23	1017.3	0.212
R145	3638.34	5547.82	6478.6	8984.88	2.567
R146	3640.61	5551.32	6482.7	8990.63	2.7697
R147	3795.19	5790.19	6763.08	9382.67	3.05
R148	3691.1	5697.3	6560.8	8539.4	3.5875
R151	350.87	542.19	636.38	889.88	0.26327
R152	3691.1	5697.3	6560.8	8539.4	3.5975
R153	10200.7	15715	18444.6	26328	13.2024
R155	2686.21	4060.18	4737.78	6561.83	1.9216
R156	497.16	772.87	909.42	1277.39	0.31
R157	1784.1	2724.8	3184.4	4432.9	1.00467
R158	1345.27	2064.67	2417.58	3370.65	0.904
R159	0.0001	0.0002	0.0003	0.0004	0.063435
R160	1756.1	2688.7	3146.8	4383.4	1.06207

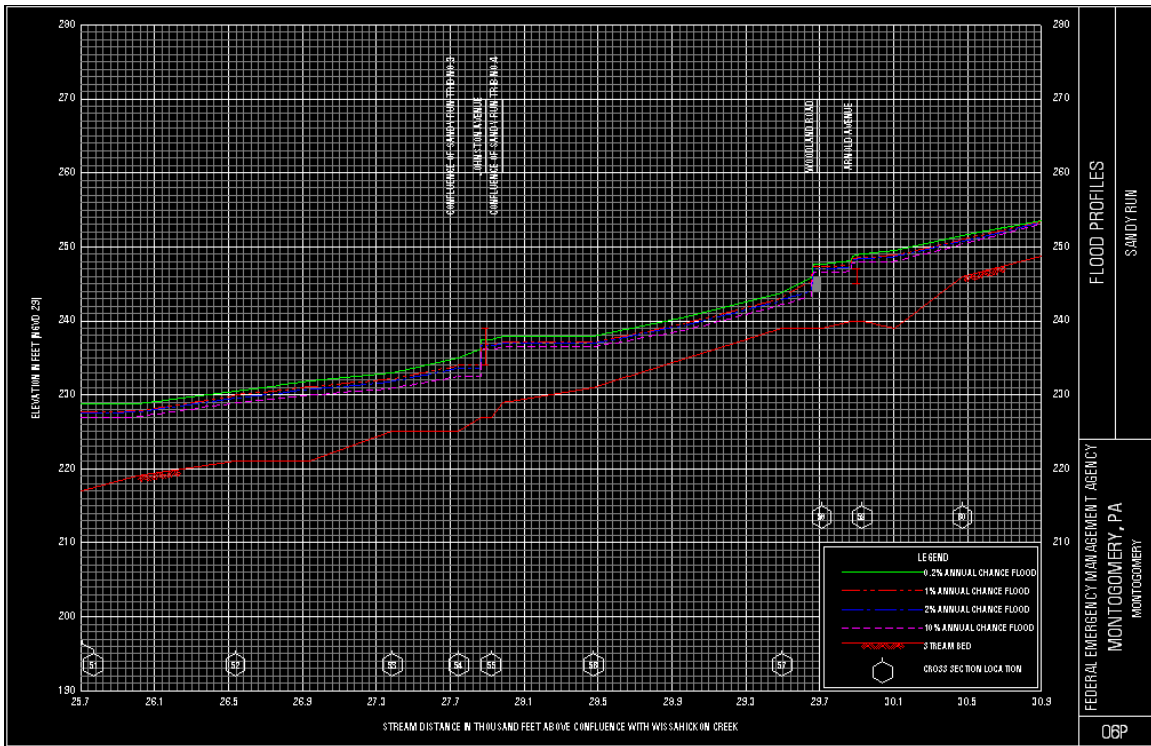
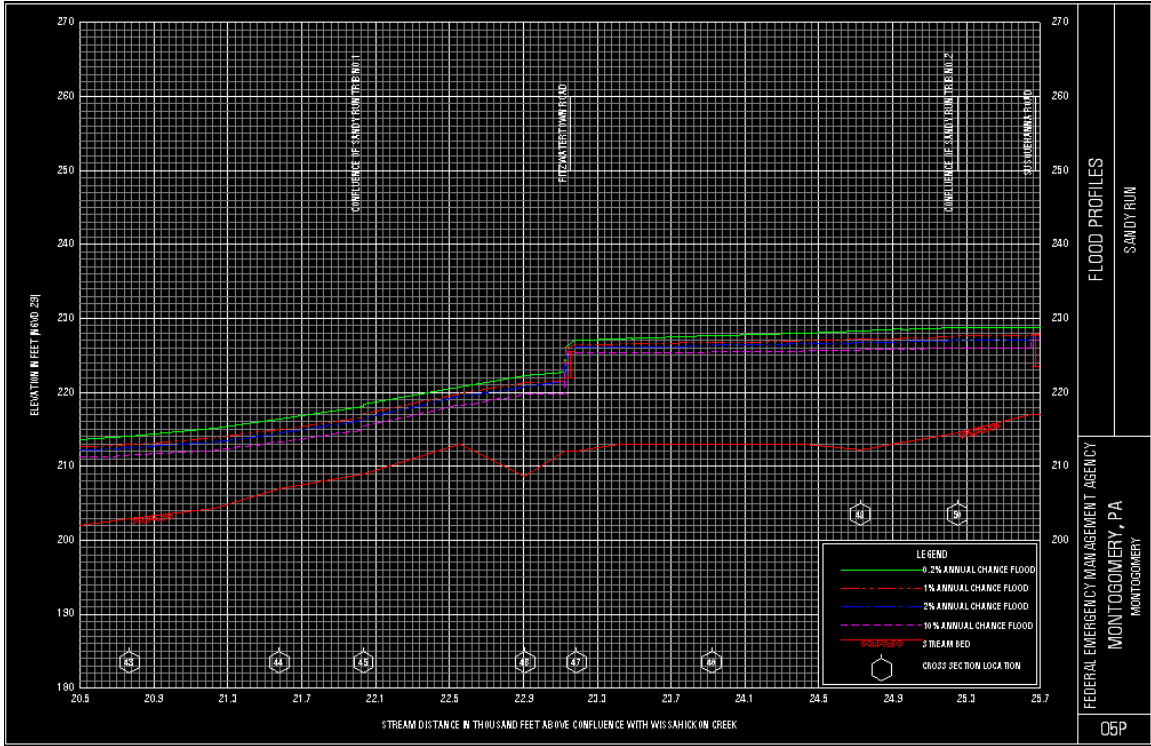


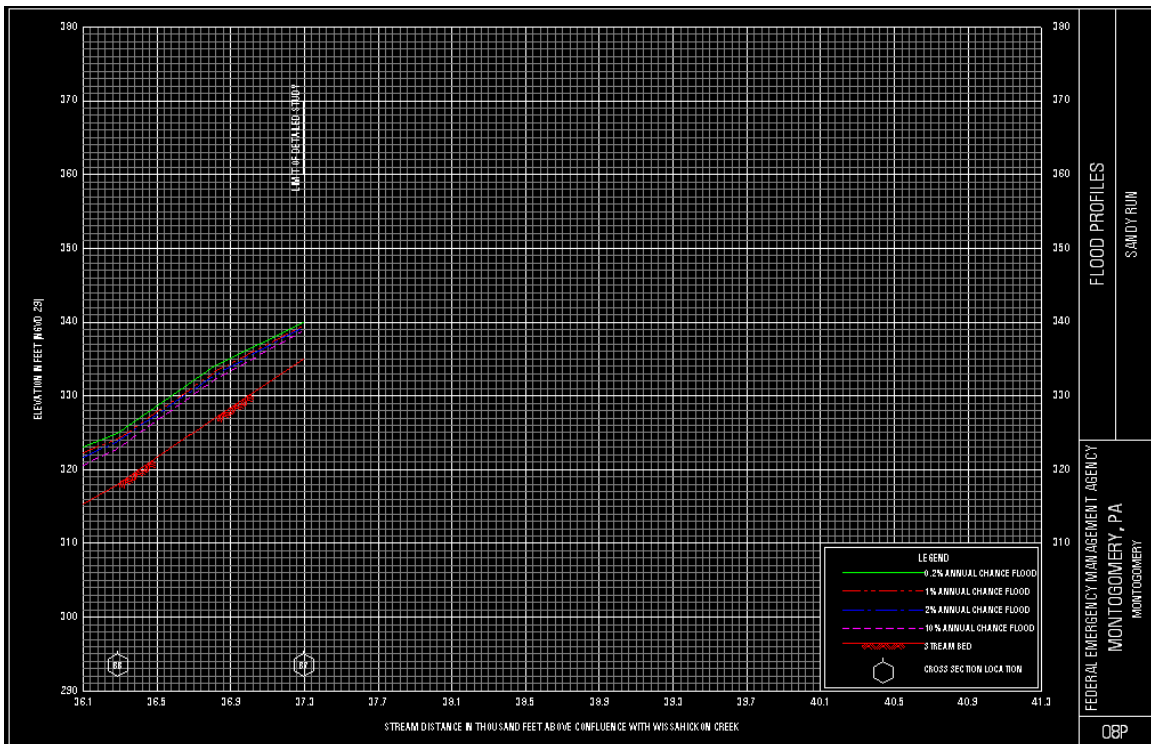
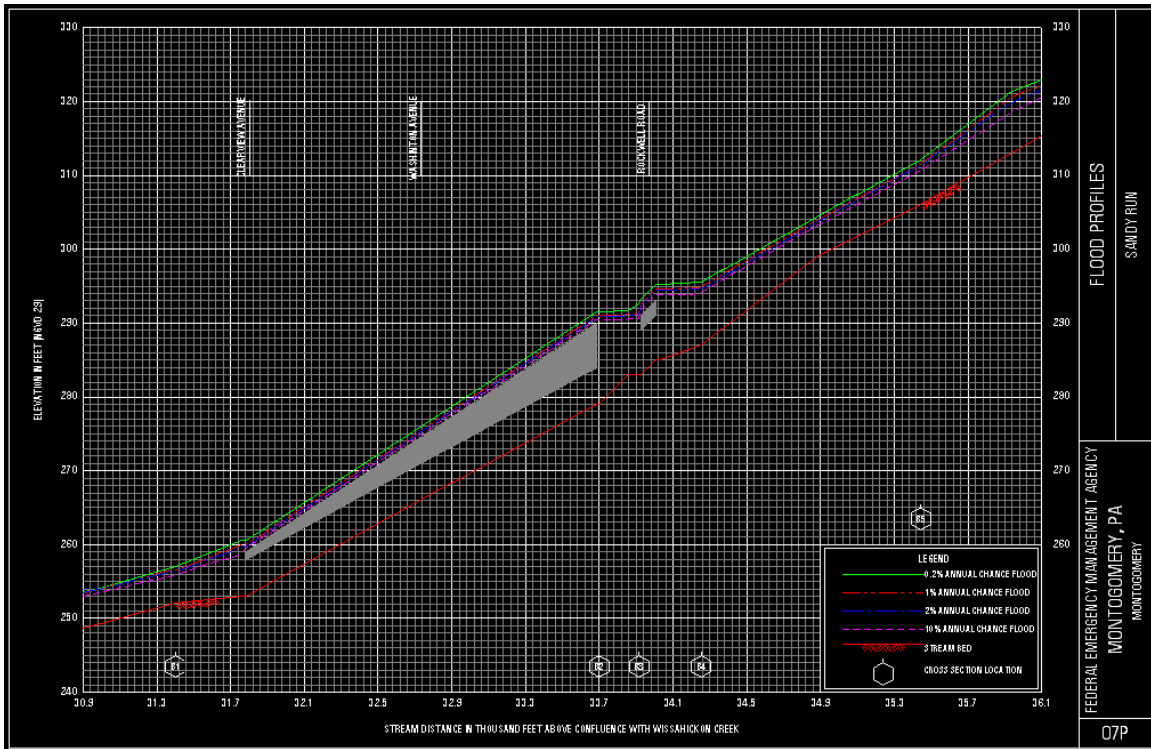
PROFILES

Sandy Run Main Stem

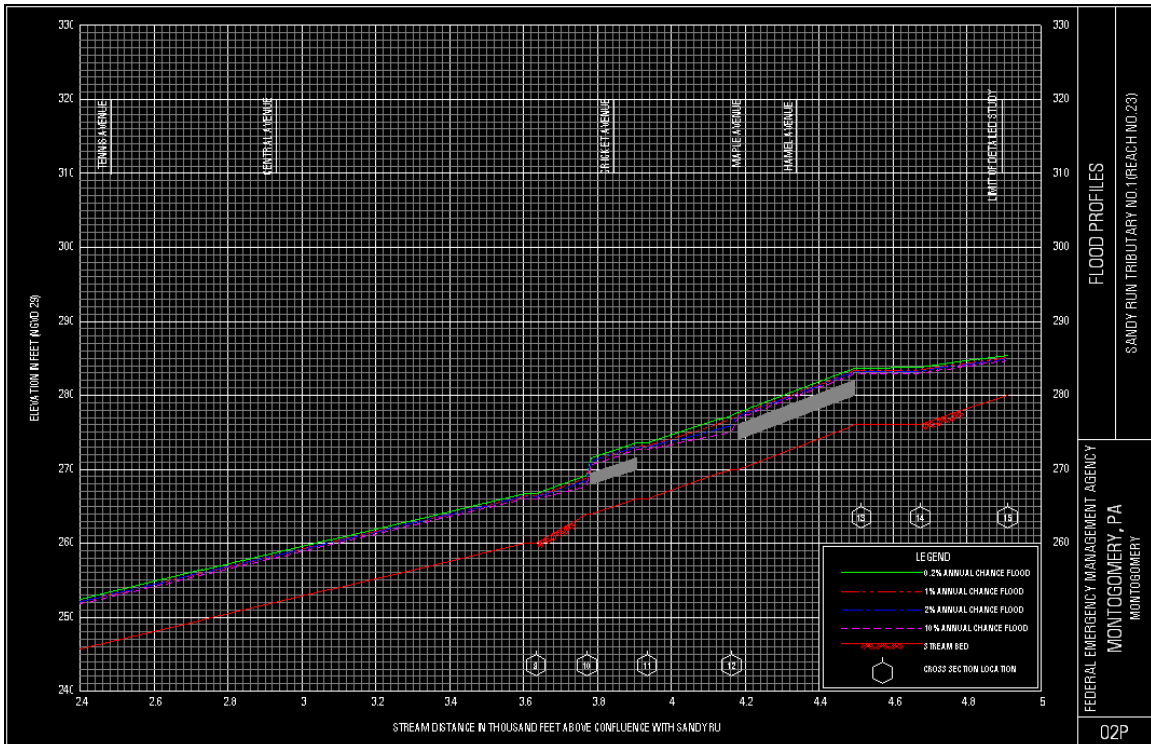
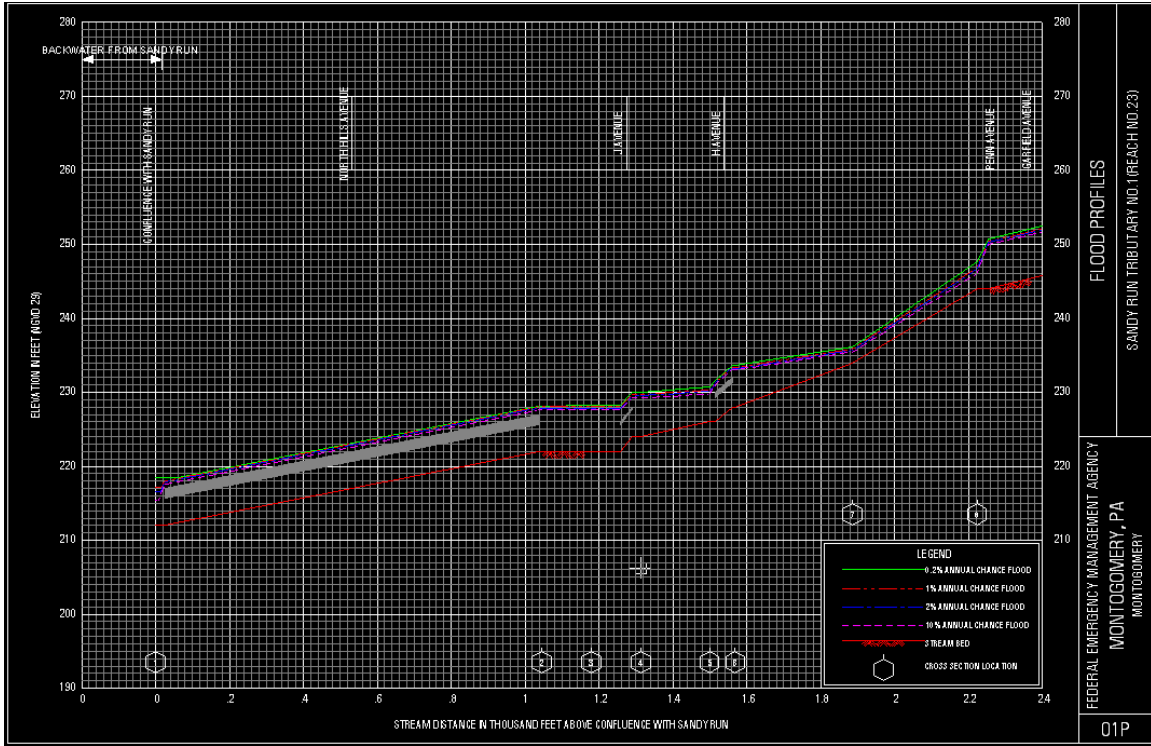


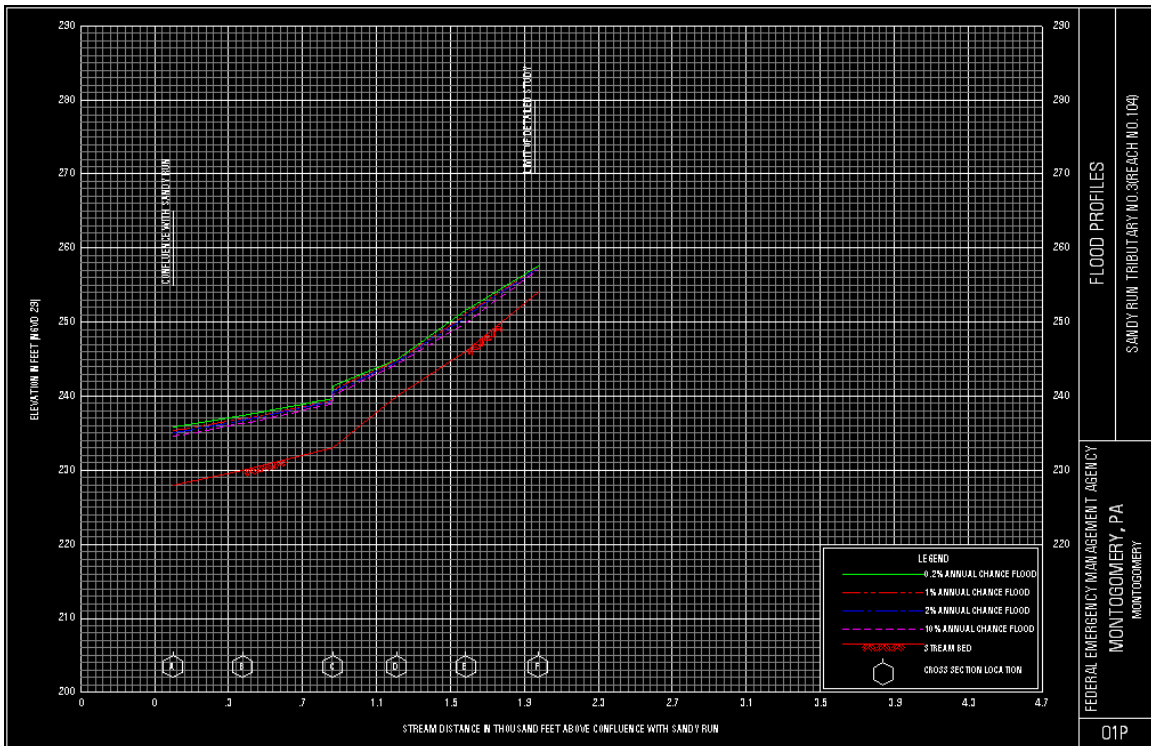
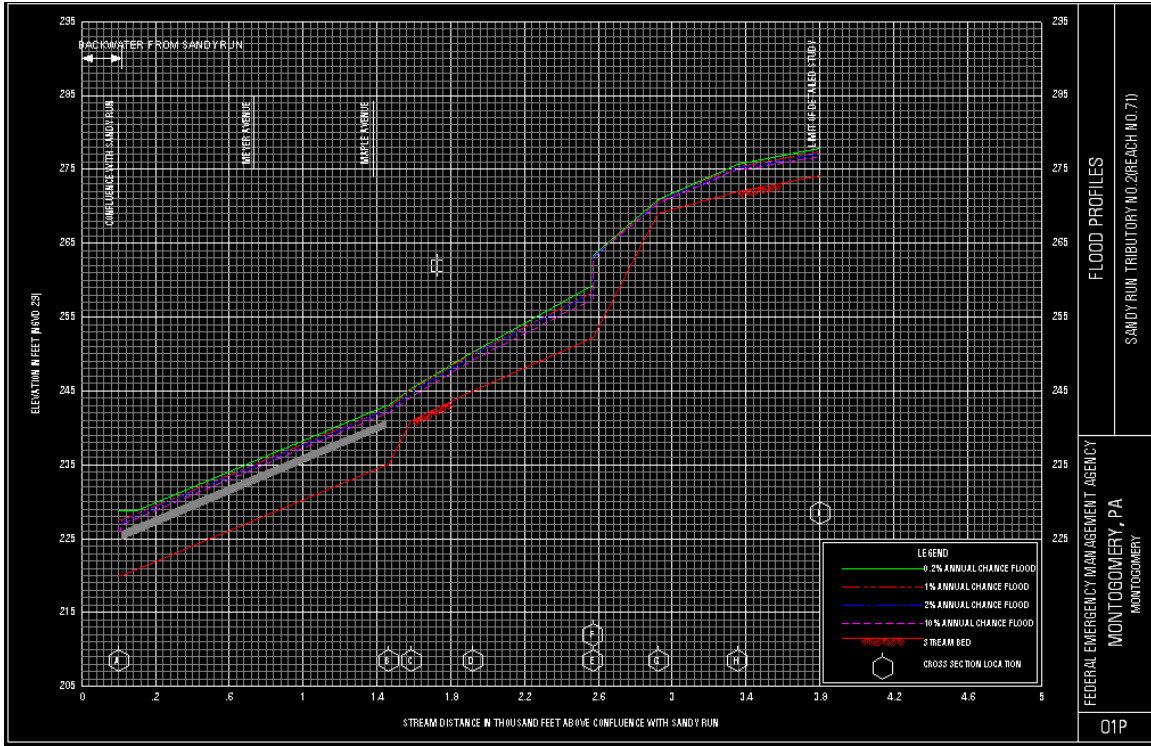


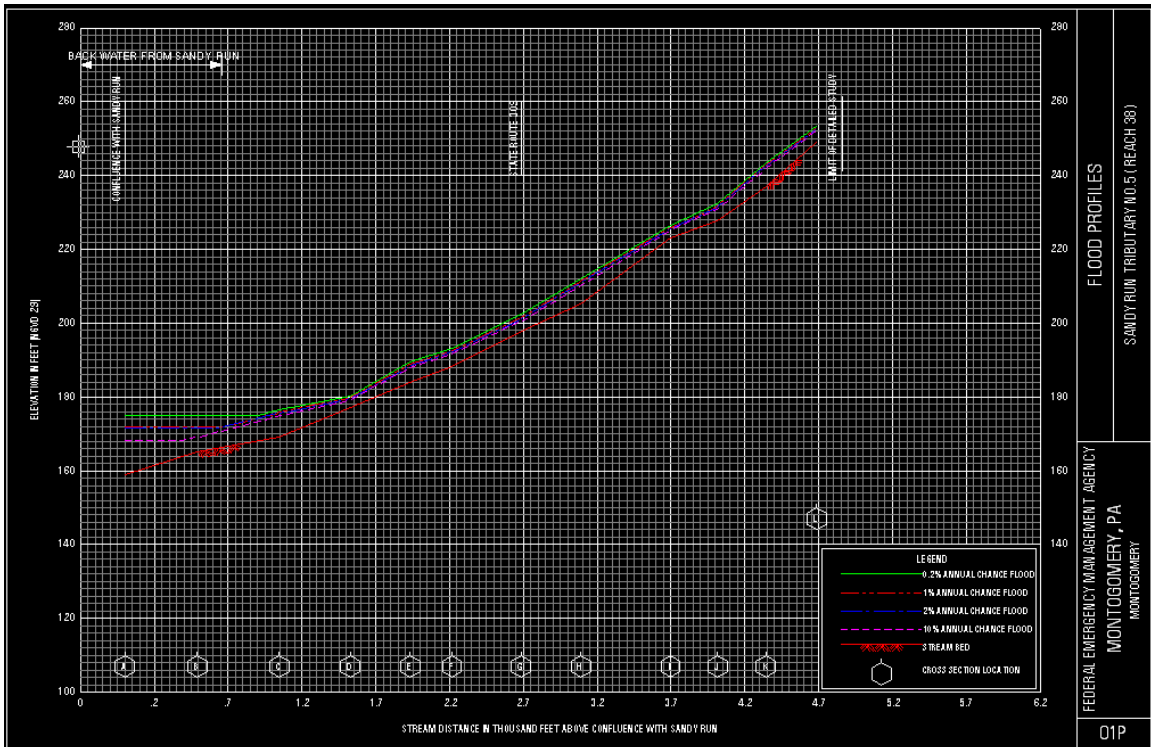
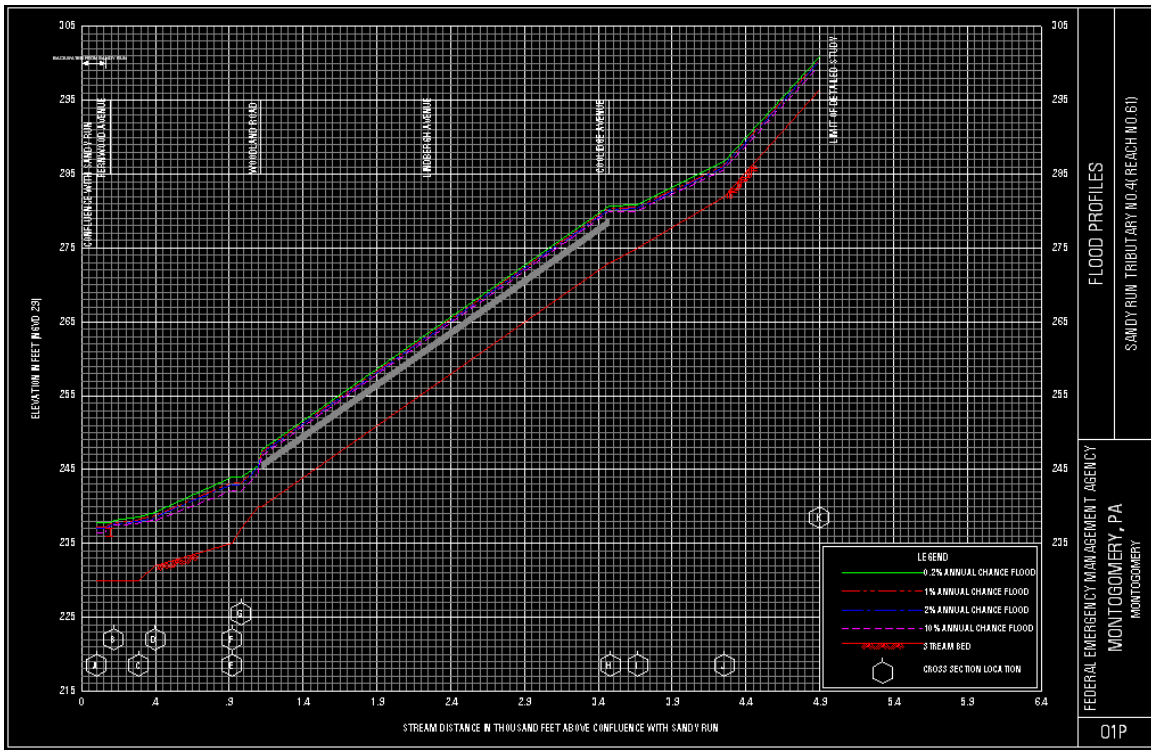


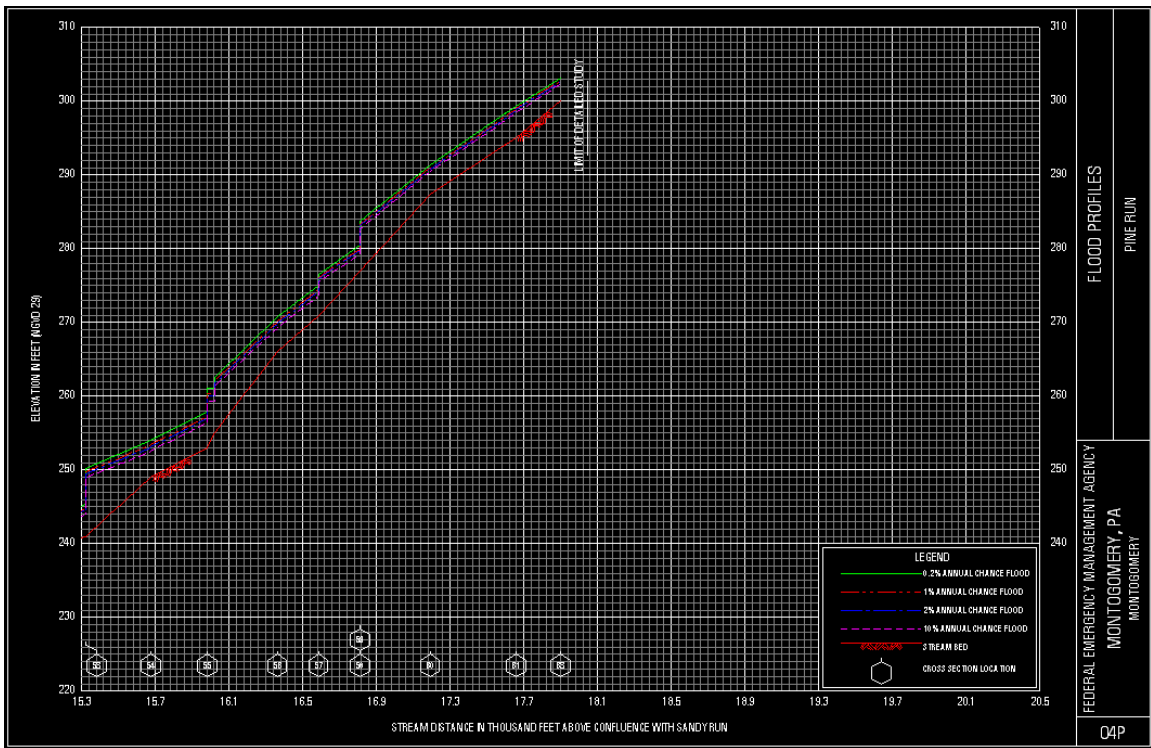
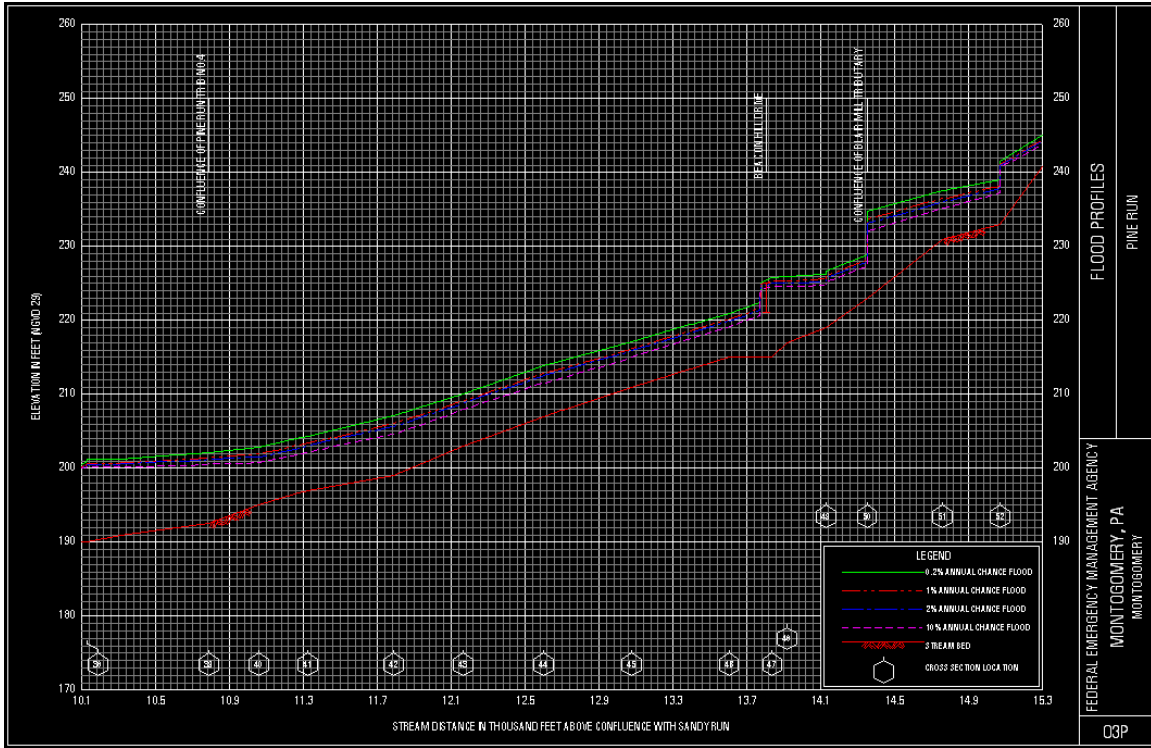


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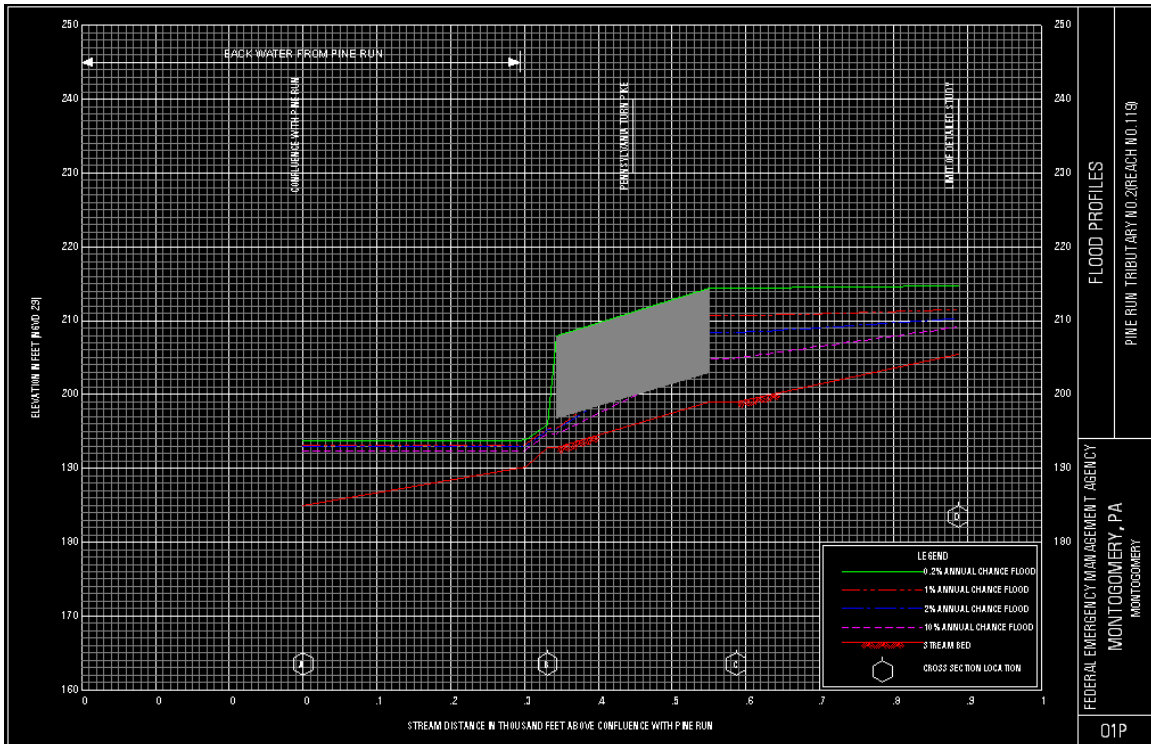
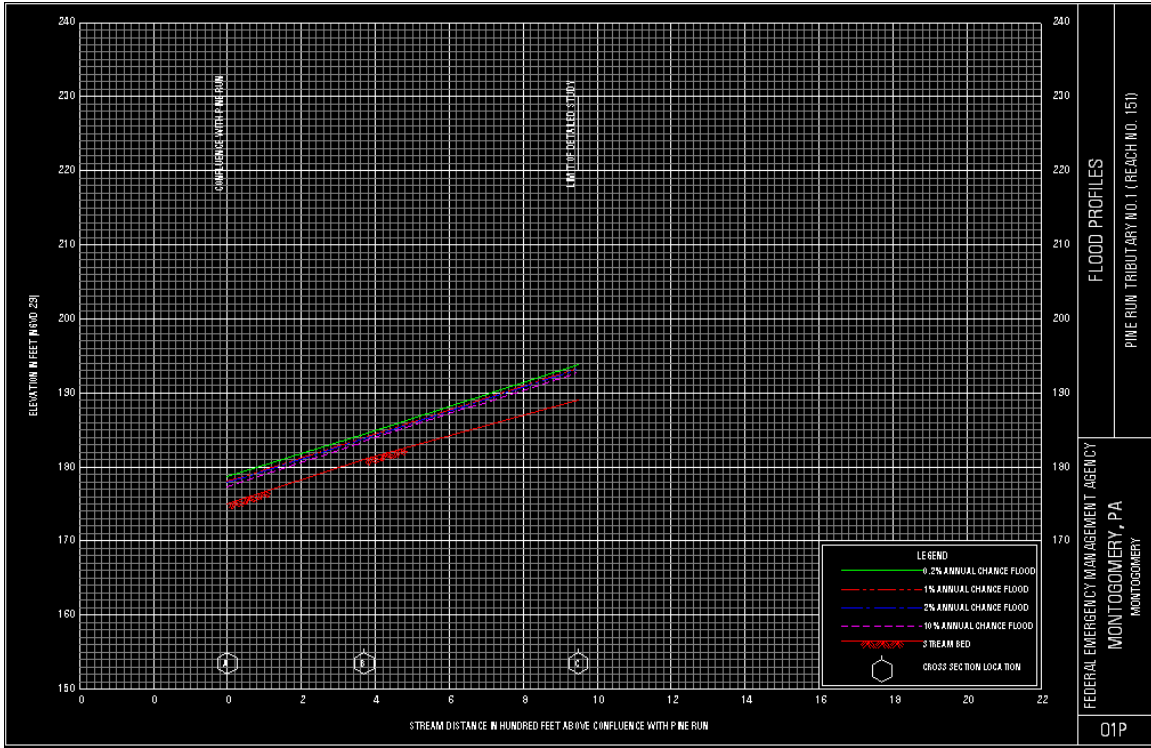


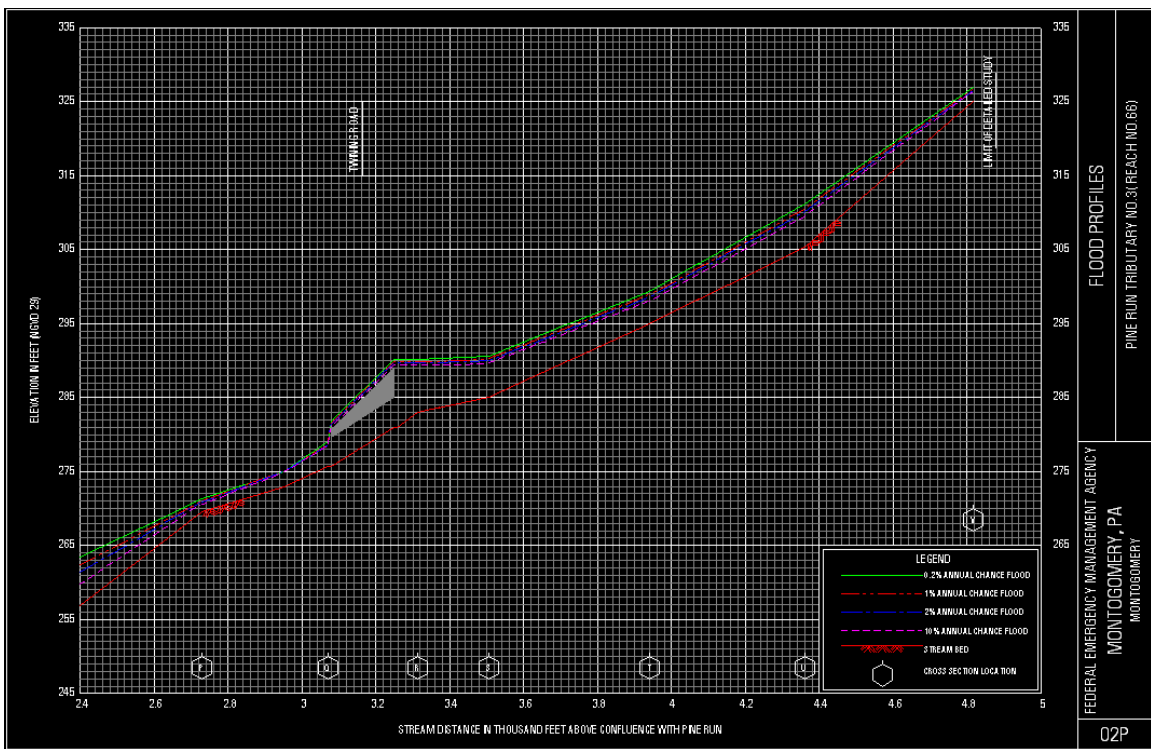
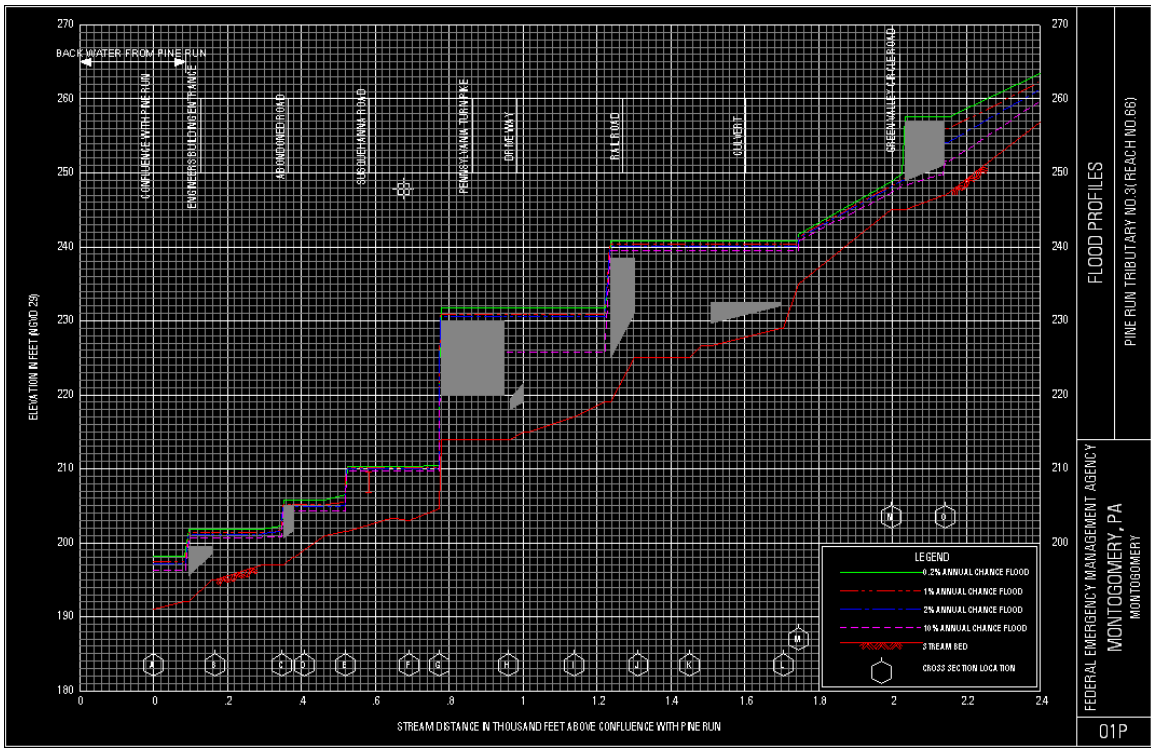


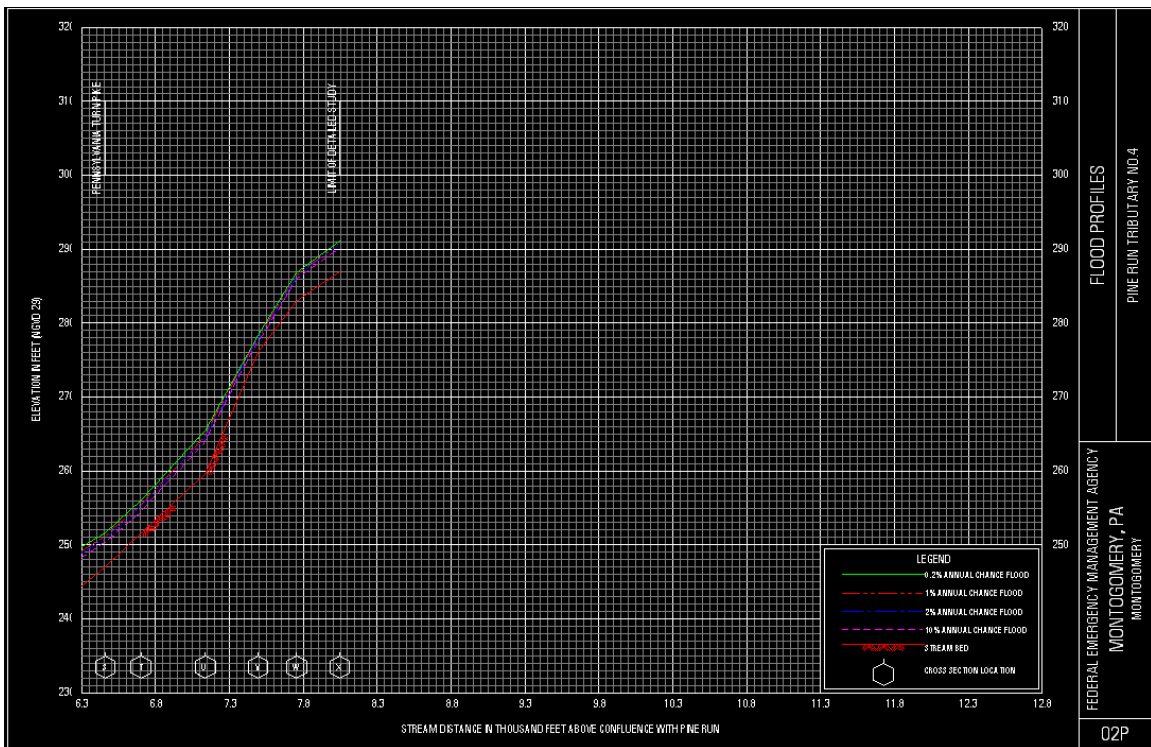
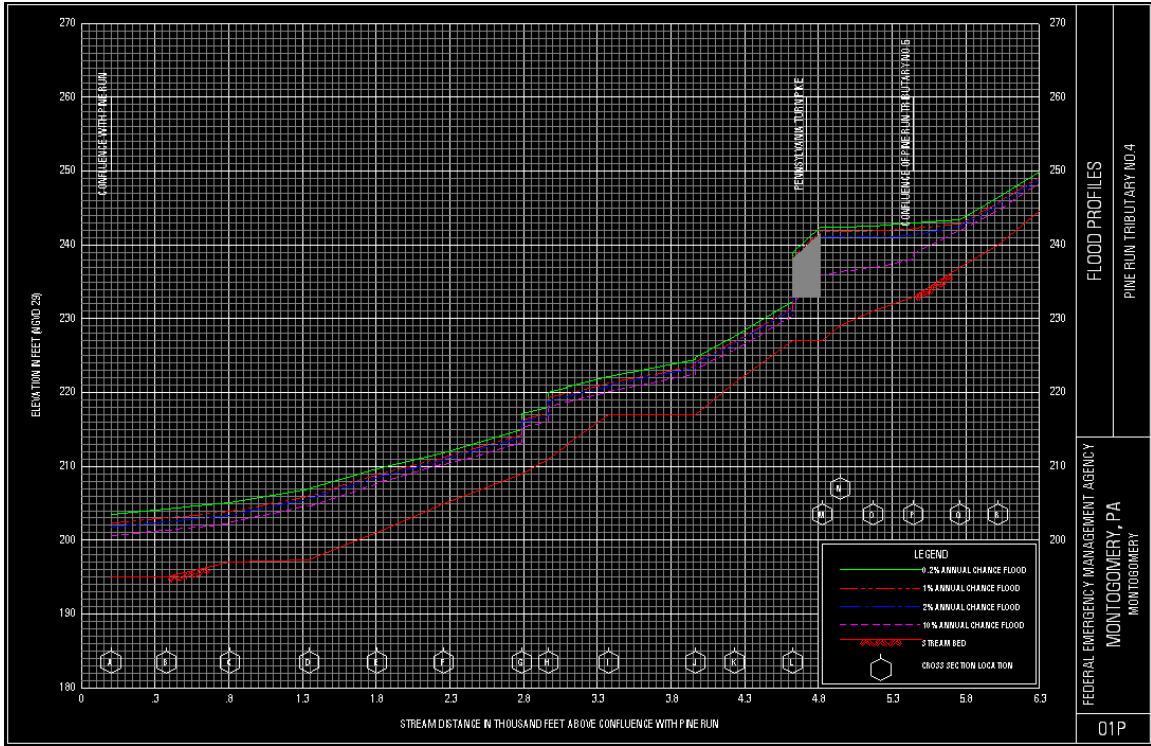


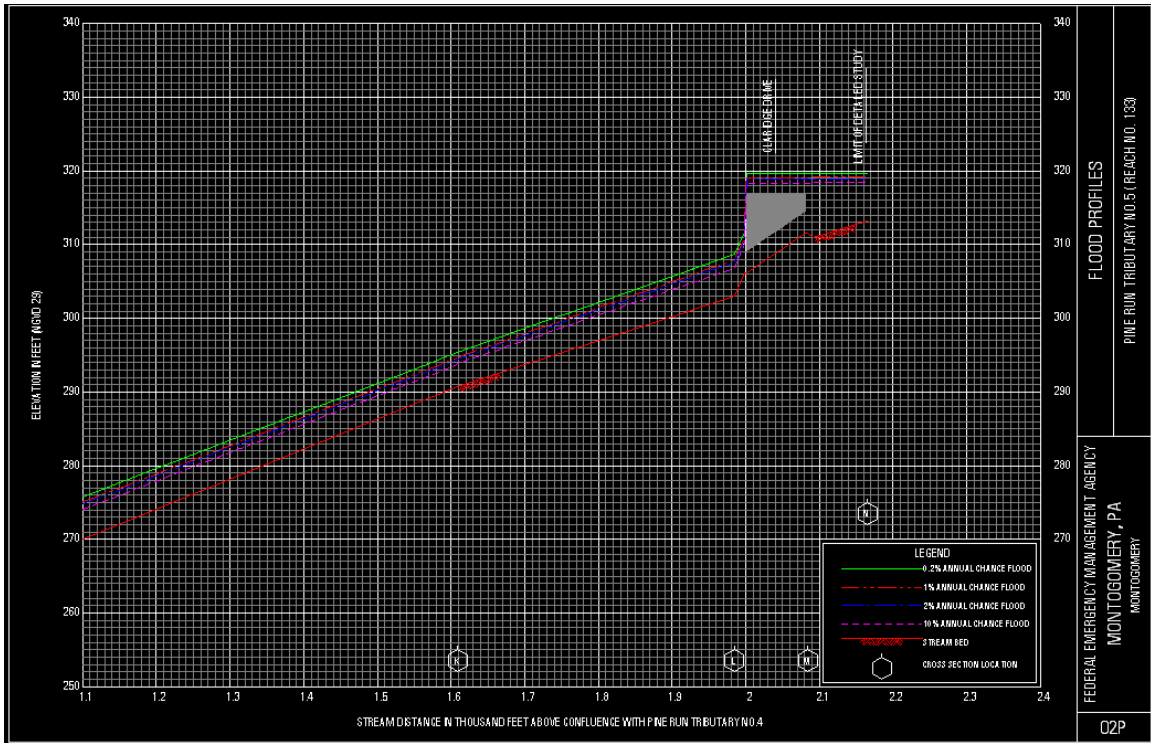
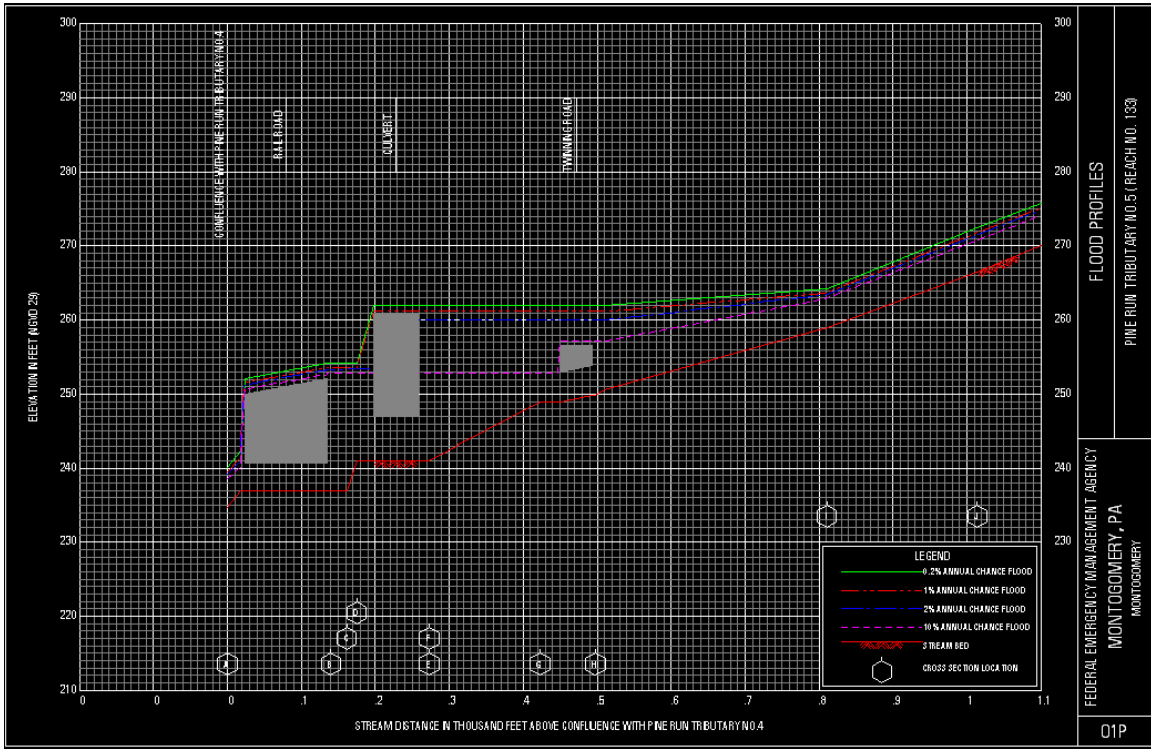


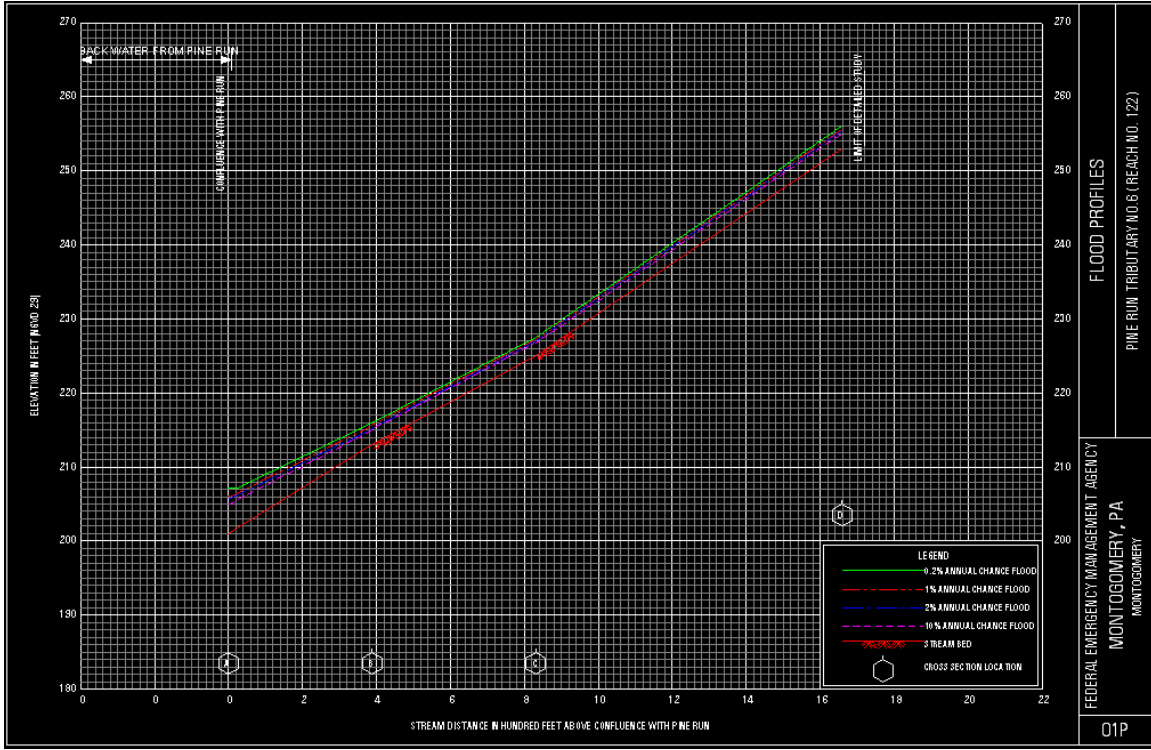
Pin Run Tributaries



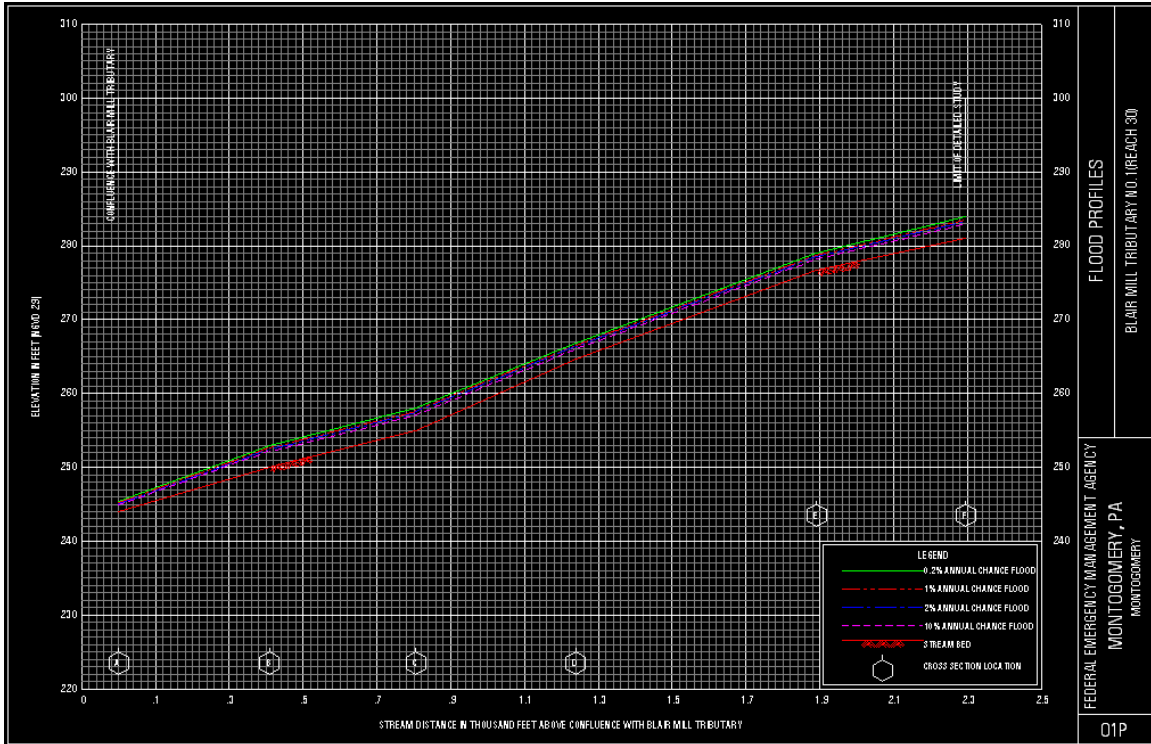
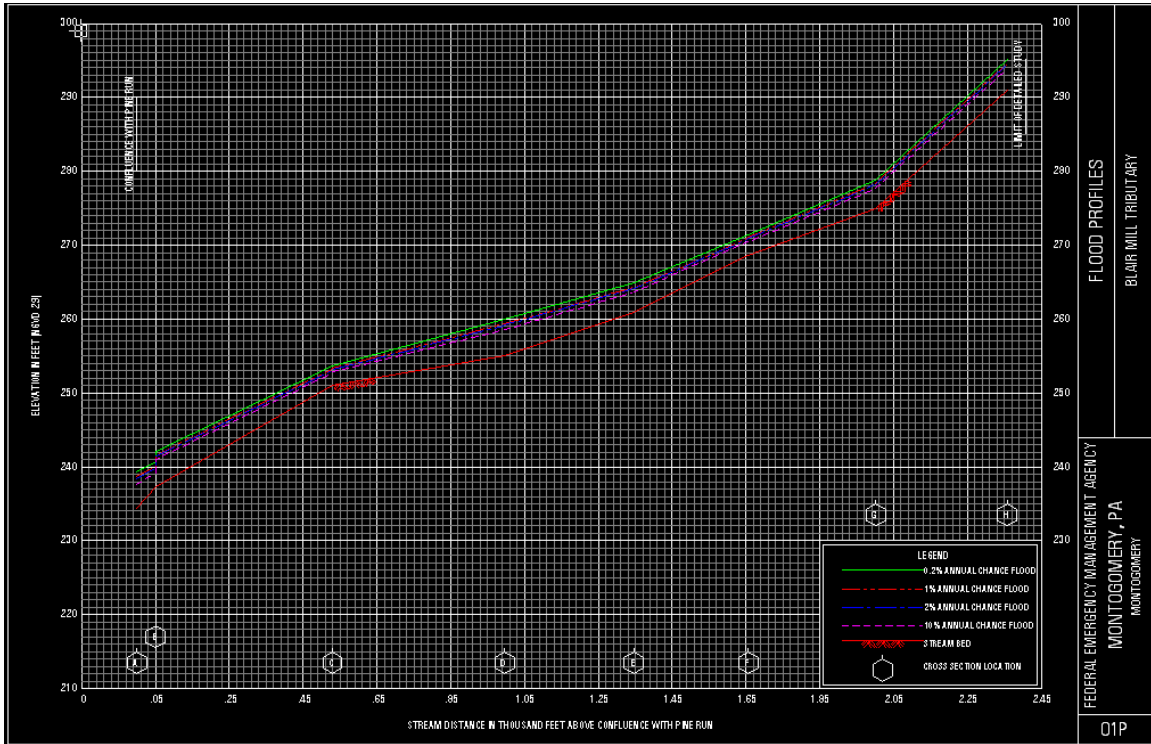




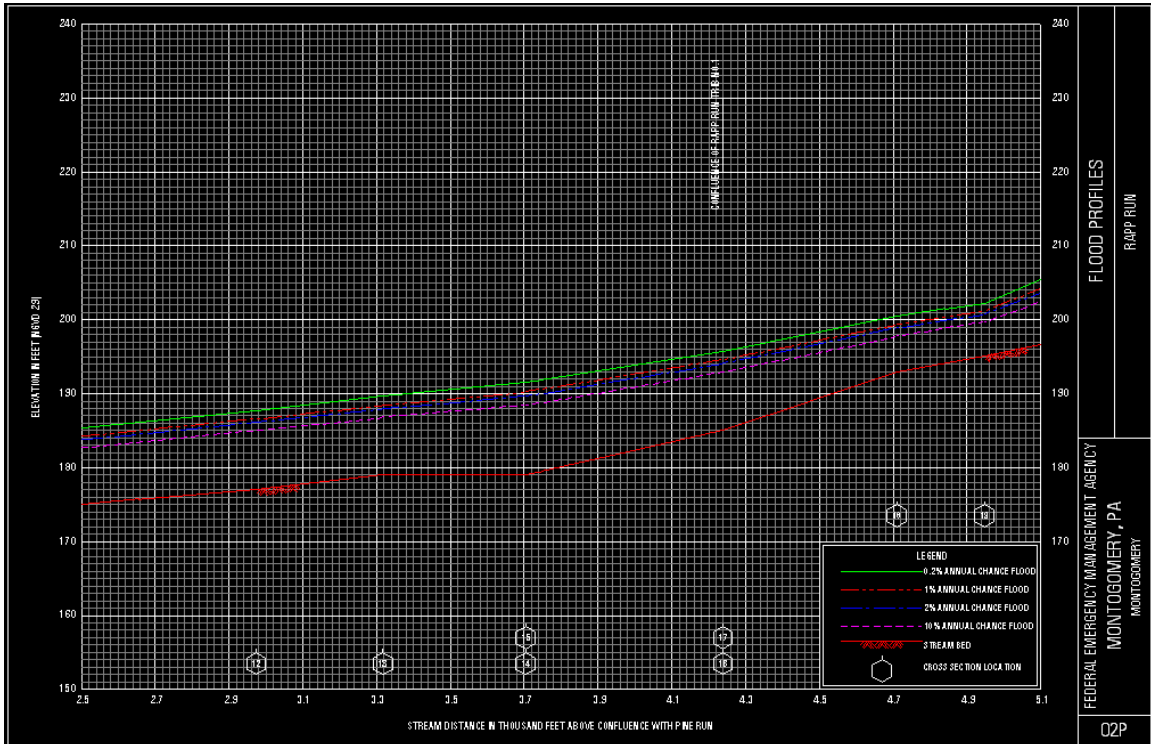
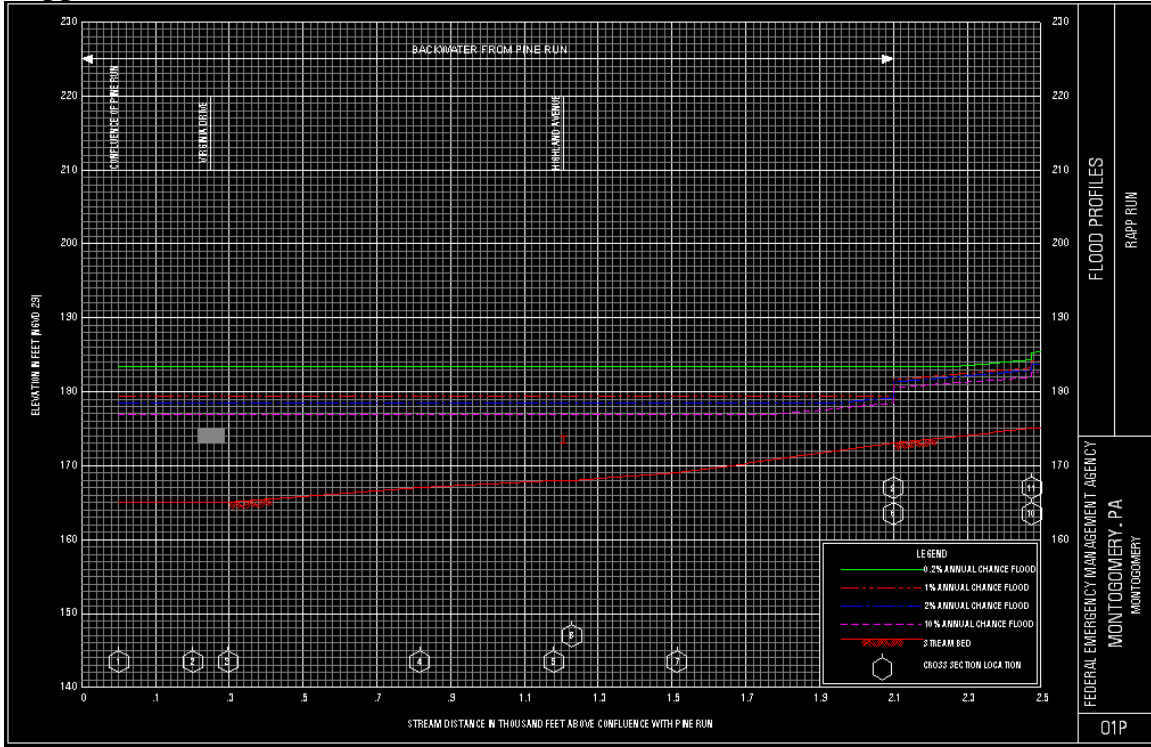


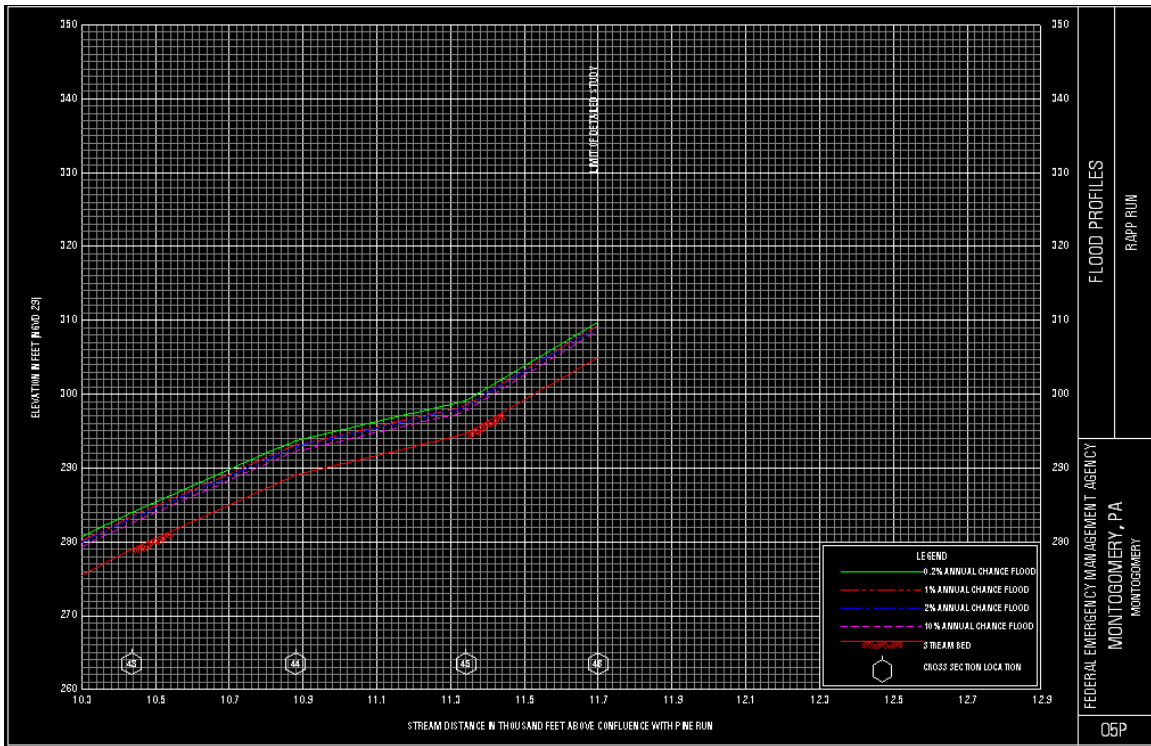


Blair Mill



Rapp Run Main Stem





Rapp Run Tributaries

