Technical Memorandum for Record

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Subject: Chester Creek Flood Insurance Study
Hydrology Re-evaluation

Introduction

In 2004, WEST Consultants, Inc. (WEST) completed a detailed hydrologic analysis of Chester Creek in the City of Spokane Valley, WA as part of the Federal Emergency Management Agency (FEMA) Flood Insurance Study (FIS) of Spokane County, WA. The analysis was completed using the Hydrological Simulation Program-FORTRAN (HSPF) software developed by the U.S. Department of Environmental Protection Agency (EPA, 2005). Detailed information about the development of the HSPF model for the FEMA FIS is documented in *Flood Insurance Study Hydrologic Analysis for Chester Creek, Spokane County, Washington* (WEST, 2004), and it will be referred to as the FEMA FIS HSPF model in the remainder of this memorandum.

During the appeal period following the release of the preliminary FIS results, the City of Spokane Valley, WA sent an appeal letter (City Spokane Valley, October 2006) to FEMA requesting that additional hydrologic analysis be completed to evaluate the impact of 43 drywells located within the lower Chester Creek floodplain. As a result, WEST was contracted by FEMA to re-evaluate the hydrology of lower Chester Creek. Detailed information about the re-evaluation is documented in this memorandum.

This memorandum also documents additional hydrologic analysis completed on Subbasin C2. Subbasin C2 is located in the lower northeastern portion of the watershed. It is the most densely developed area of the watershed, but it is comprised of an underlain of highly infiltrative glacial flood deposits. There are also several stormwater infiltration drywell systems that capture and infiltrate the runoff from this area. It was assumed for the FIS that runoff from this subbasin would not contribute any flood flows to Chester Creek due to the presence of a large number dry wells within the subbasin. As Subbasin C2 contains 22 of the 43 drywells located within the Chester Creek floodplain, additional analyses was required to determine the validity of using these 22 drywells to reduce peak flood discharges given that they were previously assumed to be part of the dry well system responsible for preventing Subbasin C2 flood discharge from reaching Chester Creek.

Hydrologic Analysis of Subbasin C2

The runoff from this subbasin typically drains in a southwest direction to one of four low spot locations along the east side of Dishman-Mica Road. The delineation of this subbasin is shown in Figure 1. Storage Area 3 (SA3) is located within Subbasin C2 and contains 22 of the 43 drywells located in the Chester Creek floodplain. In the FEMA FIS it was assumed that no flow from Subbasin 2 contributes to Chester Creek and that local flow within the basin is infiltrated by the drywells. Some upstream flood flows from Chester Creek overtop Dishman Mica road just downstream of 28th Avenue and flow east to Storage Area 3 where they pond and infiltrate. A hydrologic analysis of Subbasin C2 was conducted to determine the validity of including the 22 drywell located in SA3 in the reduction of flood discharge in addition to local flow from Subbasin C2.

The analysis was conducted using the HSPF computer program. An HSPF model was developed using information from the HSPF model developed for the FEMA FIS (WEST, 2004) and topographic, land-use, and geologic/soil type information for the subbasin. Information utilized from the FEMA FIS HSPF model (WEST, 2004) included the meteorological data and calibrated HSPF parameters. The meteorological data consists of precipitation, temperature, solar radiation, evaporation, dew point temperatures, and wind speed measured at the Spokane Airport. The HSPF parameters were calibrated using a two-step procedure. The parameters controlling snow accumulation and melt were first calibrated to observed snow depth data collected at the Spokane Airport for water years 1948 through 2002. Then, the parameters controlling runoff were calibrated to the Chester Creek stream flow record. The calibrated HSPF parameters are included in this memorandum in Table 1.

Table 1. Calibrated HSPF Parameters for Pervious Areas

Pervious Land Type	FOREST	LZSN	INFILT	LSUR	SLSUR	KVARY	AGWRC
Bedrock Undeveloped	0.800	5.50	0.20	400	0.10	0.50	0.975
Bedrock Developed	0.100	5.50	0.10	400	0.10	0.50	0.975
Outwash Undeveloped	0.800	5.50	2.00	400	0.05	0.50	0.975
Outwash Developed	0.100	5.50	0.80	400	0.05	0.50	0.975

Pervious Land Type	PETMAX	PETMIN	INFEXP	INFILD	DEEPFR	BASETP	AGWETP
Bedrock Undeveloped	0.0	0.0	2.0	2.0	0.0	0.0	0.0
Bedrock Developed	0.0	0.0	2.0	2.0	0.0	0.0	0.0
Outwash Undeveloped	0.0	0.0	2.0	2.0	0.0	0.0	0.0
Outwash Developed	0.0	0.0	2.0	2.0	0.0	0.0	0.0

Pervious Land Type	CEPSC	UZSN	NSUR	INTFW	IRC	LZETP
Bedrock Undeveloped	0.20	0.20	0.35	6.0	0.60	0.60
Bedrock Developed	0.10	0.10	0.05	6.0	0.60	0.20
Outwash Undeveloped	0.20	0.20	0.35	0.0	0.60	0.60
Outwash Developed	0.10	0.10	0.05	0.0	0.60	0.20

The area within each subbasin was classified into areas of common land-use and geologic/soil type called PERLNDS (short for pervious land segments), and the same type of PERLNDS considered in the FEMA FIS HSPF model were used. The total surface area for each PERLNDS was determined using the Geographical Information System (GIS) computer software (ArcGIS Version 9) and GIS shapefiles of the land-use and geology, and they are summarized in Table 2.

Table 2. Summary of Existing Land-Use for Subbasin C2

Subbasin	Land-Use (acres)					
	Impervious	Urban Outwash	Undevelope d Outwash	Urban Bedrock	Undeveloped Bedrock	Total Area
C2A	312.7	1104.7	0.0	0.0	0.0	1417.4
C2B	44.6	149.5	0.0	0.0	0.0	194.1
C2C	23.9	80.0	0.0	0.0	0.0	103.9
C2D	22.0	73.6	0.0	0.0	0.0	95.6

A statistical analysis of the HSPF results was conducted to determine the discharge-frequency relationship for each of the subbasins of Subbasin C2. The discharge-frequency relationship was determined using the same methodology utilized in the FIS. Briefly, the relationship was determined using a probability-plot regression approach since many of the annual maximum values were zero or near zero. The discharge-frequency relationship for each of the subbasins of Subbasin C2 is summarized in Table 3.

Table 3. Discharge-Frequency Relationship for Subbasin C2

Subbasin	Discharge (cfs)				Unit Discharge (cfs/acre)			
	10-yr	50-yr	100-yr	500-yr	10-yr	50-yr	100-yr	500-yr
C2A	216	290	322	394	0.152	0.205	0.227	0.278

C2B	32	41	45	53	0.164	0.210	0.230	0.275
C2C	17	22	24	29	0.163	0.211	0.231	0.278
C2D	15	20	22	27	0.159	0.211	0.233	0.285

A GIS coverage consisting of the surveyed location of all drywells within subbasin C2 was provided by the City of Spokane Valley. Based on this coverage 1059 dry wells are located within subbasin C2 of which 709 are double depth, 332 are single depth and 18 are unknown. The drywells are evenly distributed throughout the subbasin (Figure 2). For the purposes of this analyses the unknown drywells were considered to be single depth. Single depth drywells are typically 8 feet deep with an approximately 4-foot high perforated section and double depth drywells are typically 12 feet deep with an approximately 8-foot high perforated section. Based on field measurement test, the design outflow rate of a single drywell is 0.3 cubic feet per second (cfs) and 1.0 cfs for a double depth drywell. In 2006 the City of Spokane Valley conducted infiltration tests on 7 drywells to determine their normalized outflow rates. The tests resulted in normalized rates that were 2.7 to 9.1 times greater than the design flows (City Spokane Valley, October 2006).

A comparison of total dry well outflow capacity and basin discharge is shown in Table 4. Subbasins 2A, 2B and 2C have 1.8 to 2.0 times more drywell capacity than 100-yr basin discharge and 1.6 to 1.7 times more drywell capacity than 500-yr basin discharge. The well outflow for Subbasin 2D exceeds the basin discharge for the 100-yr flood. Though the 500-yr basin discharge for Subbasin 2D exceeds the drywell outflow capacity by 1 cfs the topography in this area is relatively flat and during large floods that exceed the drywell capacity, water would be stored at the dry well inlets and depressions and would eventually infiltrate as the flood subsided. It was noted for basin 2A (which contains SA3) the well capacity exceeds the basin discharge by a factor of 2. Taking this in conjunction with the well design flow safety factor and the even distribution of drywells throughout the entire basin we believe it valid to conclude that no flow from Subbasin 2A will flow to SA3 and that the dry wells within SA3 can be assumed to help reduce peak flood discharge from Chester Creek and be included in the hydrology re-evaluation.

Table 4. Comparison of drywell outflow to basin discharge

Subbasin	Doubles	Singles	Total Well Outflow Capacity (cfs)	100-yr Basin Discharge (cfs)	500-yr Basin Discharge (cfs)
2A	574	284	659	322	394
2B	73	33	83	45	53
2C	41	16	46	24	29
2D	21	17	26	22	27

Re-evaluation of the Hydrology for Lower Chester Creek

The hydrology for the lower Chester Creek was re-evaluated using the HSPF computer program. The re-evaluation involved making three revisions to the FEMA FIS HSPF model. The first revision involved dividing the single reach downstream of 24th Avenue (Storage Area 5) into five smaller reaches: (1) Reach 1 is from 24th Avenue to about 1,400 feet downstream, (2) Reach 2 is from the downstream end of Reach 1 to 16th Avenue, (3) Reach 3 is from 16th Avenue to 8th Avenue, (4) Reach 4 is from 8th Avenue to about 600 feet downstream, and (5) Reach 5 is from the downstream end of Reach 4 to 2nd Avenue. This revision was made to include several storages areas within the reach and to obtain discharge values at more locations than considered in the FEMA FIS. As a result of this revision, Subbasin C1 and C3 had to be re-delineated to determine the portion of these subbasins that contribute flows to each of the reaches and the total surface area of PERLNDS had to be calculated for the each of new subbasins. The five reaches and the re-delineation of Subbasins C1 and C3 are shown in

Figure 3. The total surface area of the PERLNDS determined for all of the subbasins within the watershed is summarized in Table 5.

The second revision involved adding storage areas immediately upstream of the street crossings at 2nd Avenue, 8th Avenue, 16th Avenue, and 24th Avenue. The added storage areas are also shown in

Figure **3**. The surface area-volume-elevation relationship for each storage area was determined using ArcGIS software and the Triangulation Irregular Network (TIN) created from 2-foot contours developed from LiDAR data collected in 2003. The stage-discharge relationship for each storage area was determined from the HEC-RAS model developed for the FIS. The discharge associated with infiltration for each basin was assumed to be equal to the rate (2 inches per hour) considered for Subbasin C3 in the FEMA FIS HSPF model.

The last revision included the influences of the drywells located within the floodplain. Information about the drywells provided by the City of Spokane Valley, WA is summarized in Table 6. Table 6 provides the number of wells, the City's Well Number, well type, and rim elevation within each of the storage areas. As indicated in this table, there are single and double depth drywells. Single depth drywells are typically 8 feet deep with an approximately 4-foot high perforated section and double depth drywells are typically 12 feet deep with an approximately 8-foot high perforated section. Based on field measurement test, the design outflow rate of a single drywell is 0.3 cubic feet per second (cfs) and 1.0 cfs for a double depth drywell. HSPF models were developed with and without the influences of the drywells. The outflow of the drywells was simulated in the HSPF model using a discharge rating curve defined using the design outflow rate at the surveyed rim elevation. As an example, the drywell outflow rating curve for a storage area that has a bottom elevation of 96 feet, a single drywell with an rim elevation of 100 feet, and a double drywell with an rim elevation of 102 feet would be 0 cfs from elevation 96 to 100 feet, 0.3 cfs from elevation 100 to 102 feet, and 1.3 cfs for elevations greater than 102 feet.

Table 5. Summary of Existing Land-Use for Chester Creek

Subbasin	Land-Use (acres)					
	Impervious	Urban Outwash	Undeveloped Outwash	Urban Bedrock	Undeveloped Bedrock	Total Area
C1A	0.0	0.0	39.4	0.0	69.1	108.5
C1B	0.0	0.0	19.4	0.0	9.9	29.3
C1C	0.0	0.0	21.2	0.0	197.5	218.7
C1D	0.0	0.0	30.4	0.0	141.0	171.4
C1E	0.0	0.0	10.7	0.0	1.9	12.6
C1F	0.0	0.0	29.7	0.0	6.1	35.9
C2[1]	403.2	1810.9	0.0	0.0	0.0	1810.9
C3A	13.2	117.9	0.0	0.0	0.0	131.0
C3B	6.0	54.3	0.0	0.0	0.0	60.4
C3C	1.8	16.5	0.0	0.0	0.0	18.3
C3D	1.4	12.8	0.0	0.0	0.0	14.2
C3E	4.4	40.0	0.0	0.0	0.0	44.5
C3F	0.4	4.0	0.0	0.0	0.0	4.4
C3G	2.6	22.8	0.0	0.0	0.0	25.4
C4	0.0	0.0	185.1	0.0	1367.4	1552.5
C5	63.9	296.3	0.0	279.0	0.0	639.3
C6	10.5	0.0	195.3	0.0	57.2	263.0
C7	25.9	0.0	218.0	0.0	403.9	647.8
C7A	10.2	0.0	205.0	0.0	39.2	254.4
C8	0.0	0.0	50.2	0.0	246.8	297.0
C9	0.0	0.0	158.9	0.0	197.3	356.1
C10	0.0	0.0	111.8	0.0	1279.2	1391.0
C11	0.0	0.0	15.5	0.0	588.9	604.3
C12	0.0	0.0	220.6	0.0	1223.2	1443.8
C13	0.0	0.0	86.1	0.0	724.1	810.2
C14	0.0	0.0	6.3	0.0	430.7	437.0
C15	0.0	0.0	248.1	0.0	2068.8	2317.0
C16	0.0	0.0	92.2	0.0	1272.9	1365.2

Notes:
1. Runoff from Subbasin C2 infiltrates into the ground through various drywells and does not contribute flow to Chester Creek.

Table 6. Information of Drywells within the Storage Areas of Chester Creek

Storage Area	Number of Wells	Well Number	Well Type	Rim Elevation (ft)
1	0	n.a.	n.a.	n.a.
2	0	n.a.	n.a.	n.a.
3	18	DW – 2	Single	2000.97
		DW – 3	Double	1999.08
		DW – 4	Double	1999.09
		DW – 5	Double	1999.54
		DW – 6	Double	1999.30
		DW – 7	Double	1999.48
		DW – 8	Double	1999.27
		DW – 9	Double	2002.35
		DW – 10	Double	2002.37
		DW – 11	Double	2000.52
		DW – 12	Single	1999.96
		DW – 13	Single	1999.65
		DW – 14	Double	1998.72
		DW – 15	Double	1998.07
		DW – 16	Single	1998.26
4	0	n.a.	n.a.	n.a.
5	3	DW – 17	Double	1999.72
		DW - 18	Double	1998.11
		DW - 19	Double	1998.30
6	0	n.a.	n.a.	n.a.
7	0	n.a.	n.a.	n.a.
8	0	n.a.	n.a.	n.a.
9	15	DW - 23	Single	1990.19
		DW - 24	Double	1988.80
		DW - 25	Double	1987.61
		DW - 26	Single	1989.14
		DW - 27	Double	1989.03
		DW - 28	Double	1988.32
		DW - 29	Double	1988.32
		DW - 30	Double	1988.32
		DW - 31	Single	1986.54
		DW - 32	Single	1986.62
		DW - 33	Double	1986.80
		DW - 34	Double	1988.36
		DW - 35	Single	1988.39
		DW - 36	Single	1991.49
		DW - 37	Single	1991.74
10	6	DW - 38	Double	1985.36
		DW - 39	Single	1984.15
		DW - 40	Single	1983.29
		DW - 41	Double	1981.80
		DW - 42	Double	1985.77
		DW - 43	Double	1985.77

The HSPF results were analyzed using the same statistical methodology as in the FIS to determine the discharge-frequency relationship for the lower Chester Creek. The resulting relationships are provided in Table 7 and Table 8. Table 7 provides the discharge-frequency relationship at various locations along the lower reach of the Chester Creek for with and without the drywell influences, while Table 8 provides the stage-frequency relationship for the storage areas in the lower reach of the Chester Creek. The results indicate that there will be no flow downstream of 8th Avenue (Storage Area 9). However, there will be minor ponding within Storage Area 10 due to local runoff to these areas. This ponding would average less than 1 foot in depth.

Table 7. Discharge-Frequency Relationships for Chester Creek

Location	Discharge (cfs) without Drywells				Discharge (cfs) with Drywells			
	10-yr	50-yr	100-yr	500-yr	10-yr	50-yr	100-yr	500-yr
Cross Section H	81	118	134	170	n.a.	n.a.	n.a.	n.a.
Cross Section K	35	49	54	67	n.a.	n.a.	n.a.	n.a.
Cross Section L	2	3	4	5	n.a.	n.a.	n.a.	n.a.
Storage 5 Outflow	35	46	51	62	30	41	46	57
Storage 8 Outflow (16th Avenue)	17	30	35	48	13	25	30	43
Storage 9 Outflow (8th Avenue)	0	0	0	0	0	0	0	0
Storage 10 Outflow (2nd Avenue)	0	0	0	0	0	0	0	0

Table 8. Water Surface Elevation-Frequency Relationship for Storage Areas of Chester Creek

Location	Overflow Elevation (ft)	WS Elevation (ft) without Drywells				WS Elevation (ft) with Drywells			
		10-yr	50-yr	100-yr	500-yr	10-yr	50-yr	100-yr	500-yr
Storage Area 3	1999.80	2000.44	2001.15	2001.45	2001.9	1999.99	2000.74	2001.05	2001.78
Storage Area 5	2001.90	2000.44	2001.15	2001.45	2001.9	1999.99	2000.74	2001.05	2001.78
Storage Area 7	1996.85	1996.53	1997.05	1997.07	1997.10	n.a.	n.a.	n.a.	n.a.
Storage Area 8	1993.35	1993.59	1993.69	1993.73	1993.83	1993.56	1993.66	1993.70	1993.79
Storage Area 9	1992.50	1990.65	1991.88	1992.00	1992.28	1989.15	1990.64	1990.73	1990.95
Storage Area 10	1986.00	1983.28	1983.44	1983.51	1983.66	1983.04	1983.19	1983.25	1983.39

Conclusions

WEST completed two hydrologic analyses of Chester Creek using HSPF. The first analysis involved analyzing Subbasin C2 to determine validity of using the 22 drywells located in SA3 to reduce peak flood discharges for Chester Creek. The discharge-frequency relationship for the four subbasins of Subbasin C2 is provided in Table 3. A comparison of drywell capacity and basin discharge is provided in Table 4. The runoff from the subbasin was compared to the infiltration potential of the drywells existing within the subbasin, and it was determined that the runoff from this subbasin will not contribute to either SA3 or Chester Creek and therefore the dry wells located within SA3 can be considered to help reduce peak flood discharge from Chester Creek in addition to the dry wells located further downstream.

The second analysis involved re-evaluating the hydrology for the lower Chester Creek. The re-evaluation included additional outflow locations downstream of 24th Avenue, additional storage areas at the downstream end of the watershed, and the effects of drywells within the floodplain. The results of the re-evaluation are provided in Table 7 and Table 8. The results indicate that there will be no flow downstream of 8th Avenue (Storage Area 9), but there will be minor ponding with Storage Area 10 due to local runoff to these areas. This ponding would average less than 1 foot in depth.

References

City of Spokane Valley, 2006 (July), *Data for Drainage Structures in Lower Chester Creek Floodplain*.

City of Spokane Valley, 2006 (October), *Letter from Neil Kersten, City of Spokane Valley, to Ryan Ike, U.S. Department of Homeland Security, Re: Chester Creek Floodplain Revisions*.

City of Spokane Valley, 2006 (November), *Letter from Henry Allen, City of Spokane Valley, to Joseph T. Weber, Jr., U.S. Department of Homeland Security, Re: Chester Creek Floodplain Revisions*.

WEST Consultants, Inc., 2004 (December). *Flood Insurance Study Hydrologic Analysis for Chester Creek, Spokane County, Washington*, prepared for FEMA Region X.

United States Environmental Protection Agency (EPA), 2005 (July), *Hydrological Simulation Program-FORTRAN, Release 12.2*.

ATTACHMENT 1

FIGURES

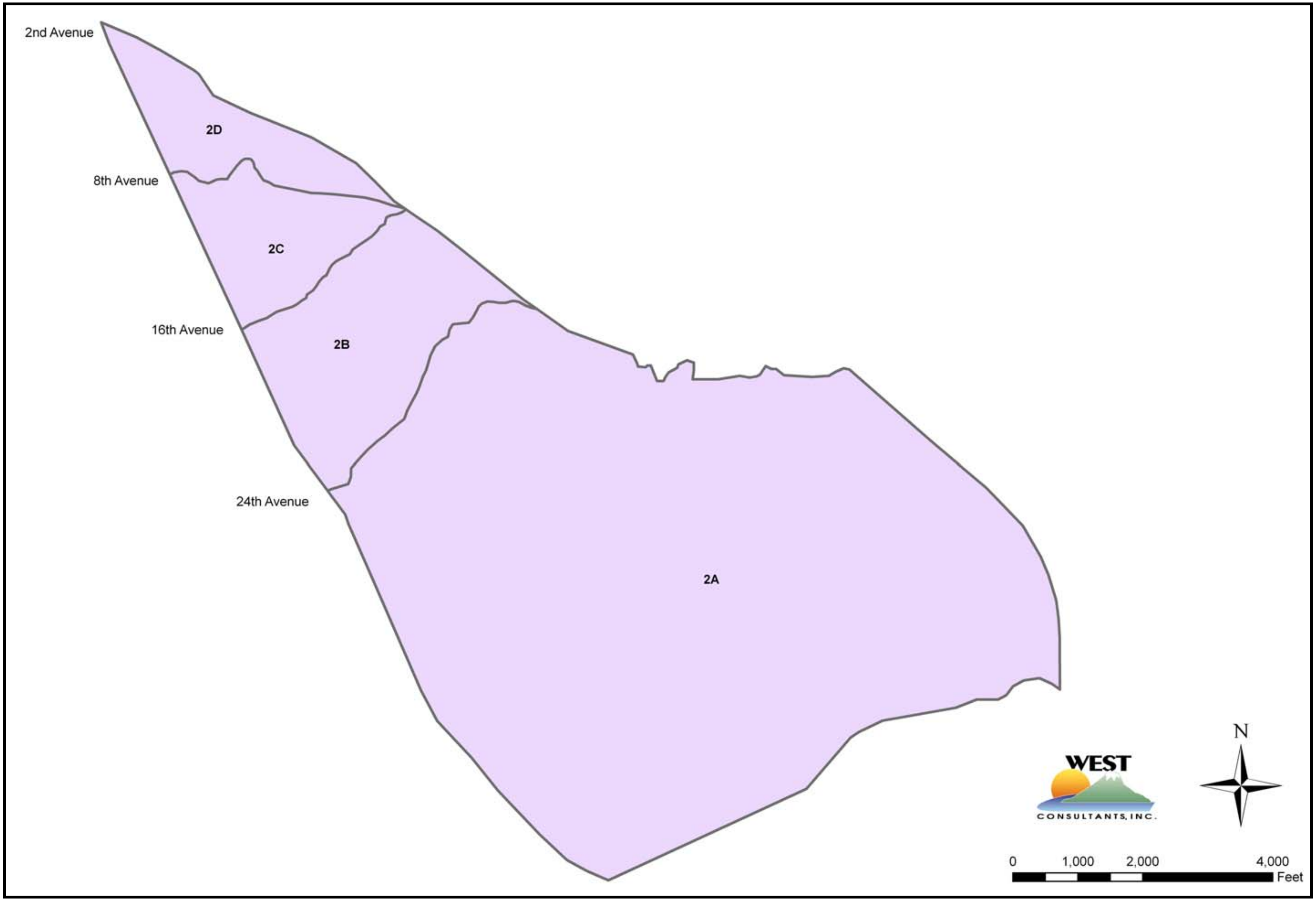

Figure 1. Subbasin delineations for Subbasin C2

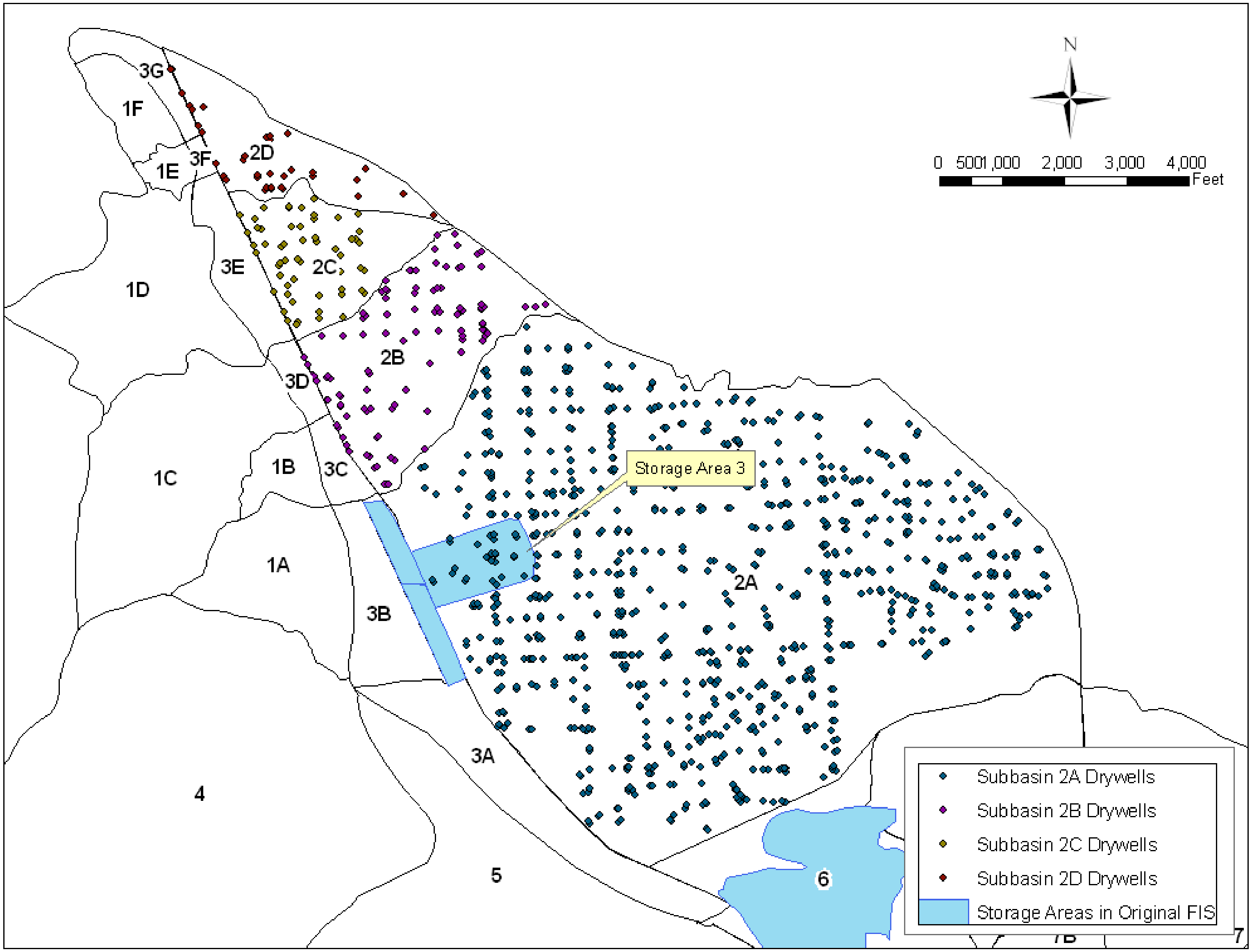

Figure 2. Drywell distribution for Subbasin C2

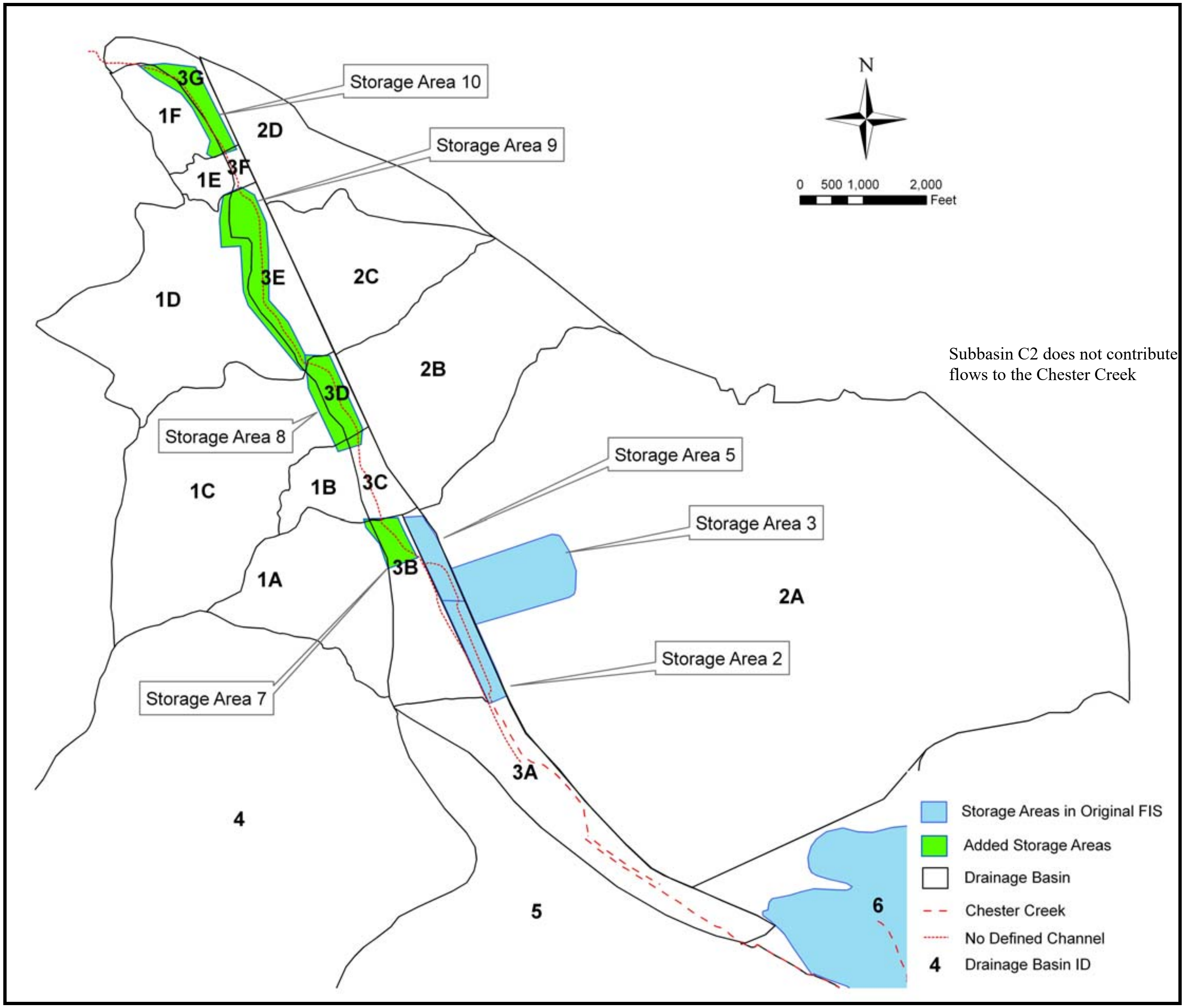

Figure 3. Subbasin delineations for Lower Chester Creek