TETRA TECH

MEMORANDUM

TO:	Anita Hairston, Chief of Staff, DC Office of Planning
FROM:	Patti Sexton, P.E.
SUBJECT:	**Interior Drainage Analysis**
Cc:	Mary Wiedorfer, Tetra Tech
DATE:	December 8, 2008; UPDATED: January 21, 2008

As part of the Conditional Letter of Map Revision (CLOMR) request that will be submitted for the Potomac Park levee, an interior drainage analysis is required. That analysis has been completed and per the milestone schedule established between the District of Columbia (District) and FEMA is being provided for review. Any comments received from the District or FEMA will be incorporated in the analysis that is submitted with the CLOMR request.

Description of the Interior Area

The Potomac Park Flood Protection System includes high ground, an earthen levee and 2 closures between the Lincoln Memorial and the Washington Monument as shown in Figure 1. An additional closure located at P and Canal Streets is also considered part of the Potomac Park Flood Protection System and is located southwest of the National Mall area. This system provides protection to the Federal Triangle area.

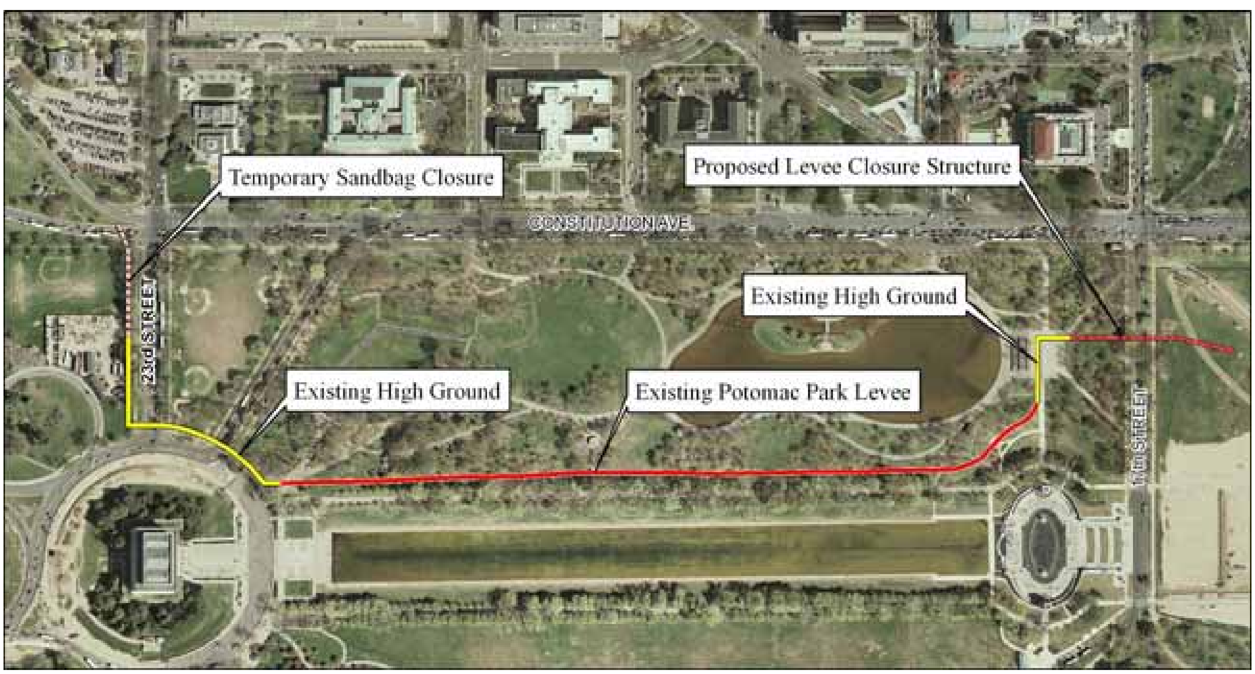

Figure 1. Potomac Park Flood Protection System

The Federal Triangle is at the bottom of a watershed that extends north to Buchanan Street NW and is shown on Figure 2. This watershed is approximately 5.2 square miles. The Potomac Park levee itself is outside of this watershed and is located such that very little overland flow is generated in the drainage area directly tributary to the levee. This levee watershed is also shown in Figure 2. Note in Figure 2 that the watershed boundary separating the Federal Triangle and Potomac Park basins is not governed entirely by the topographic contour lines because the subsurface storm drainage system handles a portion of flood runoff.

The Federal Triangle area is served by a partially separated sewer system. The combined system is part of a large and complex sewer system that serves the combined and separate sewered areas in the District of Columbia and portions of the separately sewered areas Maryland and Virginia. The combined system is operated by the District of Columbia Water and Sewer Authority (DC WASA). The Federal Triangle area is part of the B Street / New Jersey (NJ) Avenue system. This system includes a network of pipes which terminate in the O Street and Main Pumping Stations. The O Street Pump Station provides the primary service for the Federal Triangle area. These pump stations handle combined sewage during large storms. The Federal Triangle area is also drained by a storm drain that drains by gravity to the Tidal Basin and then into the Potomac River.

The O Street and Main Pumping Stations serve an area much greater than the Federal Triangle. The Main Pumping Station serves the entire area in the northeast and southeast portions of the District. Flows are conveyed to the pump station primarily by the B Street / NJ Avenue Trunk Sewer, the Tiber Creek Trunk Sewer and the East Side Interceptor. The O Street Pumping Station which is adjacent to the Main Pumping Station can be considered a supplement to the Main Pumping Station (O&M Manual, 1993). Overflow from both pump stations is discharged to the Anacostia River. The operation and maintenance manual for these pump stations (included in Appendix B) indicates that the main purpose of the pump stations is to prevent sewage from entering the river by pumping it to the Blue Plains Wastewater Treatment Plant. Each pump station includes sanitary and stormwater pumps. The effect of the pumps on the Federal Triangle area is dependent on the amount of flow that is being conveyed to the pumps from the other service areas.

Previous Study

In 1992 the U.S. Army Corps of Engineers (Corps) developed a General Design Memorandum for the Modifications to Washington D.C. and Vicinity Flood Protection Project. As part of that report an interior drainage analysis was prepared to document the residual flooding in the interior area. This analysis focused on the effects from local rainfall and states that because the storm sewer capacity is a function of pumping capacity, the stage of the river has little impact on the interior pond elevation. A conclusion of the report is that the project will not worsen interior flooding in most areas.

While no significant changes in the WASA sewer system have occurred since the Corps study was completed, new topography has become available. Much of the methodology used by the Corps is similar to what is reflected in this updated study.

The final interior ponding area identified in this report is shown on the figures associated with the analyses performed for this current study. The significant area of ponding in the Corps' analysis is identified as Pond IA. The pond elevation associated with the 100-year rainfall in Pond IA is 10.76 feet NGVD29 (approximately 10 feet NAVD88).

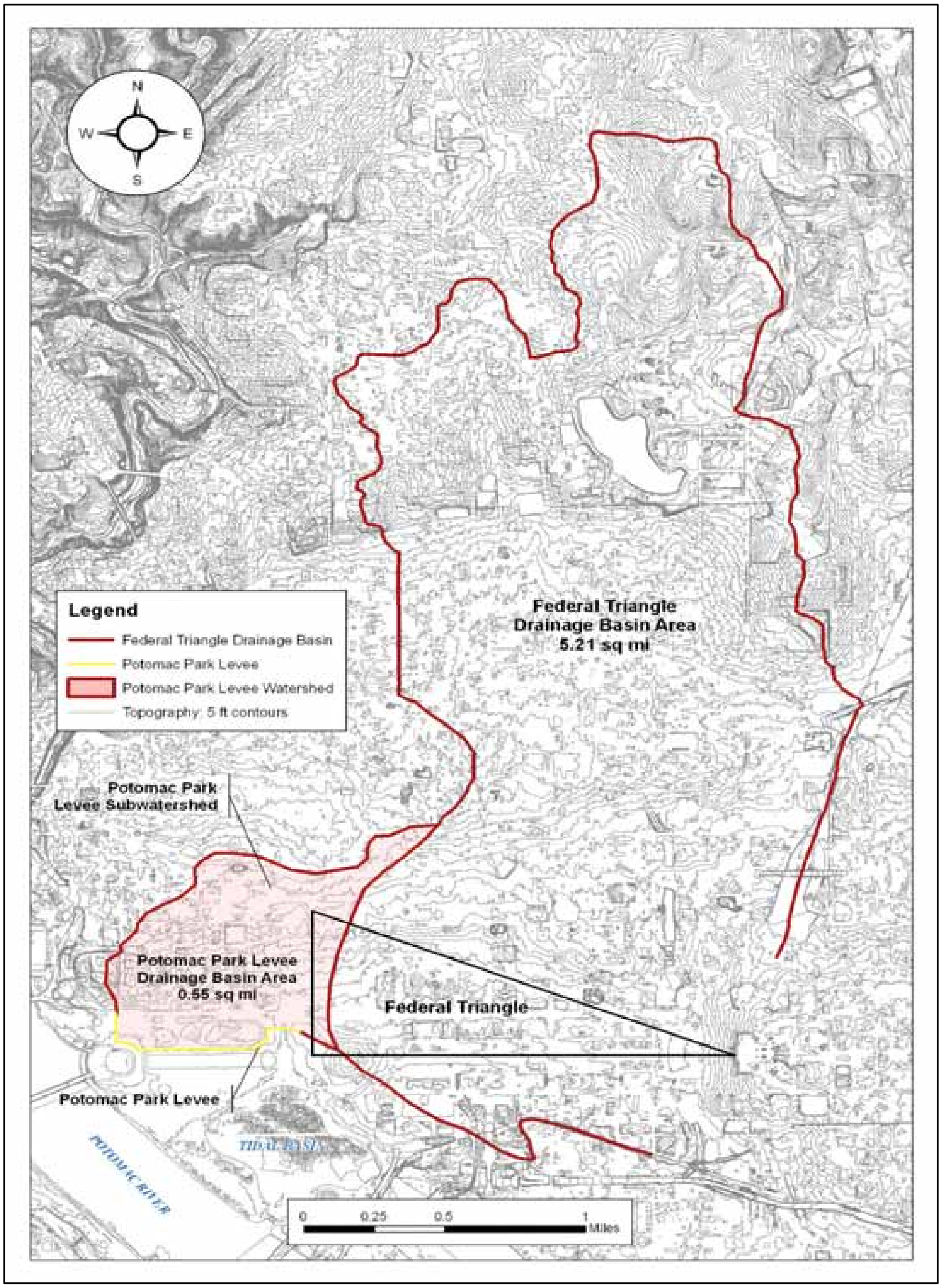

Figure 2. Watershed Areas

Interior Drainage Analysis

An interior drainage analysis was performed to assess the residual flooding in the area protected by the Potomac Park Levee system. This analysis looks at both the impacts of rainfall within the District of Columbia (the interior area) and flood stages on the Potomac River and the interaction between the interior and exterior conditions.

The approach for the interior drainage analysis relies on an assessment of a range of scenarios to quantify the anticipated range of flooding associated with the interior ponding area. In several of these scenarios the impact of the pumping stations were not directly considered. This was deemed necessary because of the fact that the system serves an area much larger than the Federal Triangle area. As such, the ability of the pumping stations to evacuate floodwaters from the Federal Triangle area depends on the geographical distribution of rain and the timing of runoff produced by areas geographically far removed from the Federal Triangle and the pumping stations. Therefore, the operating procedures for the pumping stations do not definitively address flooding in the Federal Triangle area in a way that would satisfy the FEMA requirements.

Watershed Data

To support the analysis WASA provided a map delineating the Federal Triangle Basin Catchments. This map is provided in Appendix A and identifies the individual sewersheds associated with each combined sewer outflow (CSO). Following the sewershed map is a schematic that shows the layout of the sewer system in the study area. In conjunction, these two maps with Figure 2 illustrate that the boundary of the watershed on the ground surface changes once flow is conveyed into the pipe system.

Throughout the watershed stormwater is picked up by catch basins distributed throughout the system. WASA provided information for each sewershed regarding the number of catch basins and the capacity of those catch basins to convey flow into the pipe network system.

Ponding Area

Runoff that is not conveyed into the pipe system via the catch basins will flow down the streets to the low point of the watershed which is the Federal Triangle area. Once water reaches this area it will collect and pond. Elevation-volume curves were generated using the 2008 LiDAR data that was provided through the Office of the Chief Technology Officer (OCTO). Contours and subsequent 3D raster surfaces were created from the LiDAR points which were spaced at 100-ft intervals, allowing 2-ft contours to be generated. Some areas of the topo are distorted due to ‘blurring’ of the data in areas of high national security priority such as around the White House, Washington Memorial, and the Capital. The data was assembled and analyzed in ArcGIS 9.2. The storage-elevation curve is included in Appendix B.

Interior Drainage Outlets

The interior drainage of the Federal Triangle can be drained in two ways: (1) the Constitution Avenue gravity storm drain and (2) the B Street / New Jersey combined sewer system. The Constitution Avenue gravity storm drain ranges in diameter from 57” to 72” pipe and runs for approximately one mile along Constitution Avenue from 6th Street NW to 15th Street NW.

The storm drain then turns south, crosses the National Mall, and discharges to the Potomac River at the Tidal Basin. Appendix A includes an analysis of the outlet capacity of this pipe under different tailwater conditions.

The B Street / New Jersey combined sewer flows to the O Street and Main Pumping Stations. The combined sewer also contains two gravity overflow points that discharge flows to the Anacostia River.

The two pump stations are both separated into a sanitary and stormwater side. The sanitary side of both pump stations pump flows to the Blue Plains Treatment Plant. The stormwater side of both pump stations discharges flows to the Anacostia River. The stormwater side of the O Street Pump Station contains 6-100 MGD pumps (design capacity 500 MGD (775 cfs) with one pump held in reserve.) The stormwater side of the Main Pumping Station contains 6-80 MGD pumps (400 MGD (620 cfs) capacity with one pump held in reserve.) While O Street and Main Pumping Stations are both connected to the B Street / New Jersey combined sewer line, the sewer is primarily drained by the O Street Pump Station.

Interior Drainage Model

Using the U.S. Army Corps of Engineers (Corps) HEC-HMS software, a model of the Federal Triangle watershed was developed. The following describes the drainage basin parameters that were used in the model. Summary HEC-HMS data is provided for one analysis scenario in Appendix B. All input and output files are included on the CD attached to this memorandum.

The HMS model was used to generate runoff throughout the watershed area, route the flows down to the low point (the Federal Triangle), and route the flows through the detention basins using various outlet scenarios. The model was also used to determine the elevation of the interior pond.

Drainage Area

A sewershed shapefile, provided by WASA, was used as the basis for the subwatersheds in the HEC-HMS model. The sewersheds were clipped to match the extent of the Federal Triangle overland flow drainage area, also provided by WASA as a shapefile. The subsequent clipped sewersheds were used to calculate drainage areas and assist in delineating flow routes for the HEC-HMS model. Sewershed processing was done in ArcGIS.

The topographic data base used is a 2008 LiDAR dataset provided by OCTO. Spot checks were done between this dataset and the previous OCTO data that was generated in 2004. This verification resulted in elevation discrepancies on the order of 2.5 feet. The 2008 data was corrected to remove the effects of vegetation while this was not done in the 2004 data. The 2004 data has a smaller grid (1 meter) as compared to the 100-foot grid in the 2008 data. Data from the U.S. Coastal and Geodetic (USCG) Survey were obtained for several benchmarks in the study area and compared with elevations from the 2004 and 2008 data at the same locations. Several of these points are shown in the table below.

Table 1. Elevation Comparison

Point	USCG elevation	2004 elevation	2008 elevation	Location
1	11.02’	10.12’	11.2’	Capitol Grounds
2	6.23’	6.58’	4.21’	Constitution & 9th
3	6.49’	6.74’	4.00’	Pennsylvania & 9th
4	12.30’	12.83’	12.69’	Constitution & 15th
5	14.56’	14.56’	14.05’	Pennsylvania & 13th

An analysis of the data indicates that agreement among all 3 data sets is good except along Constituion Avenue. In this area the USCG and 2004 data are approximately 2 feet to 2.5’ higher than the 2008 data. The 2008 data was used for this analysis because it is the most recent available data. If further analysis by OCTO results in a shift in the 2008 elevations along Constitution Avenue it would have some impact on the ponding elevation and ponding footprint. Preliminary analyses were performed to assess the likely range of impact if elevations along Constitution Avenue were increased by 2.5’. The results of this analysis show that the ponding elevation and footprint are unaffected due to the relatively small volume of storage in question.

Rainfall

Various rainfall frequency events were defined in the HMS model. The rainfall amounts were interpolated from the NOAA Atlas 14, Volume 2 and are shown below in Table 1. The SCS 24-hour Type II rainfall distribution was used.

Table 2. Precipitation Depth

Frequency	Precipitation (inches)
100-year	8.30
50-year	7.15
10-year	4.80
2-year	3.14

Losses

Using the SCS method, a curve number was defined for each of the sewersheds. Table 2 shows the values that were used for the land types found in the watershed. Based on visual inspection of the aerial photography a composite for the sewershed was developed using the Table 2 values. The final curve numbers ranged from 70 to 93.

Table 3. SCS Curve Numbers

Land Type Description	SCS CN
Urban: Commercial	93
Residential: 1/8 acre or less	89
Open Space: Good	70

Routing

Lag times were developed within each sewershed to determine the time for the runoff to reach the collection point of the sewershed. Flow Velocity was calculated based on the Manning's equation:

$$V = (1.49/n) \times R^{0.67} \times S^{0.5}$$

A Manning's n-value of 0.013 was used to represent asphalt, a typical street section was used to determine the hydraulic radius (R), and the slopes were identified from the topographic data. Times of concentration for each sewershed ranged from 2 minutes (5 minute minimum used in the analysis) to 19 minutes. From the base of each sewershed routing reaches were identified along which to convey flow to the low area in the Federal Triangle. Flow routes were determined through interpretation of the digital elevation models topography as well as the CSO network information.

Reservoir

The reservoir component of the HEC-HMS model was used to determine the depth of ponding that would result from the watershed runoff.

Pond Outlet

As described previously, flow can be discharged from the pond via a gravity drain or through the pump stations. Various HMS simulations were set up to analyze the impacts of the possible outlets.

<u>Interior Drainage Scenarios</u>

A series of simulations were performed to assess various scenarios. The following pages include the map showing the interior ponding elevation resulting from each simulation. The maps were generated using the LiDAR topographic base. Minor manual corrections were made to compensate at the locations where the topography had been obscured for security reasons. These locations included the Washington Monument grounds and the Capitol grounds. The maps show the inundation area associated with that scenario as well as the one determined in the 1992 Corps study.

Scenario 1 – no outlets

In this simulation the total runoff from a 100-year storm was routed down to the Federal Triangle. The river stage was assumed to be at the 100-year level at which time the gravity drain outlet has negligible impact on the pond elevation. The pumps were not used to drain the interior in order to reflect the uncertain operational procedures. Thus, this scenario is a conservative estimate of the interior ponding area and was generated to establish a maximum extent of the expected inundated area. The elevation of the ponded area was calculated based on the elevation-storage curve to be 9.4 feet NAVD88 and the footprint of the area is shown on the map included as Exhibit 1.

It should be noted that 3 tunnel entrances are located within the identified interior drainage area or north of the area. This will allow water to enter the tunnels and be conveyed to the south. The inundation area shown on Exhibit 1 includes a ponding area south of the main pond that identifies the ponding at the south limit of the tunnel. It should be noted that the analysis performed does not consider storage within the tunnel.

Scenario 2 – catch basin diversions

In this simulation the runoff from a 100-year storm was generated for the watershed. The capacity of the catch basins was modeled to divert flow out of the watershed. It is assumed that the water will be conveyed through the combined sewer pipe system and the pump stations will discharge the flow to the Blue Plains Treatment Plant or the Anacostia River. The flow not collected by the catch basins was routed to the Federal Triangle and allowed to pond in the low areas. The river stage was assumed to be at the 100-year level at which time the gravity drain outlet has negligible impact on the pond elevation. The elevation of the ponded area was calculated based on the elevation-storage curve. The interior pond elevation in this scenario is 6.1 feet NAVD88 and the footprint of the area is shown on the map included as Exhibit 2. This scenario produces a minimum 1% probability interior area flood stage.

The Scenario 2 flooded area is smaller compared to Scenario 1 due to the significant diversion of flow that is assumed to occur through the catch basins. The analysis of the catch basins (included in Appendix A) assumes that 25% of the catch basins are clogged and accept minimal flow while the remaining catch basins are fully operable under orifice flow. Flow that bypasses the catch basin in the originating watershed is not given an opportunity to enter the system at a downstream catch basin, but is routed to the Federal Triangle. An underlying assumption of this analysis is that the pipes have sufficient capacity to convey the flow collected by the catch basins. The ability of the pipes to convey that capacity is in part dependent on the operation of the combined system contributing to the pump stations and the operation of the pump stations themselves. This scenario provides a possible inundation limit that could result under a certain pumping operation.

It should be noted that 3 tunnel entrances are located within the identified interior drainage area or north of the area. This will allow water to enter the tunnels and be conveyed to the south. The inundation area shown on Exhibit 2 includes a ponding area south of the main pond that identifies the ponding at the south limit of the tunnel. It should be noted that the analysis performed does not consider storage within the tunnel.

Scenario 3 – pump discharge

In this simulation the total runoff from a 100-year storm was routed down to the Federal Triangle. No diversion of flow through the combined sewer system in the watershed was considered. The pumping capacity of the O Street pump station was used to drain the ponded areas. Based on the design capacity of the pump station, a constant pumping rate of 500 MGD was used. The river stage was assumed to be at the 100-year level at which time the gravity drain outlet has negligible impact on the pond elevation. The maximum elevation of the ponded interior in this scenario is 7.6 feet NAVD88; the footprint of the area is shown on the map included as Exhibit 3.

It should be noted that 3 tunnel entrances are located within the identified interior drainage area or north of the area. This will allow water to enter the tunnels and be conveyed to the south. The inundation area shown on Exhibit 3 includes a ponding area south of the main pond that identifies the ponding at the south limit of the tunnel. It should be noted that the analysis performed does not consider storage within the tunnel.

An assumption made in this analysis is that the full pumping capacity of the O Street pump station is available to drain the Federal Triangle area which is part of the B / NJ combined sewer. However, as shown in the schematic of the system (included in Appendix A) B St /NJ also drains a large area upstream of the Federal Triangle. The upstream system includes many other pump stations and combined sewer overflow points. Previous modeling efforts made by WASA indicate that during the 100-year storm event, the pipes downstream of the Federal Triangle are conveying 900+ cfs. This indicates that the pumps cannot fully keep up with the total flow in the system and some ponding would be expected. This scenario provides another possible inundation limit that could results under certain pumping operations. However its likely that the pumps would be partially (rather than full) used to drain the Federal Triangle area. This would indicate that a realistic interior pond that accounts for the pumping as the only pond outlet is between the one shown in this scenario (7.6 feet) and Scenario 1 (9.4 feet) where no pumping is considered.

Scenario 4 – gravity drain

This scenario is a joint probability analysis that looks at a range of rainfalls on the interior and the ability of the Constitution Avenue drain (the gravity drain outlet) to discharge from the Federal Triangle area based on a range of river stages in the Potomac River. High stages on the Potomac River impact the interior flooding only at the Constitution Avenue gravity drain outlet. This outlet includes a closure structure so flow from the river cannot backup into the Federal Triangle area; however during high river stage, the interior would need to pond to a sufficient depth to create enough hydraulic head to force flow through this drain. The details of the joint probability analysis are included in Appendix C. A review of the results shows that the stage of the river has little impact on the elevation of the pond interior. This same conclusion was reached in the 1992 Corps study. Based on the analysis of this scenario, the interior pond elevation that has a 1% probability of occurring is 9.3 feet NAVD88; the footprint of the area is shown on the map included as Exhibit 4.

No direct benefit of the pumping station is considered in this scenario. However an indirect benefit considered is that the pumping capacity will provide enough relief to the combined sewers that no surcharging of the B St / NJ Avenue line will occur through the Federal Triangle area.

It should be noted that 3 tunnel entrances are located within the identified interior drainage area or north of the area. This will allow water to enter the tunnels and be conveyed to the south. The inundation area shown on Exhibit 4 includes a ponding area south of the main pond that identifies the ponding at the south limit of the tunnel. It should be noted that the analysis performed does not consider storage within the tunnel.

Future Studies

It should be noted that an additional study that addresses the interior drainage is anticipated to begin in the near future. This study will be performed by DC WASA in conjunction with the National Capital Planning Commission, the District of Columbia, the General Services Administration, the Smithsonian Institute, and FEMA. This study will provide a more in-depth analysis of the complexities of the combined sewer system and the impact on the interior flooding through the District. It is anticipated that this study will provide a greater level of detail and eliminate some of the conservative assumptions used in this study. The study will also identify alternatives to reduce the magnitude and duration of predicted ponding in the Federal Triangle area. At this time, the results of that study are expected to supersede this study before the Letter of Map Revision is submitted for the Potomac Park Levee project.

Conclusion and Recommendation

Scenarios 1 through 4 simulate interior drainage runoff and ponding for a range of conditions reflecting the uncertainties inherent in the operation and performance of the WASA storm drain system, catch basins, and pumping stations. Scenarios 1, 3, and 4 indicate maximum ponding elevations that range from 7.6 feet to 9.4 feet NAVD88. The calculated 1% probability ponding elevations among these scenarios is not significantly different. The Scenario 4 analysis with an estimated 1% probability interior pond elevation of 9.3 feet NAVD88 is a conservative analysis of the ponding elevation for which adequate documentation can be provided. The pond footprint associated with Scenario 4 is recommended to be adopted as the interior drainage pond area associated with the Federal Triangle and is recommended for adoption as part of the FEMA Flood Insurance Rate Maps (FIRMs).

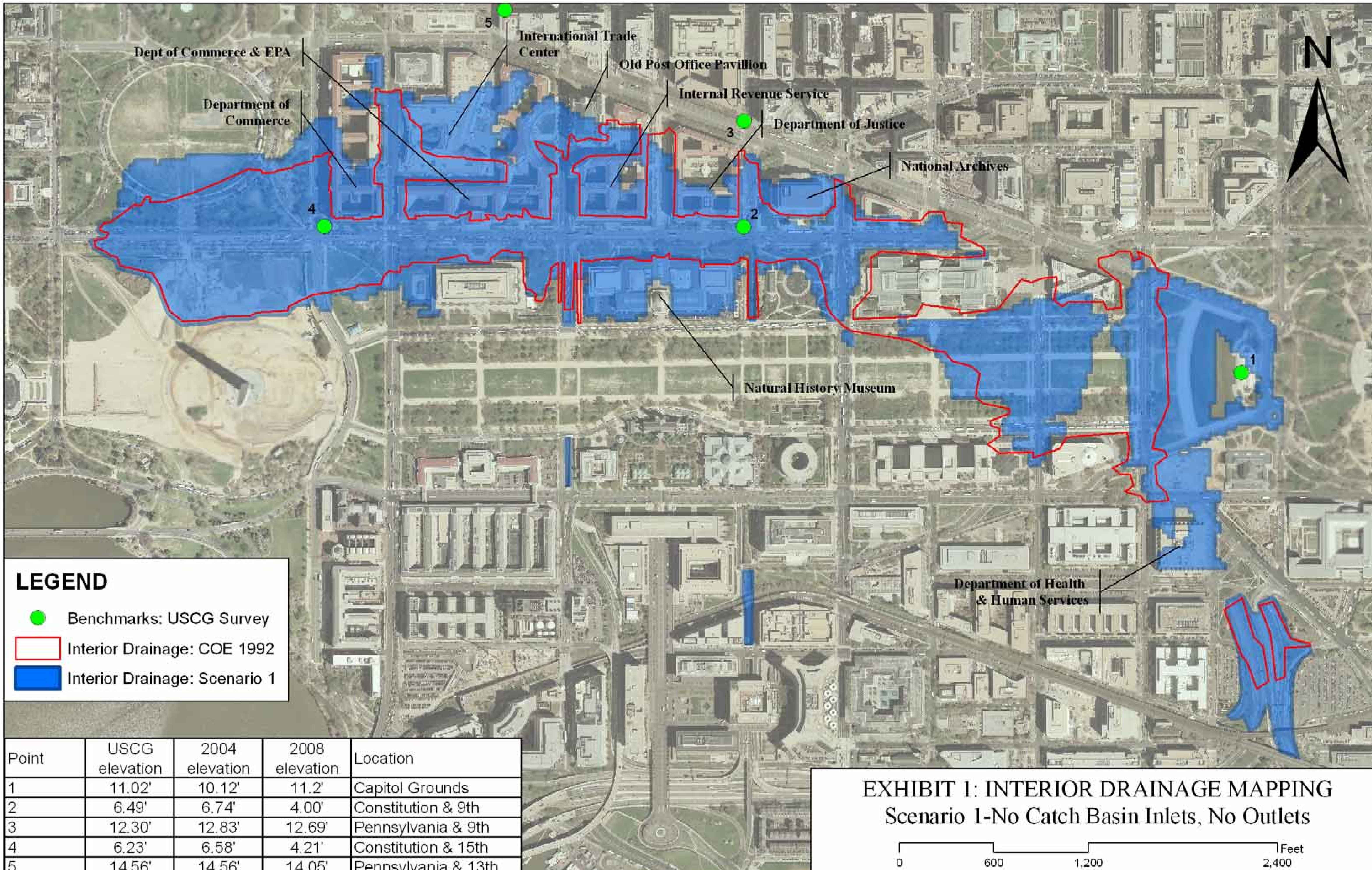

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EXHIBIT 1: INTERIOR DRAINAGE MAPPING

Scenario 1-No Catch Basin Inlets, No Outlets

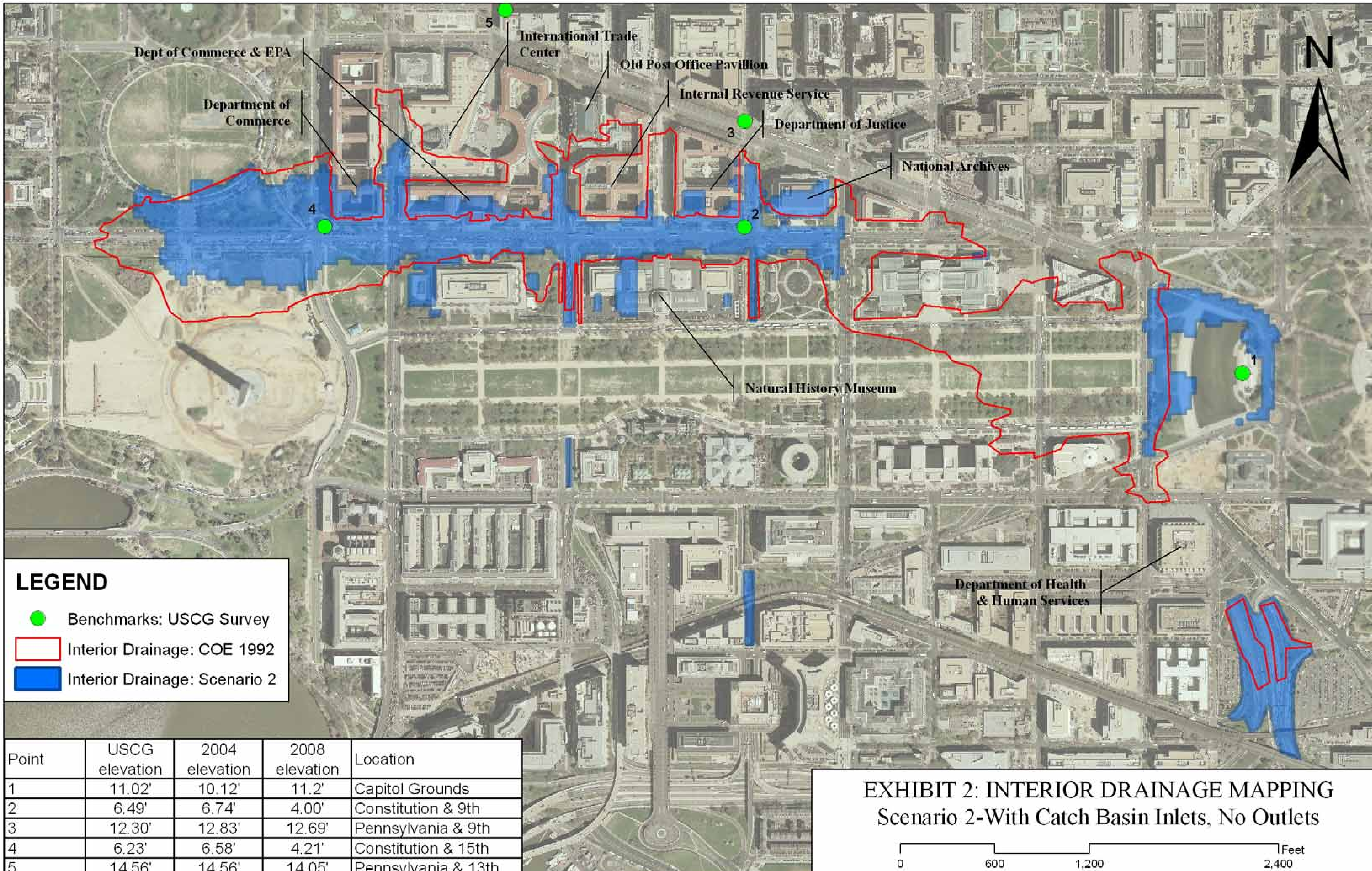

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EXHIBIT 2: INTERIOR DRAINAGE MAPPING
Scenario 2-With Catch Basin Inlets, No Outlets

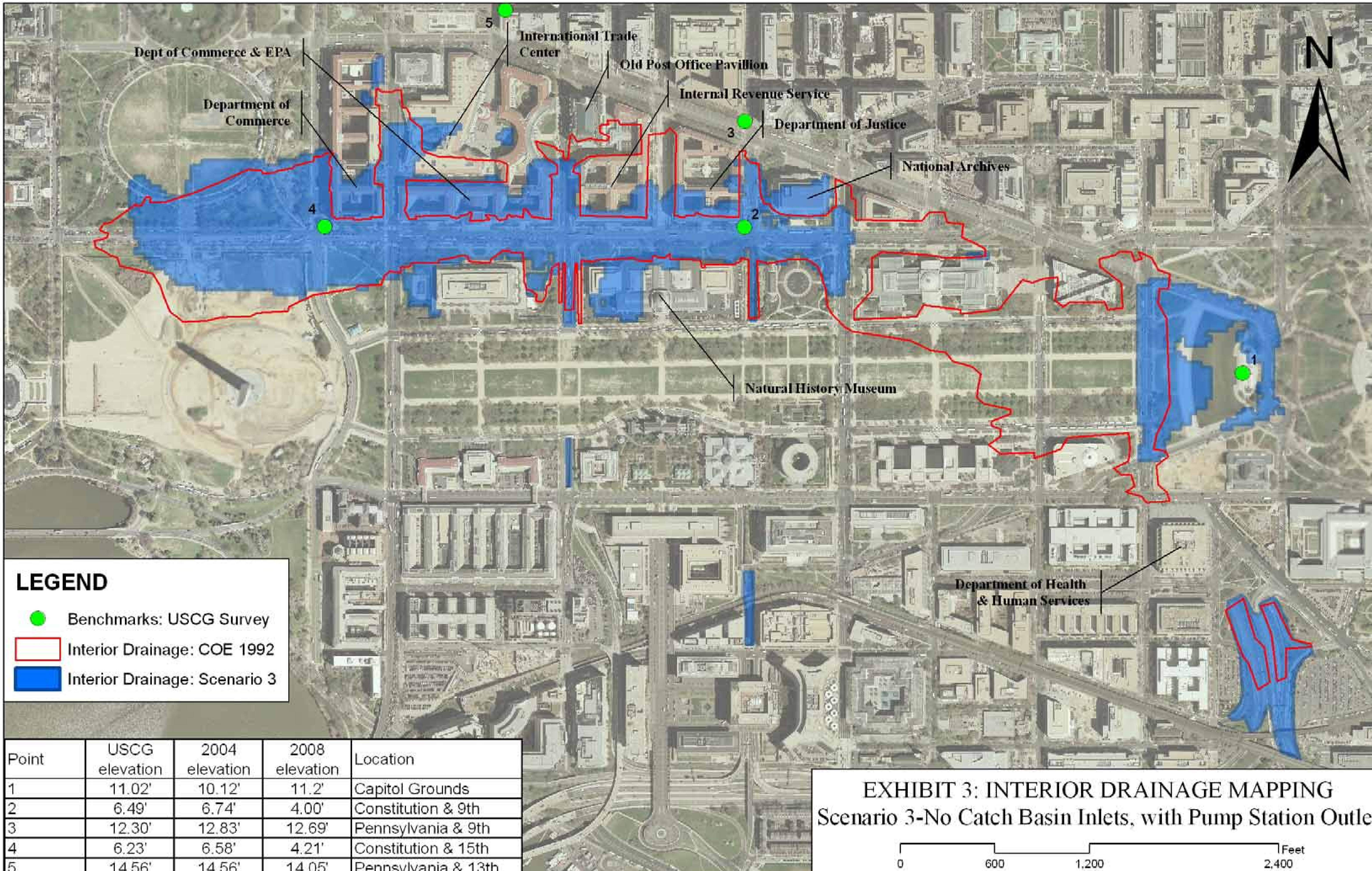

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EXHIBIT 3: INTERIOR DRAINAGE MAPPING
Scenario 3-No Catch Basin Inlets, with Pump Station Outlet

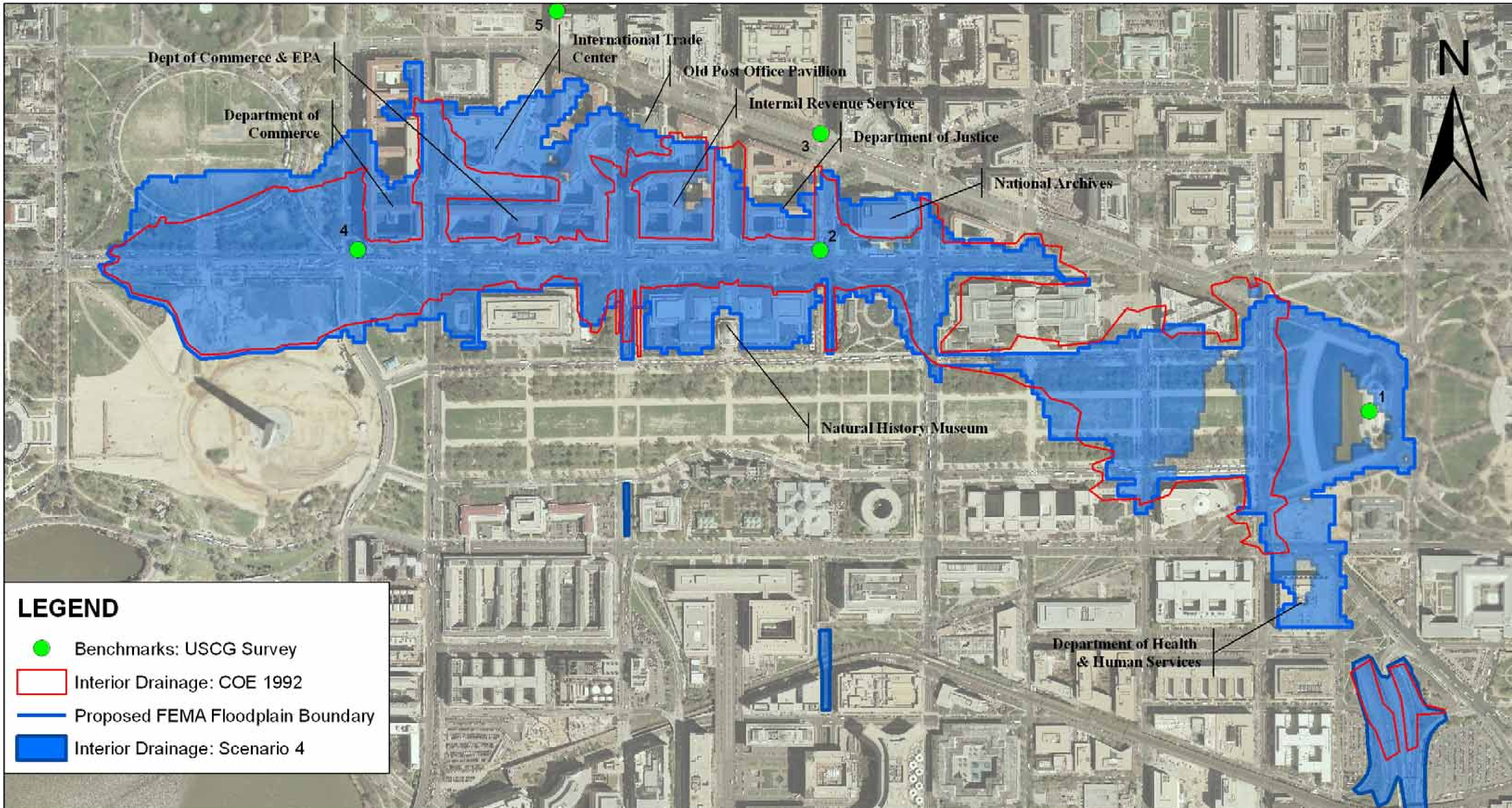

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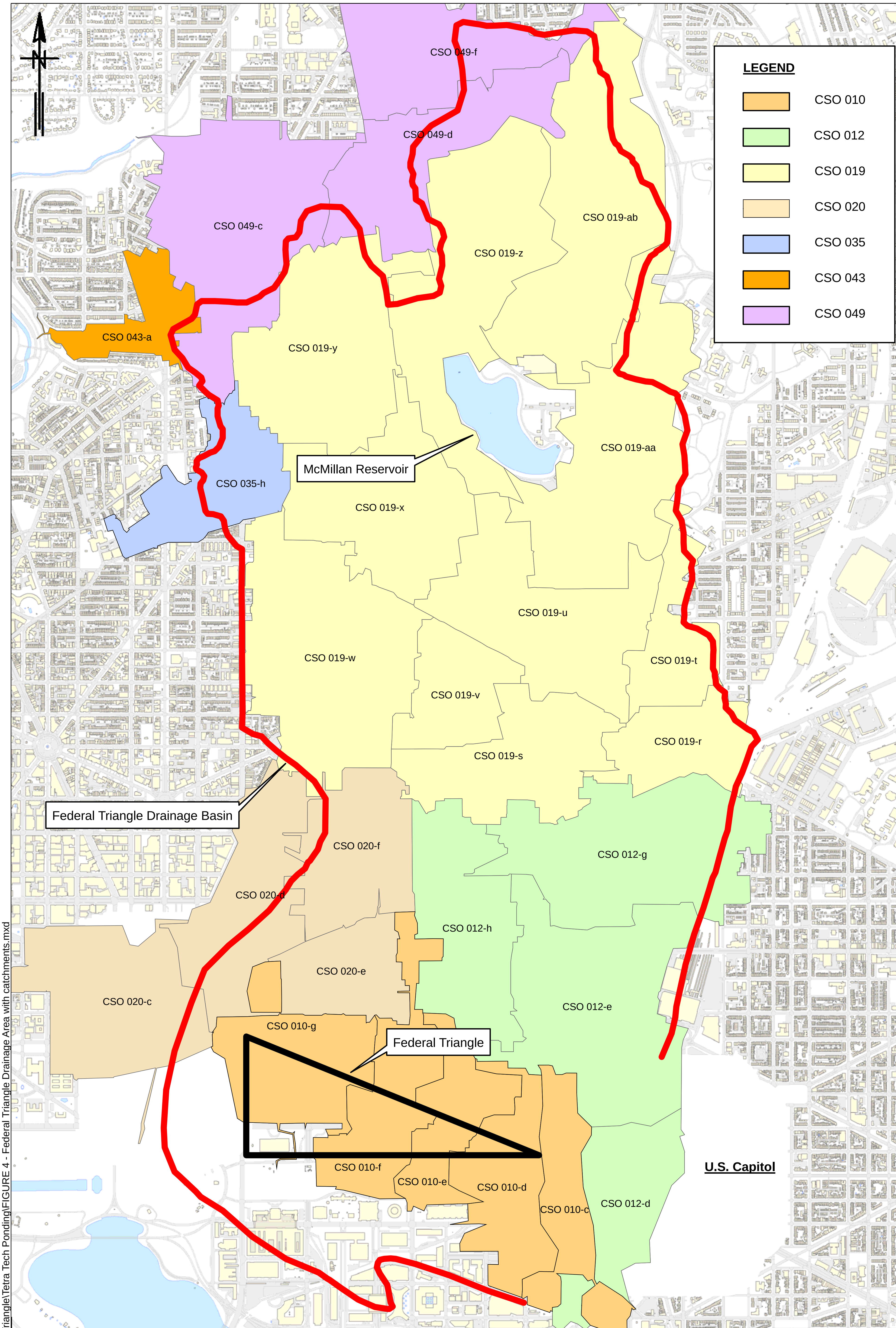
EXHIBIT 4: INTERIOR DRAINAGE MAPPING

Scenario 4-Gravity Drain Outlet, Joint Probability Analysis

Appendix A

Sewershed Catchment Areas
Catch Basin Capacity Analysis
Sewer System Schematic



EPMC-3A

D.C. WATER & SEWER AUTHORITY

FEDERAL TRIANGLE DRAINAGE BASIN CATCHMENTS

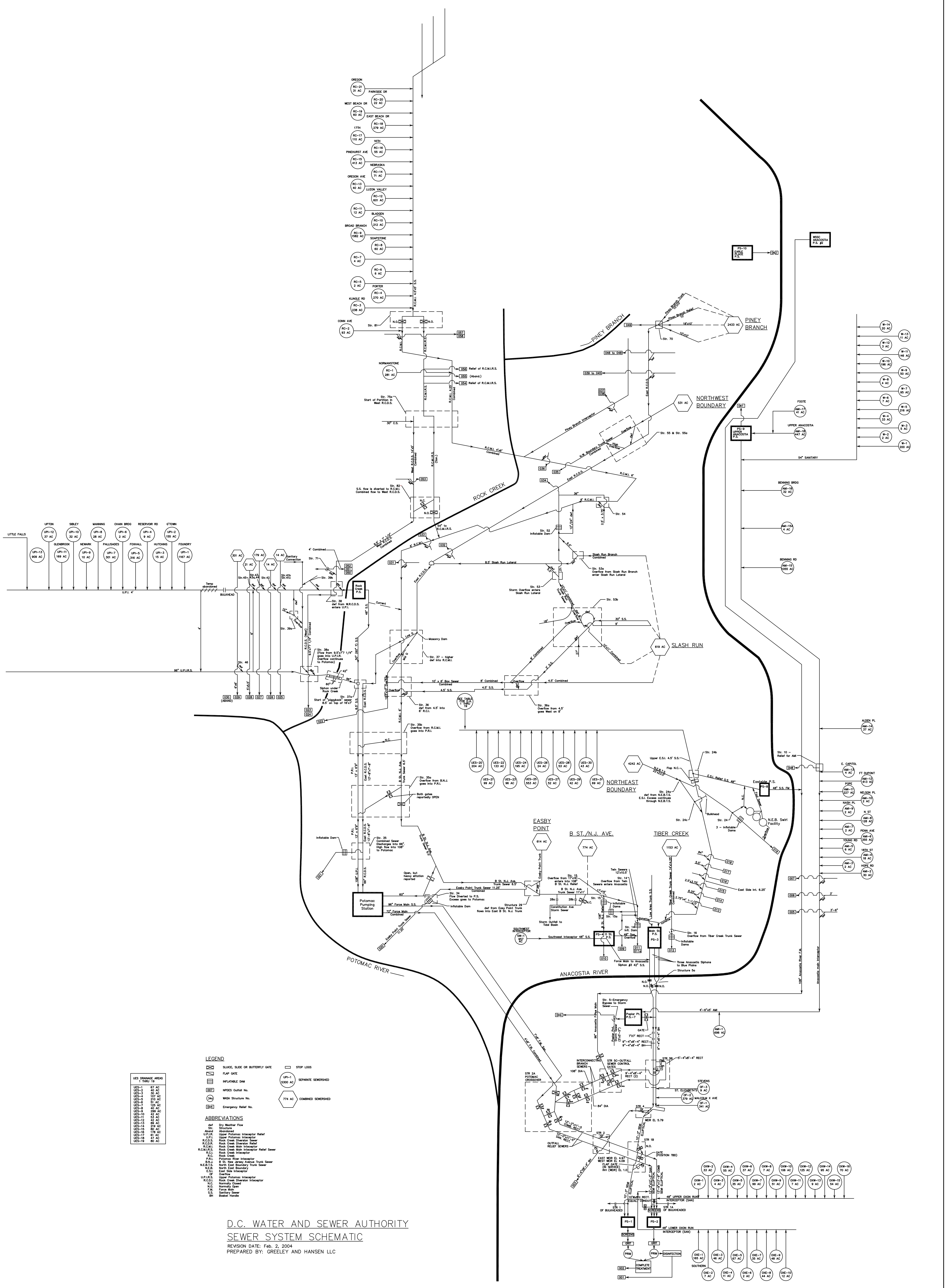
0 750 1,500 3,000 4,500 6,000 Feet

FIGURE 4

H:\1163\Misc\Federal Triangle\Tetra Tech Ponding\FIGURE 4 - Federal Triangle Drainage Area with catchments.mxd

Total Capacity of Catch Basins in Federal Triangle Drainage Basin

Catchbasin Information		Inlet not submerged - per VDOT Drainage manual				Inlet submerged 6" deep - Treat like orifice: $Q=0.6A(2gh)^{0.5}$										Total Capacity	
Subshed	# of catch basins	# of CBs (Assuming 25%	Inlet capacity per CB	Total CB Capacity (cfs)	Total CB Capacity (mgd)	CB length (ft)	CB opening (ft)	Area per CB (sq ft)	Area per CB with 25%	Water Depth @ CB inlet	Centerline of CB opening	Head on orifice (ft)	Q into each CB (cfs)	Total CB Capacity (cfs)	Total CB Capacity (mgd)	CFS	MGD
010-c	108	27	0.5	14	9	3	0.33	0.99	0.74	0.50	0.17	0.34	2.08	169	109	182	118
010-d	110	27.5	0.5	14	9	3	0.33	0.99	0.74	0.50	0.17	0.34	2.08	172	111	186	120
010-e	49	12.25	0.5	6	4	3	0.33	0.99	0.74	0.50	0.17	0.34	2.08	77	50	83	53
010-f	105	26.25	0.5	13	8	3	0.33	0.99	0.74	0.50	0.17	0.34	2.08	164	106	177	115
010-g	106	26.5	0.5	13	9	3	0.33	0.99	0.74	0.50	0.17	0.34	2.08	166	107	179	116
012-d	92	23	0.5	12	7	3	0.33	0.99	0.74	0.50	0.17	0.34	2.08	144	93	155	100
012-e	300	75	0.5	38	24	3	0.33	0.99	0.74	0.50	0.17	0.34	2.08	469	303	507	327
012-g	191	47.75	0.5	24	15	3	0.33	0.99	0.74	0.50	0.17	0.34	2.08	299	193	322	208
012-h	148	37	0.5	19	12	3	0.33	0.99	0.74	0.50	0.17	0.34	2.08	231	150	250	162
019-r	80	20	0.5	10	6	3	0.33	0.99	0.74	0.50	0.17	0.34	2.08	125	81	135	87
019-s	108	27	0.5	14	9	3	0.33	0.99	0.74	0.50	0.17	0.34	2.08	169	109	182	118
019-t	56	14	0.5	7	5	3	0.33	0.99	0.74	0.50	0.17	0.34	2.08	88	57	95	61
019-u	186	46.5	0.5	23	15	3	0.33	0.99	0.74	0.50	0.17	0.34	2.08	291	188	314	203
019-v	85	21.25	0.5	11	7	3	0.33	0.99	0.74	0.50	0.17	0.34	2.08	133	86	144	93
019-w	269	67.25	0.5	34	22	3	0.33	0.99	0.74	0.50	0.17	0.34	2.08	421	272	454	294
019-x	116	29	0.5	15	9	3	0.33	0.99	0.74	0.50	0.17	0.34	2.08	181	117	196	127
019-y	172	43	0.5	22	14	3	0.33	0.99	0.74	0.50	0.17	0.34	2.08	269	174	290	188
019-z	140	35	0.5	18	11	3	0.33	0.99	0.74	0.50	0.17	0.34	2.08	219	141	236	153
019-aa	130	32.5	0.5	16	11	3	0.33	0.99	0.74	0.50	0.17	0.34	2.08	203	131	220	142
019-ab	74	18.5	0.5	9	6	3	0.33	0.99	0.74	0.50	0.17	0.34	2.08	116	75	125	81
020-c	97	24.25	0.5	12	8	3	0.33	0.99	0.74	0.50	0.17	0.34	2.08	152	98	164	106
020-d	156	39	0.5	20	13	3	0.33	0.99	0.74	0.50	0.17	0.34	2.08	244	158	263	170
020-e	94	23.5	0.5	12	8	3	0.33	0.99	0.74	0.50	0.17	0.34	2.08	147	95	159	103
020-f	112	28	0.5	14	9	3	0.33	0.99	0.74	0.50	0.17	0.34	2.08	175	113	189	122
035-h	79	19.75	0.5	10	6	3	0.33	0.99	0.74	0.50	0.17	0.34	2.08	124	80	133	86
043-a	46	11.5	0.5	6	4	3	0.33	0.99	0.74	0.50	0.17	0.34	2.08	72	46	78	50
049-c	212	53	0.5	27	17	3	0.33	0.99	0.74	0.50	0.17	0.34	2.08	331	214	358	231
049-d	131	32.75	0.5	16	11	3	0.33	0.99	0.74	0.50	0.17	0.34	2.08	205	132	221	143
049-f	121	30.25	0.5	15	10	3	0.33	0.99	0.74	0.50	0.17	0.34	3.40	309	199	324	209



UES DRAINAGE AREAS 1 THRU 19	
UES-1	67 AC
UES-2	40 AC
UES-3	30 AC
UES-4	107 AC
UES-5	210 AC
UES-6	51 AC
UES-7	125 AC
UES-8	40 AC
UES-9	299 AC
UES-10	42 AC
UES-11	53 AC
UES-12	42 AC
UES-13	89 AC
UES-14	219 AC
UES-15	80 AC
UES-16	178 AC
UES-17	61 AC
UES-18	47 AC
UES-19	80 AC

LEGEND

- SLUICE, SLIDE OR BUTTERFLY GATE
- FLAP GATE
- INFLATABLE DAM
- 007 NPDES Outfall No.
- 34c WASA Structure No.
- 004 Emergency Relief No.
- STOP LOGS
- UPI-1 5300 AC SEPARATE SEWERSHED
- 774 AC COMBINED SEWERSHED

ABBREVIATIONS

dwf	Dry Weather Flow
Str.	Structure
Aband	Abandoned
U.P.I.R.	Upper Potomac Inteceptor Relief
U.P.I.	Upper Potomac Inteceptor
R.C.D.S.	Rock Creek Diversion Sewer
R.C.D.R.	Rock Creek Diversion Relief
R.C.M.I.	Rock Creek Main Inteceptor
R.C.M.I.R.S.	Rock Creek Main Inteceptor Relief Sewer
R.C.I.	Rock Creek Inteceptor
R.C.	Rock Creek
P.R.I.	Potomac River Inteceptor
B.N.J.	B St. New Jersey Avenue Trunk Sewer
N.E.B.T.S.	North East Boundary Trunk Sewer
N.E.B.	North East Boundary
E.S.I.	East Side Inteceptor
OF	Overflow
U.P.I.R.S.	Upper Potomac Inteceptor
R.C.D.I.	Rock Creek Diversion Inteceptor
N.C.	Normally Closed
N.O.	Normally Open
F.M.	Force Main
S.S.	Sanitary Sewer
BH	Basket Handle

D.C. WATER AND SEWER AUTHORITY
SEWER SYSTEM SCHEMATIC

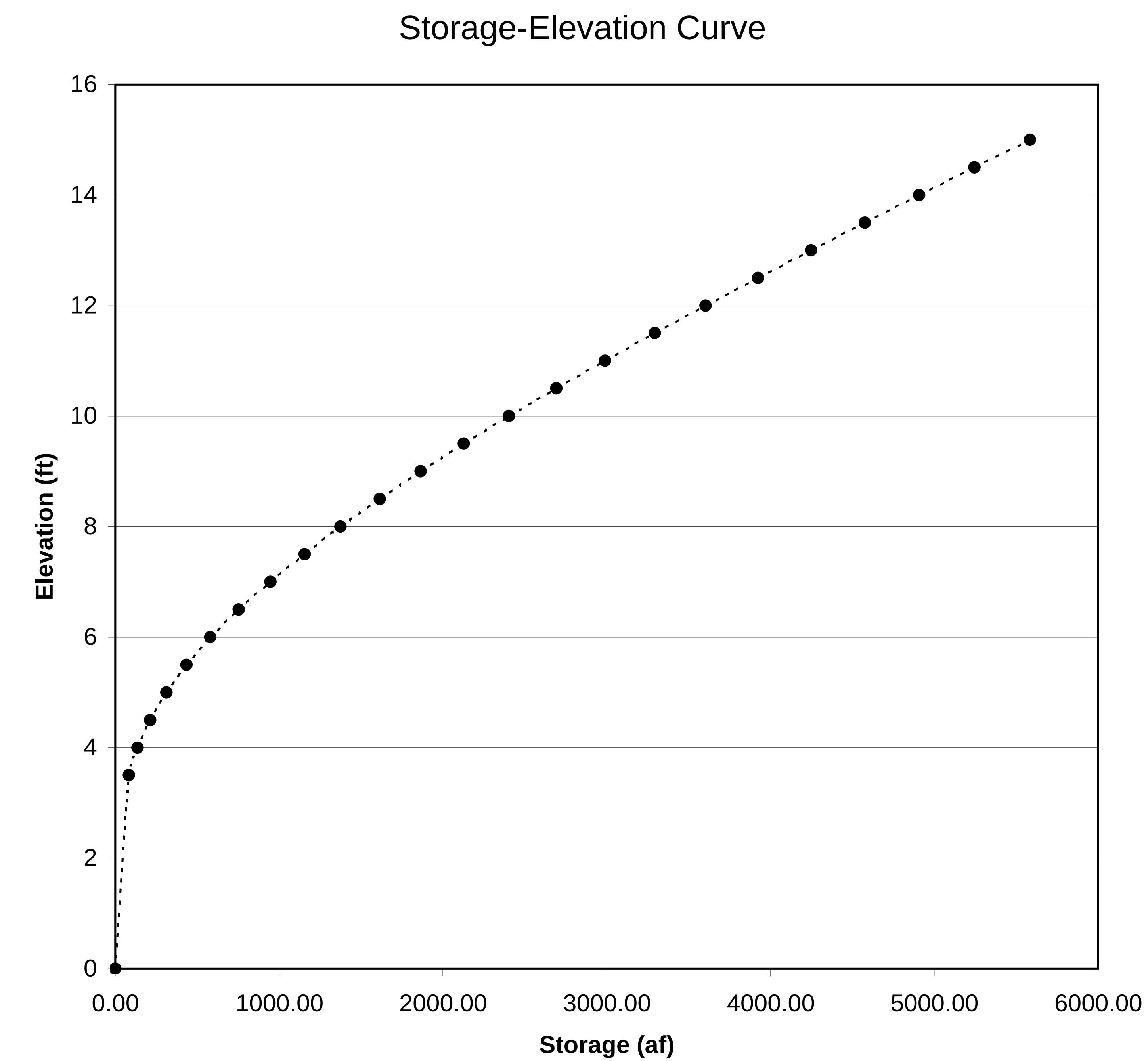
REVISION DATE: Feb. 2, 2004
PREPARED BY: GREELEY AND HANSEN LLC

1163/dwg/sewershed/wasa system schematic.dwg

Appendix B

Storage-Elevation Curve
HEC-HMS Summary output (100-year rainfall, gravity drain outlet)
Joint Probability Analysis

ELEVATION (ft)	STORAGE (af)
0	0.00
3.5	84.17
4	135.79
4.5	213.54
5	312.89
5.5	434.83
6	580.67
6.5	754.40
7	947.96
7.5	1156.19
8	1375.57
8.5	1614.64
9	1865.31
9.5	2128.28
10	2403.24
10.5	2692.78
11	2990.00
11.5	3294.01
12	3603.88
12.5	3924.40
13	4248.76
13.5	4576.71
14	4908.22
14.5	5245.66
15	5585.44



Project: DC HEC HMS Simulation Run: 100yr 24hr-noDiv,w/Outlet

Start of Run: 01Jan2000, 00:00 Basin Model: DC Basin-NoDiv,w/Outl
End of Run: 02Jan2000, 01:00 Meteorologic Model: SCS 100yr-24hr
Compute Time: 21Jan2009, 13:35:29 Control Specifications: 24-HR

Volume Units: IN

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
010-c	0.119411	487.1	01Jan2000, 12:10	8.17
010-d	0.143024	713.4	01Jan2000, 12:05	7.94
010-e	0.106172	684.8	01Jan2000, 11:58	7.94
010-f	0.155635	933.1	01Jan2000, 12:00	7.94
010-g	0.172351	1021.2	01Jan2000, 12:01	8.17
012-d	0.138559	925.9	01Jan2000, 11:58	8.17
012-e	0.328665	1749.3	01Jan2000, 12:03	8.17
012-g	0.261754	1562.4	01Jan2000, 12:01	8.17
012-h	0.202255	1336.8	01Jan2000, 11:58	8.17
019-aa	0.274847	1024.7	01Jan2000, 12:07	6.15
019-ab	0.289872	1906.2	01Jan2000, 11:58	7.76
019-r	0.107064	669.5	01Jan2000, 11:59	8.03
019-s	0.186882	826.1	01Jan2000, 12:08	7.84
019-t	0.092788	590.0	01Jan2000, 11:59	7.84
019-u	0.256473	1596.1	01Jan2000, 11:59	7.84
019-v	0.110934	601.0	01Jan2000, 12:03	7.84
019-w	0.342820	1430.3	01Jan2000, 12:09	7.84
019-x	0.240868	1599.7	01Jan2000, 11:58	8.03
019-y	0.261430	1696.1	01Jan2000, 11:58	7.84
019-z	0.303061	1490.3	01Jan2000, 12:01	6.15
020-c, Outside	0.349647	2311.7	01Jan2000, 11:58	7.94
020-d	0.062320	416.4	01Jan2000, 11:58	8.17
020-e	0.115978	775.0	01Jan2000, 11:58	8.17
020-f	0.150275	856.7	01Jan2000, 12:02	8.17
035-h	0.079981	525.8	01Jan2000, 11:58	7.84

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
049-c,043-a	0.071716	406.4	01Jan2000, 12:02	7.84
049-d	0.093847	617.0	01Jan2000, 11:58	7.84
049-f	0.049346	356.3	01Jan2000, 11:55	7.84
Junction-1	1.010973	4770.1	01Jan2000, 12:05	6.85
Junction-2	1.862532	8218.5	01Jan2000, 12:12	7.33
Junction-3	2.654865	10528.9	01Jan2000, 12:13	7.48
Junction-A	0.858814	3790.4	01Jan2000, 12:04	8.13
Junction-B	5.067975	12254.0	01Jan2000, 12:52	7.77
Reach-01	0.049346	356.3	01Jan2000, 11:57	7.84
Reach-02	0.143193	969.0	01Jan2000, 12:12	7.84
Reach-03	0.289872	1906.2	01Jan2000, 12:05	7.76
Reach-04	0.446254	1864.8	01Jan2000, 12:05	6.69
Reach-05	1.010973	4770.1	01Jan2000, 12:12	6.85
Reach-06	1.862532	8218.5	01Jan2000, 12:13	7.33
Reach-07	0.261430	1696.1	01Jan2000, 12:04	7.84
Reach-08	0.502298	2945.6	01Jan2000, 12:13	7.93
Reach-09	0.071716	406.4	01Jan2000, 12:04	7.84
Reach-10	0.151697	864.9	01Jan2000, 12:12	7.84
Reach-11	0.494517	2272.4	01Jan2000, 12:18	7.84
Reach-12	0.605451	2472.2	01Jan2000, 12:27	7.84
Reach-13	2.654865	10528.9	01Jan2000, 12:15	7.48
Reach-14	2.761929	10662.6	01Jan2000, 12:18	7.50
Reach-15	3.023683	10997.0	01Jan2000, 12:33	7.56
Reach-16	3.352348	11261.1	01Jan2000, 12:52	7.61
Reach-A	0.150275	856.7	01Jan2000, 12:10	8.17
Reach-B	0.328573	1580.9	01Jan2000, 12:04	8.17
Reach-C	0.500924	2545.7	01Jan2000, 12:10	8.17
Reach-D	0.202255	1336.8	01Jan2000, 11:59	8.17
Reach-E	0.858814	3790.4	01Jan2000, 12:09	8.13
Reach-F	0.964986	4035.7	01Jan2000, 12:12	8.11
Reach-G	0.349647	2311.7	01Jan2000, 12:17	7.94

Project: DC HEC HMS

Simulation Run: 100yr 24hr-noDiv,w/Outlet Reservoir: Res-Outlet

Start of Run:	01Jan2000, 00:00	Basin Model:	DC Basin-NoDiv,w/Outlet
End of Run:	02Jan2000, 01:00	Meteorologic Model:	SCS 100yr-24hr
Compute Time:	21Jan2009, 13:35:29	Control Specifications:	24-HR

Volume Units: IN

Computed Results

Peak Inflow :	12254.0 (CFS)	Date/Time of Peak Inflow :	01Jan2000, 12:52
Peak Outflow :	0.0 (CFS)	Date/Time of Peak Outflow :	01Jan2000, 00:00
Total Inflow :	7.77 (IN)	Peak Storage :	2099.7 (AC-FT)
Total Outflow :	0.00 (IN)	Peak Elevation :	9.4 (FT)

JOINT PROBABILITY ANALYSIS FOR FEDERAL TRIANGLE (INTERIOR POND) AND RIVER (POTOMAC RIVER)

GRAVITY DRAIN OUTLET OF INTERIOR POND

Int Pond Stage (ft)	Discharge from Interior Pond (cfs) Based on Gravity Drain Outlet: Tailwater at 3.5'	Tailwater at 4.5'	Tailwater at 5.4' (2-year river stage)	Tailwater at 6.7' (10-year river stage)	Tailwater at 10.1' (50-year river stage)	Tailwater at 12.0' (100-year river stage)
6.0	1.0	1.0	1.0	0.0	0.0	0.0
6.5	3.7	3.7	3.7	0.0	0.0	0.0
7.0	39.8	39.8	39.8	18.1	0.0	0.0
7.5	70.3	59.0	49.9	29.5	0.0	0.0
8.0	73.7	65.8	55.6	38.6	0.0	0.0
8.5	78.2	70.3	61.2	45.8	0.0	0.0
9.0	82.8	74.8	65.8	52.2	0.0	0.0
9.5	86.2	78.2	70.5	57.8	0.0	0.0
10.0			74.8	63.5	0.0	0.0
10.5			79.4	68.0	20.4	0.0
11.0			83.5	72.6	31.3	0.0
11.5			87.3	76.7	39.7	0.0
12.0			90.7	81.6	46.5	0.0
12.5			94.6	85.0	53.3	22.7
13.0			98.2	88.9	59.0	34.0
13.5			101.4	92.3	64.2	41.5
14.0			104.8	96.2	68.9	48.5
14.5			107.7	99.3	73.7	54.4
15.0			111.1	103.0	77.8	59.2

EXTERIOR
RIVER STAGE at Tidal Basin Based on FIS

2-yr	5.4'
10-yr	6.68'
50-yr	10.1'
100-yr	12'

INTERIOR
Precipitation Frequency

precipitation	frequency	interior range
0.45"	1.3-yr	3.5'
1.0"	1.6-yr	4.5'
3.14"	2-yr	6.5'
4.8"	10-yr	7.4' - 7.5'
7.15"	50-yr	8.7' - 8.9'
8.3"	100-yr	9.3' - 9.5'

Notes: Stage-Flow relationship based on HEC-RAS done for FIS
Precipitation based on NOAA 2-yr - 100-yr; 1.3-yr and 1.6-yr interpolated

HEC-HMS FLOOD ROUTING RESULTS

100-year interior rainfall
vary tailwater for gravity drain outlet

Tailwater* (feet)	pond elev (feet)	Maximum Qout (cfs)
3.5	9.3	
4.5	9.3	
5.4	9.3	
6.7	9.3	
10.1	9.4	
12.0	9.4	

50-year interior rainfall
vary tailwater for gravity drain outlet

Tailwater* (feet)	pond elev (feet)	Maximum Qout (cfs)
3.5	8.7	
4.5	8.7	
5.4	8.7	
6.7	8.8	
10.1	8.9	
12.0	8.9	

10-year interior rainfall
vary tailwater for gravity drain outlet

Tailwater* (feet)	pond elev (feet)	Maximum Qout (cfs)
3.5	7.4	
4.5	7.4	
5.4	7.4	
6.7	7.5	
10.1	7.5	
12.0	7.5	

2-year interior rainfall
vary tailwater for gravity drain outlet

Tailwater* (feet)	pond elev (feet)	Maximum Qout (cfs)
3.5	6.5	
4.5	6.5	
5.4	6.5	
6.7	6.5	
10.1	6.5	
12.0	6.5	

*Note - tailwater varied based on 2-yr, 10-yr, 50-yr, and 100-yr

RIVER INDEX STAGE FOR CONDITIONAL PROBABILITY ANALYSIS

Stage (feet)	Q for Stage (cfs)	Proportion of time river stage exceeded	Probability Interval	Stage Interval (feet)	index stage (feet)	Proportion of time river stage is within stage interval
3	600	1.00000		NA	NA	
4	25000	0.10600	B1	3 to 4	3.5	0.89400
5	90000	0.00650	B2	4 to 5	4.5	0.09950
6	147000	0.00118	B3	5 to 6	5.5	0.00532
7	202000	0.00059	B4	6 to 7	6.5	0.00059
8	262000	0.00032	B5	7 to 8	7.5	0.00027
9	320000	0.00015	B6	8 to 9	8.5	0.00017
10	375000	0.00009	B7	9 to 10	9.5	0.00006
11	421000	0.00005	B8	10 to 11	10.5	0.00004
12	457000	0.00001	B9	11 to 12	11.5	0.00004
					Total =	0.99999

CONDITIONAL PROBABILITY ANALYSIS

Interior Elevation (feet)	River Stage=3.5' P(B1) = 0.894	River Stage=4.5' P(B1) = 0.0995	River Stage=5.4' P(B1) = 0.00532	River Stage=6.5' P(B2) = 0.00059	River Stage=7.5' P(B3)= 0.00027	River Stage=8.5' P(B4)= 0.00017	River Stage=9.5' P(B5)= 0.00006	River Stage=10.5' P(B5)= 0.00004	River Stage=11.5' P(B7)= 0.00004	Weighted Probability Pond Elevation
0	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	
3.5	0.7692	0.7692	0.7692	0.7692	0.7692	0.7692	0.7692	0.7692	0.7692	77%
4.5	0.6250	0.6250	0.6250	0.6250	0.6250	0.6250	0.6250	0.6250	0.6250	62%
6.5	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	50%
7.4	0.1000	0.1000	0.1000	0.1100	0.1100	0.1100	0.1100	0.1100	0.1100	10%
7.5	0.0760	0.0760	0.0760	0.1000	0.1000	0.1000	0.1000	0.1000	0.1000	8%
8.7	0.0200	0.0200	0.0200	0.0200	0.0220	0.0220	0.0220	0.0220	0.0220	8%
8.8	0.0170	0.0170	0.0170	0.0200	0.0200	0.0210	0.0210	0.0210	0.0210	8%
8.9	0.0150	0.0150	0.0150	0.0167	0.0170	0.0180	0.0190	0.0200	0.0200	8%
9.3	0.0100	0.0100	0.0100	0.0100	0.0100	0.0111	0.0111	0.0125	0.0125	1%
9.4	0.0008	0.0008	0.0008	0.0008	0.0008	0.00091	0.00091	0.0100	0.0100	0.83%

Interior Pond Elevation with a 1% Probability of Occurrence: is 9.3 feet