Appendix H

This appendix includes a discussion of the meaning and calculation of flood return periods (Section H.1), a summary of basic background information about the hydrology of Doan Brook (Section H.2), and a list of the references that were used to compile hydrologic information (Section H.3).

Hydrologic data are summarized in the following tables:

H-1 Summary of Doan Brook Hydrologic Information

H-2 Summary of Information About Major Doan Brook Culverts

H-3 Doan Brook Peak Ten-Year Flood Flows: Estimates from Different Sources

Figure H-1 shows a plan and profile of the University Circle Culvert.

Different sources give many conflicting figures for the basic data about the brook. Where possible, the information given here has been confirmed by direct measurement. Where measurement was not possible, different data sources were examined and the information that appeared to be most reliable was included.

H.1 Flood Return Periods: What Do We Mean by the 100-Year Flood?

When we talk about flooding on Doan Brook, we talk about what will be under water during a "ten-year flood," or a "100-year flood." But what do we mean by the ten-year flood? Flood frequency, flood return period, and flood magnitude have technical definitions that are not obvious and require some explanation.

A ten-year flood is defined as a flood[1] that has a one in ten chance of being equaled or exceeded in any given year. This can be restated in two different ways:

> *(1) There is a one in ten (ten percent) chance that a flood as large (or larger) than the ten-year flood will occur in any year. (2) On average, one flood with the magnitude of the ten-year flood, or a larger flood, will occur in any given ten-year period. (Note that the second statement does not imply that two ten-year floods cannot occur in two consecutive years.)*

The definition of the ten-year flood can be applied to a flood with any return period. Thus there is a one in X chance that the X-year flood will be equaled or exceeded in a given year.

Before we go on to discuss flood frequencies on Doan Brook, it is worth noting several points about the nature of flood return periods and flood magnitudes:

- Historical records are used to estimate the magnitudes of the floods that can be expected on a stream. Where actual historical data on stream flow are available (from a stream gage), these data are used. Where not enough stream flow data are available (as for Doan Brook), rainfall data are used in conjunction with runoff modeling and the available stream flow data to estimate flood levels.
- The magnitude of the ten-year flood is an

1 Ten years is the *flood frequency* or *flood return period*. The *magnitude* (usually expressed in cubic feet per second, or cfs) of the ten-year flood is the peak flow during the flood that has a ten-year return period.

estimate. There are many different techniques for estimating flood magnitudes, and two different techniques may give very different results. As a glance at Table H-3 will show, estimates for the ten-year flood on Doan Brook vary widely (see further discussion below).

- Floods are independent events, with each one having no impact on any other.[2] Thus the fact that a 100-year flood may, for example, have occurred last year does not change the likelihood (one in a hundred) that a 100-year flood, or a larger flood, will occur this year.[3]

Table H-3 dramatically illustrates that the magnitude of the ten-year flood is an estimate. In 1999, Montgomery Watson estimated that the ten-year flood flow in Doan Brook at University Circle would be approximately 2,243 cfs. More than thirty years earlier, the Stanley Engineering Company estimated that the ten-year flood at the same spot would be 5,515 cfs — over twice as large. The Doan Brook watershed changed little between 1964 and 1999. Why are these estimates so different and which is correct?

The answer to this question stems from the fact that two valid but very different techniques were used to estimate the two flood flows. Generally stated, the methods used by Stanley and Montgomery Watson can be described as follows:

- The authors of the Stanley report had no stream gage data from Doan Brook that they could use to correlate rainfall with flow in the brook. They therefore used rainfall data for the watershed to estimate flood flows. To do this, they divided the watershed into logical subwatersheds, evaluated the land use in each subwatershed, estimated the runoff from each area that would result from a given rainfall, and "routed" the runoff from the subwatersheds to estimate flows in Doan Brook. While a complete evaluation of the work described in the Stanley report is far beyond the scope of this handbook, the methods used were generally appropriate in the absence of stream flow data.
- Unlike the engineers who prepared the Stanley report, Montgomery Watson's hydrologists had access to some stream flow data. For a four-month period in the spring and summer of 1998, Montgomery Watson installed stream gages at a number of points on Doan Brook and collected rainfall and stream flow data from the watershed. The sampling period contained one moderate flood with about a one- to two-year return period. They used their rainfall and stream flow data to create a computer model of the way that the watershed responds to rainfall, checking their watershed model by seeing whether it could predict some of the storms they had actually observed. They then put historical rainfall data into their model and used it to extrapolate larger floods such as the five-, ten-, and fifty-year flows. Like the methods described in the Stanley report, the methods used by Montgomery Watson were generally appropriate given the information they had to work with.

These two apparently appropriate models of Doan Brook result in two estimates of the ten-year flood, one twice as large as the other. Which should we believe? One's first instinct is to rely on the estimate given by Montgomery Watson. It is based on some actual data from the watershed, and Montgomery Watson's engineers had the benefit of the hydrologic models and computers available in the year 2000. The results of their model can certainly be expected to be accurate for small floods like those that they observed while their stream gages were in place. However, the use of this kind of model to estimate larger floods may give less accurate results. For these larger floods, the results of techniques like those used by Stanley must still be considered, and the strengths and weaknesses of each approach to estimating flood magnitude must be taken into account.

Historical records of flooding in University Circle do not shed much light on the appropriate size of the ten-year flood. However, records do show that several feet of water have inundated University Circle seven times since 1959, or about once every six years. Montgomery Watson's estimates do not predict that there should be significant flooding in University Circle quite so often. Stanley's estimates, by contrast, predict that flooding might be more frequent. The historical data therefore suggest that the "true" ten-year flood flow may lie somewhere between the estimate developed by Montgomery Watson and the estimate developed by Stanley.

2 While this statement does not always hold for floods that are caused by a single weather pattern, it is generally valid.

3 The occurrence of several 100-year or larger floods within the space of a few years suggests (but does not prove) that the estimated magnitude of the 100-year flood should be reevaluated.

H.2
Hydrologic Data Summaries

Table H-1	Summary of Doan Brook Hydrologic Information	
Item	**Values**	**Notes**
Stream Length	About 8.4 miles (along the north branch)	
Total Surface Watershed	11.7 square miles (7,500 acres)	Montgomery Watson 1999 (b)
Total Sewershed	20.1 square miles (12,900 acres) in 1999 9.8 square miles (6,300 acres) after completion of the Heights/Hilltop Interceptor	Montgomery Watson 1999 (b, c)
University Circle Watershed	8.7 square miles (5,560 acres)	Montgomery Watson 1999 (d)
Lower Shaker Lake	Watershed: 5.0 square miles (3,190 acres) Surface Area: 17.6 acres (19.2 acres including Lily Pond marsh) Volume: 2,454,000 cubic feet Average Depth: 3.2 feet Maximum Depth: 8.3 feet Elevation of Dam: 905.3 feet MSL Top Width of Dam: 45 feet Top Length of Dam: 600 feet Maximum Dam Height: 17.3 feet Spillway: 39.5-foot crested masonry drop structure at elevation 903 feet MSL. Three feet clearance to bridge.	Montgomery Watson 1999 (a, d); Dam data from ODNR 1980 (a); Notes: Data on dam may have changed due to subsequent repairs. Watershed reflects adjustment to Horseshoe Lake watershed.
Horseshoe Lake	Watershed: 1.9 square miles (1,200 acres) Surface Area: 12.5 acres Volume: 1,547,000 cubic feet Average Depth: 2.8 feet Maximum Depth: 6.5 feet Outlet Elevation: 978.0 feet MSL Elevation of Dam: 982.2 feet MSL Top Width of Dam: 14 feet Top Length of Dam: 615 feet Maximum Dam Height: 30 feet Spillway: 10-foot diameter drop inlet at elevation 978 feet MSL	Montgomery Watson 1999 (a, d); ODNR 1980 (b) for dam data; Notes: Data on dam may have changed due to subsequent repairs. Watershed area includes some area between lake arms not included in Montgomery Watson area.
Green Lake	Watershed: 1.5 square miles (967 acres) Surface Area: 7.4 acres Volume: 940,000 cubic feet Average Depth: 2.9 feet Maximum Depth: 5.3 feet	Montgomery Watson 1999 (a)
Marshall Lake	Watershed: 1.8 square miles (1,440 acres) Surface Area: 6.3 acres Volume: 924,000 cubic feet Average Depth: 3.4 feet Maximum Depth: 6.6 feet	Montgomery Watson 1999 (a)
Martin Luther King, Jr., Boulevard Detention Basin	Watershed: 5.7 square miles (3,660 acres) Elevation of Dam: 761.9 feet MSL Outlet: 9-foot by 6.5-foot box culvert with upstream invert at 733.9 feet MSL (at the base of the dam) Maximum Dam Height: 28 feet (approximate)	Montgomery Watson 1999 (c)

Table H-2	Summary of Information About Major Doan Brook Culverts	
Culvert	**Data**	**Source**
South Branch – Canterbury Golf Course to Shaker Country Club Golf Course	Length: 2000 feet (very approximate)	USGS topographic maps
Middle Branch – South Park to Courtland	Length: 950 feet (very approximate)	USGS topographic maps
Under MLK at North Park	Length: 340 feet Cross-Section: 8-foot by 12.5-foot concrete box culvert	Stanley 1964
University Circle Culvert	Length: 5,160 feet (approximate) Cross-Section: Varies – (see figure H-1)	Montgomery Watson 1999 (b)
Rockefeller Park Culvert (at MLK and East 105th)	Length: 650 feet (approximate) Cross-Section: Varies – 11-foot maximum height by 36-foot arch at the inlet; divided 24-foot wide by 9-foot maximum height at outlet	Montgomery Watson 1999 (b)
Gordon Park	Length: 3,300 feet Cross-Section: Varies – entrance is a 14.3-foot by 17-foot box culvert	COE 1976; Montgomery Watson 1999 (b)

Table H-3	Doan Brook Peak 10-Year Flood Flows: Estimates from Different Sources			
Location	**Estimated Flow for 10-Year Flood (cfs)**			
	Montgomery Watson (2000)		Stanley (1964)	ODNR (1977 a, b)
Inflow to Green Lake	1,298		--	--
• Flow reduction from Green Lake	(592)		--	--
Outflow from Green Lake	706		--	--
Inflow to Marshall Lake	713		392	--
• Flow reduction from Marshall Lake	(135)		(29)	--
Outflow from Marshall Lake	578		363	--
Inflow to Horseshoe Lake	2,600		797	612
• Flow reduction from Horseshoe Lake	(2,310)		(478)	--
Outflow from Horseshoe Lake	290		319	356
Inflow to Lily Pond	1,033		1,623	--
• Flow reduction from Lily Pond Marsh	(188)		(577)	--
Inflow to Lower Lake	845		1,046	1,523
• Flow reduction from Lower Lake	(185)		(378)	--
Outflow from Lower Lake	660		668	1,162
D/S from Fairhill Road	1,025		--	--
U/S from Martin Luther King, Jr., Blvd.	673		1,685	--
• Flow reduction from MLK detention dam	(0)		NA	--
Doan Brook Culvert Inlet	668		1,843	--
• Inflow from Giddings Brook Culvert	750	684	1,702	--
• Inflow from Cedar Glen Culvert	??	687	610	--
• Inflow Cedar Glen to Euclid Avenue Culvert	??	159	1,369	--
University Circle	2,243		5,515	--
• Inflow from East 105th St. Culvert	590	493	--	--
• Inflow from Ashbury and Superior Culverts	620	144	--	--
Doan Brook at Superior Avenue	2,419		--	--
Mouth of Doan Brook	2,187		--	--

Notes:

1. In general, all figures represent the peak flow at the point shown. Where there are two figures shown for inflows to the brook, the left number shows the peak inflow and the right number shows the difference in the peak flow in the channel upstream and downstream from the inflow point.
2. Bulleted entries indicate flow reduction from a dam or other control structure or inflows to the brook (rather than flow in the stream itself).

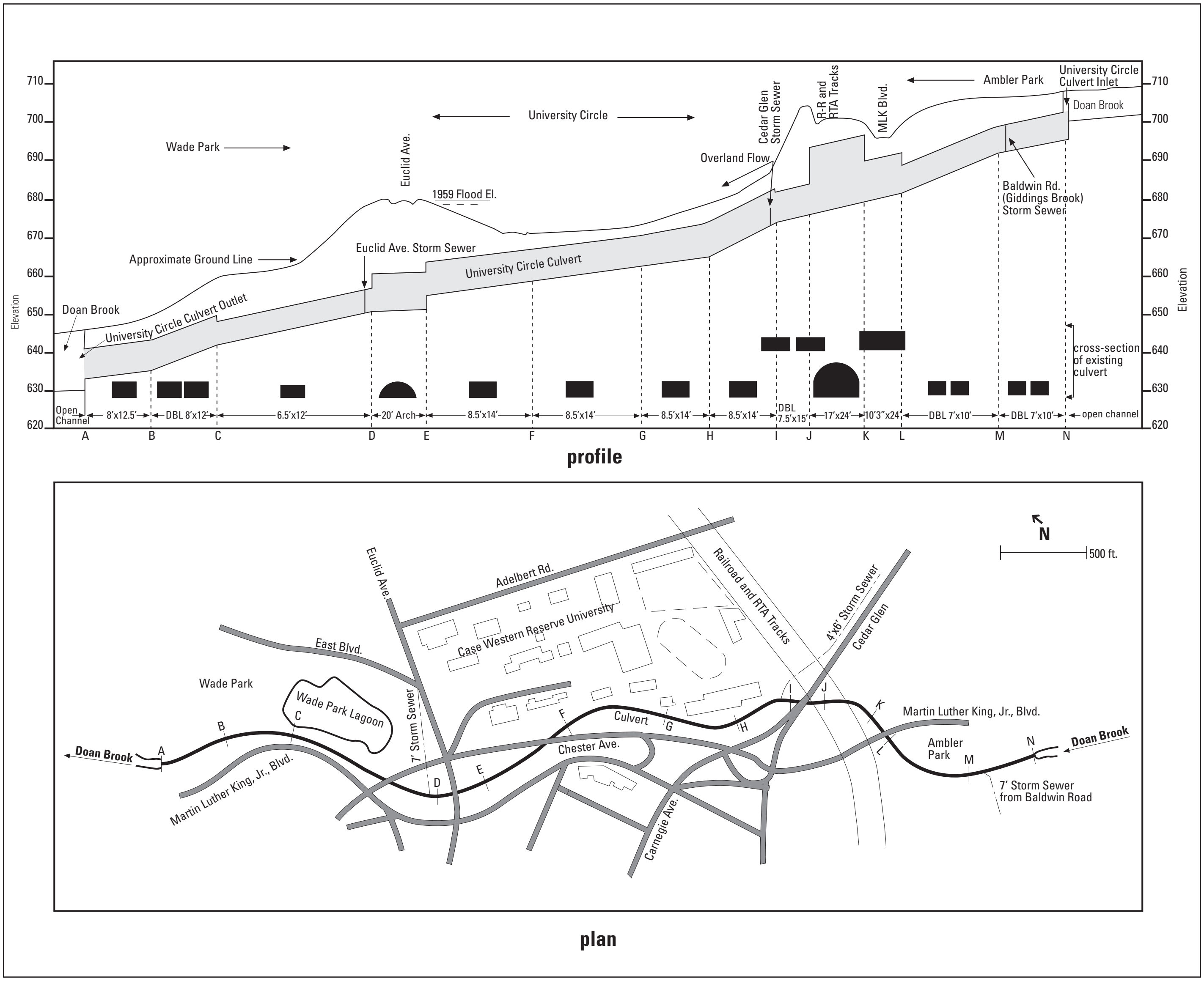

Figure H-1 University Circle Culvert – Plan and Profile. After Stanley 1964.

H.3
Hydrology References

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