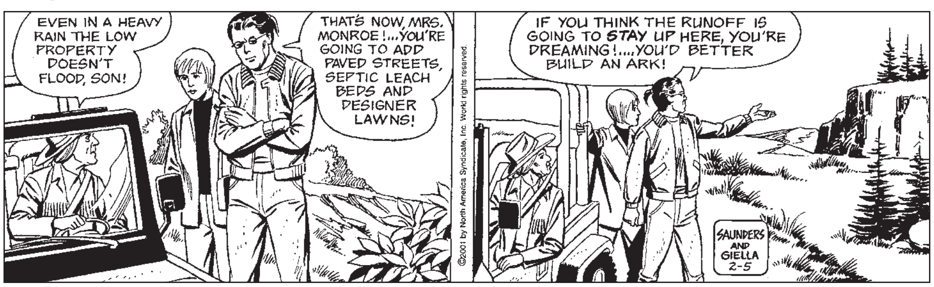
Channelized section of Doan Brook in Rockefeller Park. Photograph by L. C. Gooch.

Mary Worth



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5

The first four chapters of this handbook highlight some of the changes that Doan Brook has undergone since Nathaniel Doan first settled on its banks. Human actions have altered the stream in ways that dominate its present-day character. Understanding the behavior of the modern brook requires understanding the impact of urbanization on the stream and its watershed. More important, preserving the stream requires understanding how and why the construction of our city has degraded it. In this chapter we will explore the nature of urbanization in the Doan Brook watershed, and we will look at the ways that the city has changed stream flows and water quality.

5.1 How Have We Changed the Brook? Alterations to the Stream Shape

As soon as people settled near Doan Brook, they began to mold the stream to suit their use and convenience. The changes that they made fall into four main categories: construction of dams and lakes; diversion of the stream into underground culverts; construction of rigid channels to confine the brook to a set course; and other alterations to the stream channel shape.

5.1.1 Dams and Lakes

The most conspicuous change to the pre-settlement brook was the construction of the four lakes in the upper watershed. Although they now seem like part of the natural landscape, the Lower Shaker Lake, Horseshoe Lake, Green Lake, and Marshall Lake are all manmade. Each one submerged a portion of the natural stream valley, and each has a significant impact on the downstream brook.

A fifth dam was built in 1997 to create the flood detention basin just downstream from Martin Luther King, Jr., Boulevard. This dam does not form a permanent lake, and most of the time the stream passes unchecked through the opening at its base. In a large flood, however, the structure will temporarily detain and slowly release some water, thus reducing the peak flow downstream.[1, 2]

5.1.2 Culverts and the Vanishing Brook

A look at an older map of Doan Brook reveals a longer stream with many more fingers and branches than the Doan Brook of today (see Figure 5-1). The headwaters of the brook in 1900 extended about a mile farther east than the stream's current sources. During the development of Shaker Heights and Cleveland Heights, the upstream reaches of the brook's three branches, together with a number of smaller tributaries, were diverted into underground storm sewers,[3] and the stream channels were filled to allow houses and streets to be built where the stream had been. The most significant of the vanished tributaries were a stream that fed into the south fork just south of Shaker Boulevard, a tributary that ran down the Escarpment where Cedar Road now lies, and a tributary that cut northwest across Cleveland Heights to join the Cedar Road stream at Euclid

1 The effectiveness of the detention basin is discussed in Chapter 7.

2 Two other ponds in the watershed, the Wade Park Lagoon and the Rockefeller Park Lagoon, are not actually on Doan Brook. They sit next to the stream and drain into it, but they are filled with City of Cleveland water.

3 The distinction between a culvert and a storm sewer is somewhat arbitrary, since both serve as underground conduits for water that would naturally flow on the surface. In general, an underground pipe is called a culvert if it carries a stream from one stretch of above-ground channel to another stretch of above-ground channel. If there is no stream channel at the upstream end of a pipe, it is usually referred to as a storm sewer.

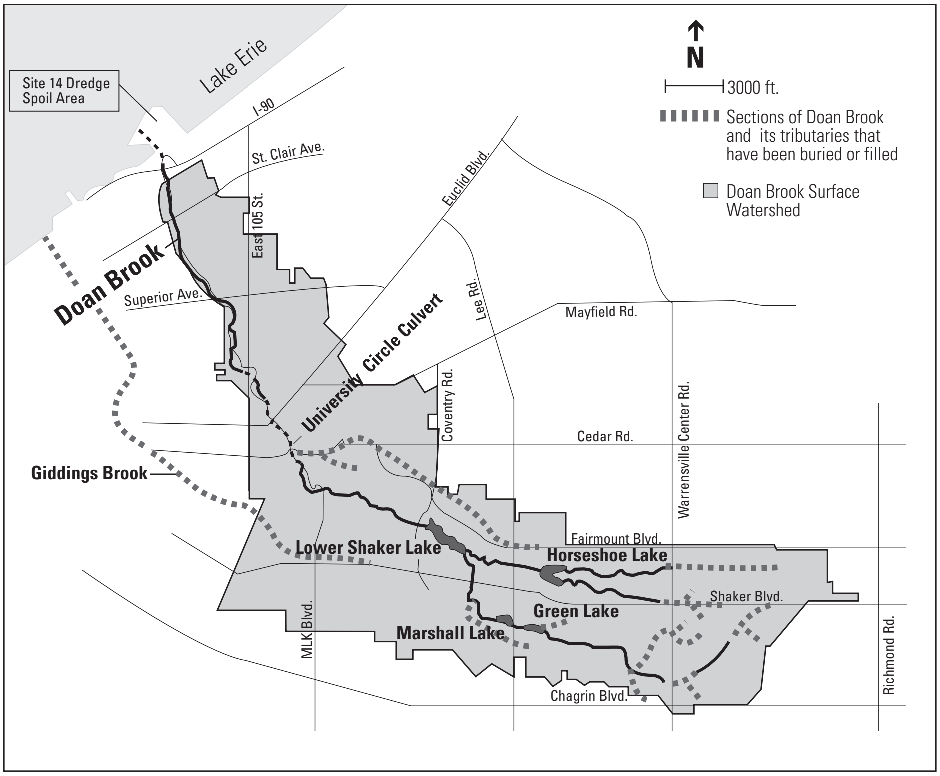

Figure 5-1 Original Doan Brook and Tributaries

Heights Boulevard. Large storm sewers now feed into the brook in these locations, carrying water that once flowed in open channels.

Just as tributaries to the brook were buried in storm sewers as the city grew, some stretches of the brook itself were forced underground into culverts to make way for roads and buildings. The University Circle culvert, the largest and longest culvert on Doan Brook, carries the main stream channel almost a mile (5,160 feet) between the base of the Escarpment (near the intersection of Martin Luther King, Jr., Boulevard and Ambleside Drive) and the northwest side of the Cleveland Museum of Art. There are two other long culverts on the main channel in the lower watershed: a 650-foot culvert that begins about 1,000 feet downstream from the outlet of the University Circle culvert and carries the stream under the Cancer Survivors' Monument, Liberty Boulevard, East 105th Street, and Hough Avenue; and a 3,300-foot culvert near the brook's mouth that carries the stream beneath Interstate 90 and the Corps of Engineers Site 14 dredge spoil area into Lake Erie. Many smaller culverts and bridge openings along the brook constrain the stream to a narrow path as it passes beneath a road or other obstruction.

5.1.3
Channelization: The Inflexible Stream

Some reaches of Doan Brook, although not confined in culverts, have been transformed into rectangular channels lined by vertical stone walls. The brook has been channelized along much of its two-mile course through Rockefeller Park, where water spreading onto the flood plain or a naturally meandering stream might threaten the road. Reinforced rectangular channels have also been built in Ambler Park and in isolated locations in the upper watershed.

5.1.4
Other Stream Channel Changes

Some sections of Doan Brook that have not been confined in channels or culverts have nonetheless been modified. In some places, one or both of the banks has been reinforced to prevent the stream from meandering. Fill material has been added along the stream in some other areas. The most obvious fill area lies along the south side of the Doan Brook gorge opposite the intersection of Kemper and Fairhill Roads. Erosion that began there in the late 1950s threatened to undermine the pavement on Fairhill Road. Beginning in 1959, the eroded side of the gorge was repeatedly "repaired" by dumping loose excavated material and construction debris. This material was itself unstable, leading to repeated slope failures, some blockage of the brook channel, and the erosion of significant amounts of fill material that was carried downstream by the brook.[4] The unstable section of the bank was finally effectively stabilized in 1976 by the construction of a *gabion*[5] retaining wall and placement of properly compacted fill material on a stable slope behind the wall.

4 Dumped debris may have been substantially responsible for the clogging of the University Circle culvert that contributed to severe flooding in 1975.

5 Gabions are rock-filled wire mesh cages that are frequently used in stream bank stabilization.

The Impact of Change

Lake Construction

Physical Impacts: The Doan Brook lakes slow flood waters from the upper watershed and store some water during a flood, so that the peak of the flood downstream from the lakes is lower, later, and spread out over a longer time than it would otherwise be.

Biological Impacts: The lakes affect the biology of the stream in a number of both positive and negative ways. They increase the downstream water temperature (a negative impact) and block any possible fish migration upstream from the dams. They provide an environment for wetland formation and a habitat for waterfowl. They collect and concentrate pollution from the watershed and allow sediments and organic matter to settle out, resulting in generally cleaner water downstream; however, large amounts of organic matter may be discharged at some times of the year, and water quality in the lakes themselves tends to be poor. In addition, the lakes attract large numbers of nuisance waterfowl (such as Canada geese) that pollute the water with their feces.

Culverts

Physical Impact: Where they are installed, culverts completely destroy the stream's habitat and aesthetic value. In addition, water flows more quickly in a culvert or storm sewer than it does in a natural channel. Because of this, water reaches the remaining natural stream more quickly, resulting in higher and sharper peak flows that occur sooner after rain begins.

Biological Impact: Culverts provide poor habitat for stream-dwelling organisms. Water in them flows at a relatively uniform depth, and they are periodically flushed out by high flows. They block light from the stream and stifle plant growth. Long culverts block the migration of aquatic organisms, including fish seeking to spawn in a flowing stream. Culverts also eliminate riparian corridors and their wildlife habitat and pollution-filtering capacity.

Channelization

Physical Impact: Conventional channelization confines the stream to a rectangular channel with a uniform water depth across the entire channel width. The channel will have relatively shallow flow most of the time and will have high-velocity, relatively deep flow during flooding. Less complete modification of the stream will have similar but less extreme impacts. Channels along Doan Brook were designed for much lower flows than are now common, and they therefore overflow regularly.

Biological Impact: Channelized streams do not readily develop the patterns of pools and riffles that are conducive to healthy aquatic environments. Regular flooding scours the entire channel and washes out aquatic organisms before they are well established. Channelization also isolates the stream from the flood plain, eliminating the riparian habitat and the water quality benefits of the riparian zone. Finally, flood plain pools that allow some aquatic organisms to breed do not form adjacent to channelized streams.

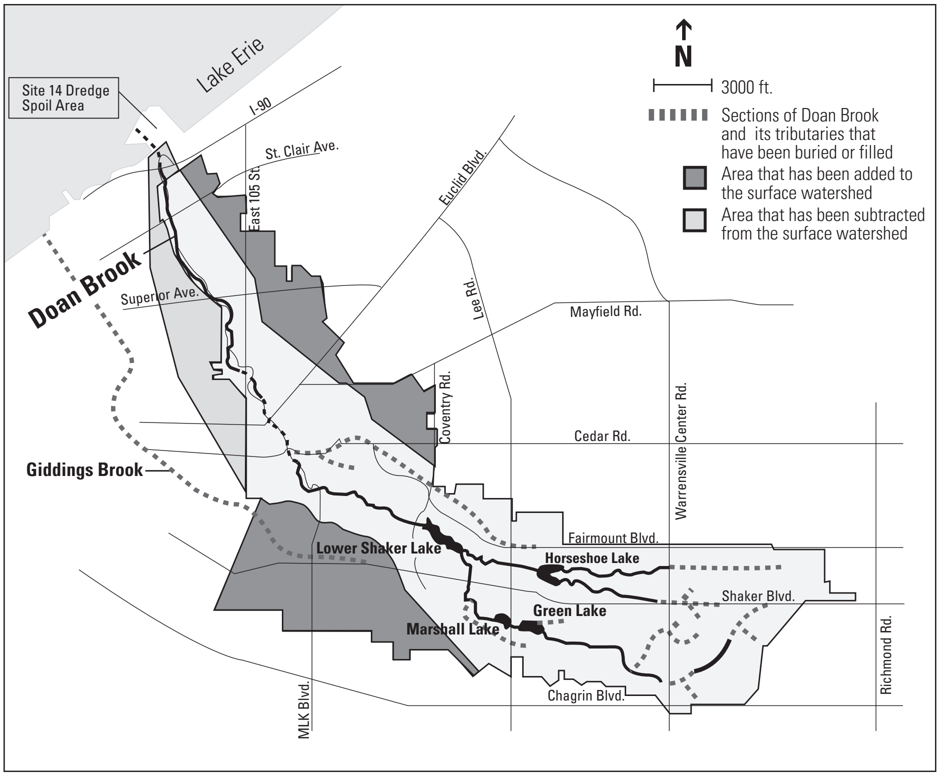

Figure 5-2 Original Doan Brook Watershed

Topographic maps that would allow an exact delineation of the Doan Brook drainage area in 1799 do not exist, but a reasonable estimate of the watershed's original outline can be made using maps from the 1920s and 1930s. Figure 5-2 shows the areas where there is a significant difference between the original and present watersheds.

As the figure indicates, a large area has been added to the southwest corner of the upper watershed. This 1.8 square mile area was once part of the drainage area of Giddings Brook (the stream immediately west of Doan Brook), but was diverted into Doan Brook via a storm sewer rerouting at some time prior to the 1960s. In addition, the lower watershed appears to have gained some land along its east side, while losing some land along its west side, with a resulting net increase in watershed area of about 0.2 square mile. Taken together, these changes to the Doan Brook watershed have increased its area by 21 percent, from an original area of approximately 9.7 square miles to its current area of 11.7 square miles.

5.2
Moving and Shaking in the Watershed: Changes in the Brook's Drainage Area

Just as the Doan Brook channel has been altered to accommodate the human environment, the brook's watershed was manipulated during the transformation of the forest into the city. Two kinds of changes to the watershed are significant: alterations to the size and shape of the land area that drains into Doan Brook and alterations to the surface of the land within the watershed. Each of these changes has a major impact on flow in the brook, particularly during floods.

5.2.1
Changes in the Watershed Land Area

It may seem unlikely that human activities can change the shape of the land enough to significantly alter the size of the area that sends runoff to a stream. Surprisingly, though, changes to an urban stream's watershed are not unusual. Drainage area changes usually occur when storm sewers or manmade channels reroute water that once flowed into one stream so that it flows into another. This kind of storm sewer rerouting has increased the size of the Doan Brook watershed by almost 21 percent.

5.2.2
Changes in the Nature of the Land

While changes to the size and shape of the watershed have had an impact on Doan Brook, changes to the nature of the watershed surface have had an even more profound effect. The dense forest that covered the area before Nathaniel Doan and the Shakers arrived responded to rainfall very differently from the modern urban landscape of parking lots, streets, driveways, rooftops, and lawns. Estimates of the fraction of the Doan Brook watershed that is *impervious*[6] indicate that about 28% of the area is now covered with

6 Impervious area is land surface that allows little or no water to infiltrate into the ground. Paved areas and building roofs are the primary impervious surfaces in most urban watersheds.

The Impact of Change

Changes in Watershed Size and Shape

The most obvious impact of the increase in the Doan Brook watershed area is a corresponding increase in the amount of water that flows into the stream. The additional flow to the brook during heavy rains will increase the frequency and severity of downstream flooding. The flow from the Giddings Brook watershed enters the brook in University Circle (see Chapter 7), which tends to increase flooding in University Circle and farther downstream. Where the stream is not channelized, the brook will erode its bed and banks to adjust to the increased flow. This erosion leads to high sediment loads in the stream and generally degrades the stream's habitat. The channelized stretches of Doan Brook in the lower watershed cannot change to adjust to the increased flow. As a result, the stream overflows more often.

The increased flooding from the Giddings Brook watershed is more than it might otherwise be because of the watershed's shape. The upper part of the Giddings Brook area lies on the moderately sloped western edge of the Plateau; however, the western part of the area lies on the steep upper edge of the Escarpment. Because this land is steep and heavily urbanized, storm runoff will flow very quickly to the brook, resulting in a short, sharp peak flow and further increasing the maximum flood flow in University Circle and the lower watershed.

Changes in Watershed Surface

Physical Impact: Rainfall flows off a paved surface more quickly and in larger quantities than it would flow from a forest floor. At the same time, less rainwater is absorbed into the ground to replenish groundwater and be slowly released to the stream at a later time. The urbanization of the Doan Brook watershed surface has thus had two main impacts: it has increased the speed and degree of flooding and decreased the groundwater-fed flow in the brook during dry periods.[7] A rough estimate of the impact of urbanization on Doan Brook flow indicates that in an average year, the runoff from a given area is as much as **three times greater than it was before development. A five-year flood[8] may be four times larger than it was in Nathaniel Doan's time.** Where it can, the stream erodes its bed and banks to accommodate the higher flows.

Biological Impact: The water that flows to Doan Brook from the urban surface of its watershed carries a wide variety of contaminants. Runoff from streets carries oil, grit, road salt, and traces of other manmade chemicals. Runoff from lawns carries fertilizers, pesticides, and domestic animal waste. Runoff from construction sites carries sediment. Additional sediment is generated as the brook erodes its bed and banks in response to higher flows. Contamination flowing into the brook has a significant impact on water quality, but the impact is perhaps less than might be feared. Water quality in the brook is discussed in detail in Chapter 6.

More frequent and severe floods wash out stream and flood plain habitats, making it difficult for aquatic organisms to become established. Lower flows that may occur during dry periods also eliminate aquatic habitat.

7 Decreases in dry-weather flow may be offset by runoff from human activities such as washing cars and watering lawns.

8 See Appendix H for the definition of the five-year flood.

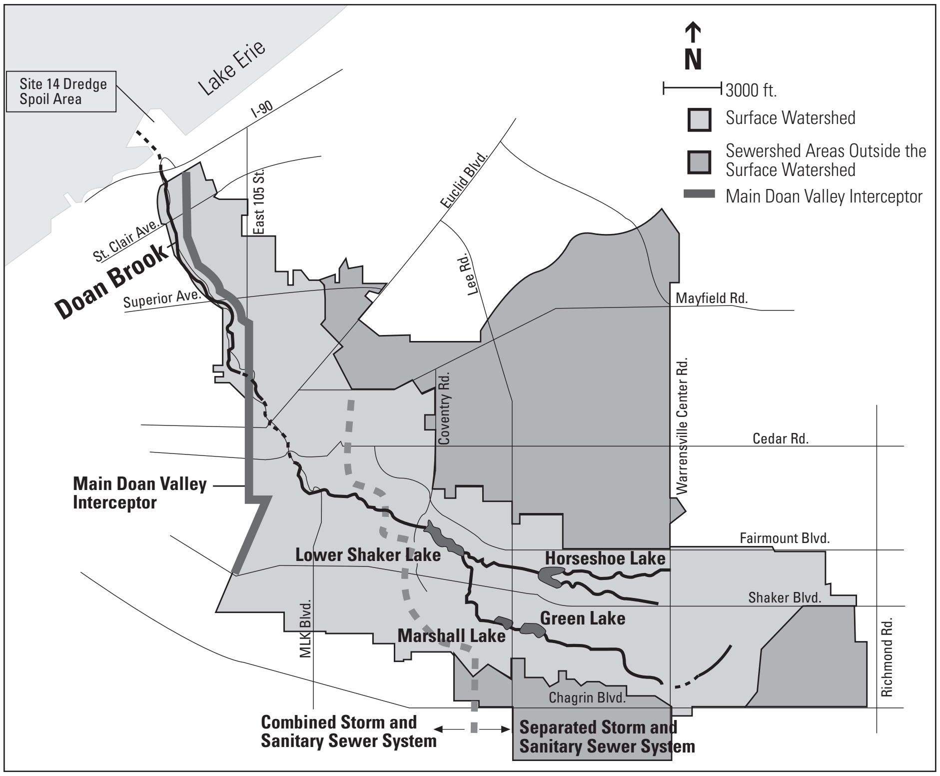

Figure 5-3 Doan Brook Sewershed

buildings or pavement. Land that has not been paved altogether has generally been transformed from deep forest with a forest floor covered in leaf litter to manicured lawns with relatively few trees and little underbrush. Rainfall quickly runs off the modern landscape, leading to more frequent Doan Brook flooding.

5.3 Where Do the Sewers Fit In? The Sewershed and Storm Sewer Drainage

Anyone who has followed the water quality debate in recent years is aware that overflows of sanitary sewage into streams and lakes — generally called Combined Sewer Overflows, or CSOs — are a major water quality concern in older urban areas. CSOs are, in fact, the major single cause of poor water quality in Doan Brook. How did a sewer system that allows sanitary sewage to discharge to Doan Brook come about, and why weren't such discharges corrected long ago?

As people developed the Doan Brook watershed, they found it necessary to move the streams and rivulets that ran to Doan Brook underground and out of the way. Over time, a sometimes-confusing web of culverts and sewers grew beneath the city to replace the streams. During the city's early life, sanitary sewage was drained directly into this pipe network, and the combined stormwater and sanitary sewage was discharged straight into streams and Lake Erie. When it became evident that we could not continue to dump our sewage directly into streams and the lake, the combined sanitary and storm sewers were diverted so that the combined sewage could be treated before it was discharged to Lake Erie. Unfortunately, the combined sewer system and the sewage treatment plants could not be made large enough to treat all the surface runoff from even a small storm. Combined sewer systems are therefore designed to overflow, sending mixed sanitary sewage and stormwater back to the streams and the lake whenever it rains more than a few drops.

Sewer systems for newer developments were designed to keep sanitary sewage and stormwater in separate pipes, diverting sanitary sewage for treatment and discharging storm flows to surface streams. However, the cost of replacing the old combined systems was too high, and they stayed in place.

Because different parts of the sewer system in the Doan Brook watershed were built at different times, there are both combined (storm and sanitary together) and separated (storm and sanitary kept apart) sewer systems in the watershed. The following sections describe the separated and combined sewer systems and their interactions with each other and with Doan Brook.

5.3.1 The Sanitary Sewer System and the Sewershed

Figure 5-3 shows that the *sewershed* associated with Doan Brook is larger than the surface watershed. For Doan Brook, the sewershed is defined as the area over which the sanitary sewers drain to the *Doan Valley Interceptor (DVI)*, a large combined sewer line that roughly parallels Doan Brook in the lower watershed between East 105th Street and I-90.[9] Some areas in the upper sewershed that send surface water to adjacent streams nonetheless contribute sanitary sewage to the DVI.[10] About 8.4 square miles that are not in the surface watershed send sanitary sewage to the DVI, making the total sewershed area about 20.1 square miles.

5.3.2 Separated Storm and Sanitary Sewers: The Upper Watershed

In most of the upper watershed, where the sewer systems are newer, the sewers are designed to keep sanitary sewage separated from stormwater runoff. Ideally, the sanitary sewer system carries only sanitary sewage, which it diverts to a sewage treatment plant (the Northeast Ohio Regional Sewer District's Easterly Wastewater Treatment Center in this case), while the storm sewer carries the storm runoff to the brook. Figure 5-3 shows the part of the Doan Brook watershed that has separate sanitary and storm sewers. Unfortunately, the separate sanitary sewer system from the upper watershed empties into the Doan Valley Interceptor, which is part of the lower watershed combined sewer system (described in the next section). Thus, sewage that is kept out of the brook by the upper watershed's separate sewers may nonetheless contaminate the stream in the lower watershed, as described below.

Why Does the Storm Sewer Stink? Problems with Separated Sewers

If the sewers in the upper Doan Brook watershed separate sanitary sewage and storm runoff, why does the storm sewer outlet in the Nature Center marsh (for example) sometimes stink of sewage? In a perfect world, the separate systems would be just that — separate, without any chance of accidental mixing between storm flows and sanitary sewage. In the real world, sanitary sewage finds a number of pathways to the storm sewers:

- Older designs of separate systems typically allow mixing when there is a minor disruption of the system. For example, water from an overflowing storm sewer may flow into the sanitary sewer, causing it to become too full. An over-full sanitary sewer is designed to relieve itself back to the storm sewer or directly to surface water. (The alternative would be for the sewage to back up into your basement.)
- Heavy rain can overtax the sanitary sewers even if they do not directly receive storm sewer overflow. The pipes that carry sanitary sewage are rarely completely watertight, and as they age they can allow a great deal of water to enter. Infiltration of groundwater into a sanitary line during a storm can overfill the sanitary system, causing spills to surface water.
- Blocked or damaged pipes may also cause sanitary sewage to back up into the storm system.
- Finally, there are occasionally accidental or deliberate illegal connections of sanitary lines from buildings directly into the storm sewers. A number of such connections have been identified in the upper Doan Brook watershed, but the process of correcting them has been slow.

9 The DVI empties into the Easterly Interceptor Sewer near I-90. The Easterly Interceptor carries its flow to the Northeast Ohio Regional Sewer District's Easterly Wastewater Treatment Center, which is located near Lakeshore Boulevard and East 142nd Street.

10 For example, surface water from most of the part of Cleveland Heights that lies northeast of the intersection of Fairmount Boulevard and Coventry Road drains into Dugway Brook (the stream that runs through Lakeview Cemetery). However, sanitary sewage from this neighborhood drains into the Doan Valley Interceptor.

Who Owns the Sewers?

Sanitary and *combined* sewers that intercept the sewage at your curb are owned by your city, which is responsible for their maintenance. When sanitary sewers from several cities combine, or when a sewer line crosses from one city into another, the Northeast Ohio Regional Sewer District takes responsibility. *Storm* sewers that collect surface runoff are almost always owned by individual cities.

The Impact of Change: Sewers

Physical Impact: The storm sewer system in the upper watershed and the combined sewer system in the lower watershed change the points at which stormwater runoff enters Doan Brook. As a result, the sewer system affects the amount of water flowing in the stream at any point. During periods of high rainfall, this may lead to more flooding in some areas and less in others. During periods of very light rain, the combined sewer system in the lower watershed may reduce inflow to the brook by diverting runoff that would otherwise flow to the stream.

Biological Impact: The combined sewer system and, where the system is damaged, the storm sewer system, carry human waste and household chemicals to the brook, as well as providing a conduit for contaminated runoff from streets and yards. The inflow of sanitary sewage to the brook is the stream's greatest single water quality problem, particularly in the lower watershed.

5.3.3
The Combined Sewer System: The Lower Watershed

In the lower watershed, where the sewer system is generally older, the storm and sanitary sewers are combined into a single pipe (see Figure 5-3). In dry weather, the combined sewer system carries sanitary sewage and any surface water runoff to large *interceptor sewers*, which divert the flow to the Easterly Wastewater Treatment Center for treatment. As a result, both sanitary sewage and urban runoff (which may contain lawn chemicals, oil from streets, or other contamination) are treated during dry weather and during very small storms. During slightly larger storms, however, the combined sewer system is overwhelmed by the storm runoff. When this happens, excess flow consisting of mixed stormwater and sanitary sewage overflows the sewer system and is released to the brook. Under the conditions that existed in the year 2000, the combined sewer system generally released its contaminated mix to Doan Brook more than 60 times each year.

5.3.4
Flowing into the Doan: Where Storm and Combined Sewers Feed the Brook

In order to understand flood flows or water quality problems in Doan Brook, it is necessary to understand where flows from different parts of the watershed enter the stream. Since the brook's modern tributaries are mostly storm or combined sewers, an examination of the sewer maps is required. Figure 5-4 shows where the watershed's large sewers feed the brook, together with the approximate land area that drains to each outflow. Table 5-1 summarizes the information in tabular form. In the part of the watershed with separate sewer systems (generally the upper watershed), the outlets shown flow from the separated storm sewers. In the combined sewer area, the outlets shown flow from the combined system.[11, 12]

Figure 5-4 and Table 5-1 show that runoff from much of the upper watershed (a total of 3,190 acres) passes through the Lower Shaker Lake. Almost three quarters of this area is also in the watershed of Horseshoe Lake (1,200 acres) or Green and Marshall Lakes (1,140 acres). Thus, runoff from about 43 percent of the total watershed area of 7,500 acres passes through the Shaker Lakes. Two other sections of the upper watershed, totaling approximately 470 acres, contribute runoff to the brook between the Lower Shaker Lake and the entrance to the University Circle culvert.

The remaining runoff from the upper watershed is carried down the Escarpment in storm or combined sewers and discharged to the brook near University Circle. Runoff from a 670-acre area in Euclid Heights (the wedge of land within the watershed west of Coventry Road and north of Doan Brook) is collected in a sewer that runs down Cedar Glen (the Cedar Glen sewer) and enters the University Circle culvert near the point where MLK crosses under the railroad tracks. Runoff from a large area (approximately 1,000 acres) south of the brook and west of Van Aken Boulevard is collected in a storm sewer that joins the University Circle culvert just downstream from the culvert inlet. Much of this 1,000-acre area was originally part of the Giddings Brook drainage area, and this storm sewer is therefore called the Giddings Brook culvert.

Farther downstream from the inlet to the University Circle culvert, runoff from the Lake Plain (lower watershed) begins to enter the

11 The combined sewer system is a complex network of interlocking pipes, and inflow to the brook from a given outlet will depend on many factors. Figure 5-4 shows approximate drainage areas that are generally correct but far from precise.

12 Instead of showing the outflow point of every storm sewer that flows to the brook, Figure 5-4 consolidates the outflows so that the watershed is broken up into significant drainage areas and outflow points. For example, there are several storm sewer outflows to the north and middle forks of Doan Brook upstream from Horseshoe Lake, but the watershed map shows only a single, large area contributing to the lake. The drainage area is shown this way because Horseshoe Lake, like most lakes, controls flow from the area that lies upstream. As a result, a fairly complete understanding of the behavior of the stream can be obtained by lumping the upstream area into a single unit that contributes flow at the lake.

Table 5-1	Summary of Estimated Doan Brook Drainage Areas[13]		
Location	**Drainage Area[13] Entering (acres)**	**Cumulative Drainage Area (acres)**	**Notes**
Horseshoe Lake	1,200	1,200	
Green and Marshall Lakes	1,140	1,140	
Lower Shaker Lake	850	3,190	
Just D/S from Lower Shaker Lake	320	3,510	
Lower Shaker Lake to MLK Detention Basin	150	3,660	
Giddings Brook Culvert	1,000	4,660	Formerly part of the Giddings Brook watershed. Enters University Circle culvert just downstream from the culvert inlet.
Cedar Glen Sewer	670	5,330	Enters University Circle culvert a short distance downstream from the culvert inlet.
Euclid Avenue	230	5,560	
East 105th Street	820	6,380	
Rockefeller Park	1,120	7,500	

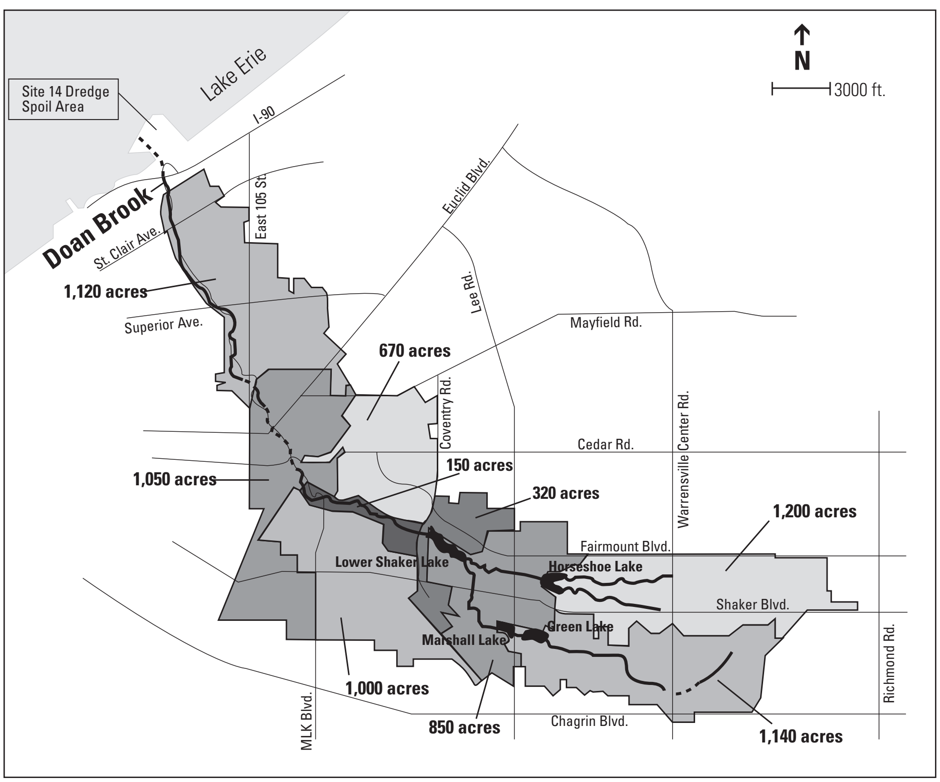

Figure 5-4 Doan Brook Subwatersheds

13 Drainage areas are approximate. Information on surface watershed areas sometimes conflicts. The data presented here represent good estimates of Doan Brook drainage areas.

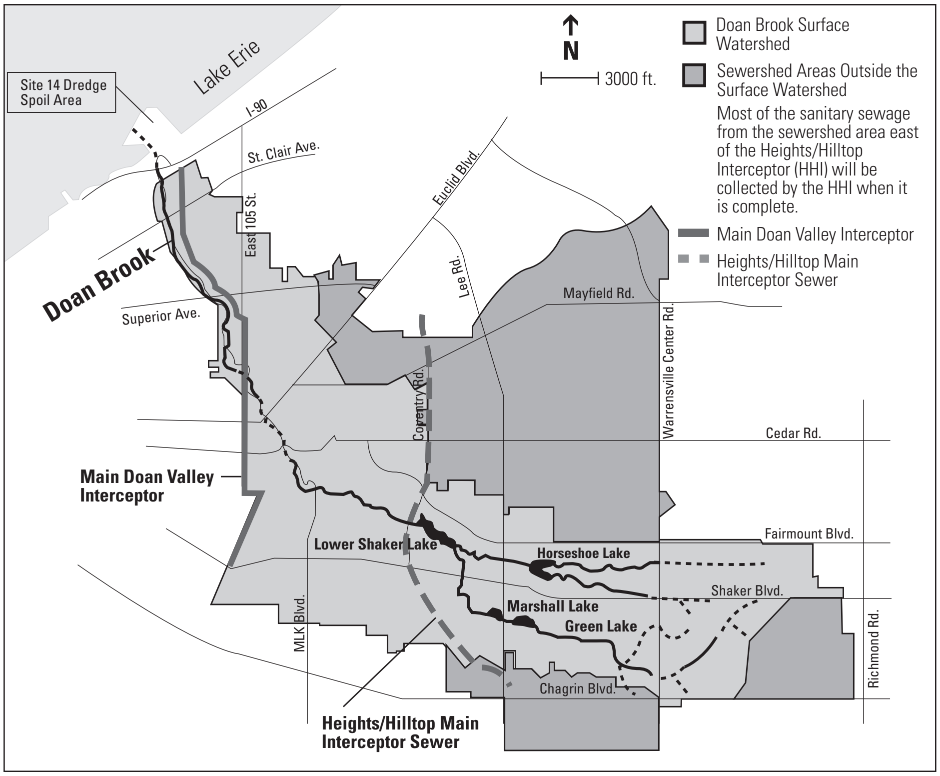

Figure 5-5 Heights/Hilltop Main Interceptor

brook. Runoff from this area reaches the stream through three main inlets and a number of smaller ones. About 230 acres south of Euclid Avenue drain into the University Circle culvert at Euclid. A strip of land along the west edge of the watershed and a smaller area north of Euclid drain into the stream at East 105th Street, adding a total of 820 acres. The remaining downstream area (1,120 acres) drains into the brook at a number of points in Rockefeller Park.

5.3.5
Change in Progress: The Impact of the Heights/Hilltop Interceptor

As this handbook is being prepared, a new interceptor, the Heights/Hilltop Interceptor Sewer (HHI), is under construction in the upper watershed. One purpose of this system of deep underground sewers is to gather sanitary sewage from the Doan Brook sewershed east of Coventry Road (see Figure 5-5), divert it away from the Doan Valley Interceptor combined system, and carry it directly to the Easterly Wastewater Treatment Center.

The completion of the HHI[14] will reduce the amount of combined sewage that reaches Doan Brook by about 50%. Although this sewage diversion will reduce the levels of bacterial contamination in the brook, it will not solve the stream's water quality problems (see Chapter 6). Because the HHI is designed to intercept sanitary sewage (rather than stormwater flow) from the separate sewer area, the volume of storm flows into the brook will not change much after the completion of the interceptor sewer. The lower watershed's combined sewer system will still discharge combined sewage into the brook many times each year — whenever there is significant rainfall — but the fraction of sanitary sewage in the combined sewage mix will be less.

5.4
What Difference Does it Make? Summarizing the Impacts of Change

This chapter began with the assertion that Doan Brook today bears little resemblance to the stream of 200 years ago and has reviewed the transformation wrought by urbanization. The condition of today's brook can be summarized as follows:

- Doan Brook has more total flow and more frequent, larger floods than it did a relatively short time ago. The combined effect of the larger watershed and more impervious area in the watershed leads to an increase of about four times in average annual flow and an increase in the five-year peak flow of about five times. The brook erodes its bed and banks as it tries to adjust its size and shape to its new flow regime.
- The upper watershed's four lakes and, to a lesser extent, the MLK detention basin store

14 The portion of the HHI in the Doan Brook watershed is expected to be partially in service by the end of 2001. The system is expected to be complete some time in 2005.

and slowly release water during floods. They reduce the peak flows downstream and partially counter the higher flood peaks that result from urbanization of the watershed.

- Doan Brook is confined to a rigid channel or culvert in many places and therefore constrained to flow in a straight path within defined limits or to completely overflow its channel and flood its surroundings. The channels were designed for yesterday's flows, so today's runoff leads to frequent floods. The fixed channels thwart the stream as it works to adjust to today's conditions.
- Runoff to Doan Brook from its urban watershed carries a variety of contaminants, including sanitary sewage. The runoff degrades the stream's water quality. Frequent flows that scour the channel, the culverts, and the lined channel sections combine with poor water quality to yield an aquatic environment poor in both species diversity and numbers of individual organisms.
- Long culverts in the lower watershed and dams in the upper watershed prevent free movement of fish and other aquatic organisms from Lake Erie into Doan Brook.

This summary of the effect that urbanization has had on Doan Brook paints a grim picture of the health of the stream. While it is true that the ecosystem of the brook is unlikely ever to regain the diversity and purity that Moses Cleaveland's surveyors found, an understanding of the negative impacts of urbanization must be balanced by an appreciation for the brook's remaining assets. As Chapter 4 demonstrates, much of Doan Brook is still surrounded by a riparian corridor that preserves a bit of wild landscape and provides habitat to a fair variety of wildlife. The Shaker Lakes, although they are not natural features, provide a migration stop for many species of waterfowl and other birds and are an active breeding area for still others. The challenge for stewards of the urban brook is to manage the stream to take best advantage of its strengths and minimize the impact of its urban setting. Approaches to watershed management that can be used to maximize the potential of Doan Brook are discussed in Chapters 8 and 9.