

DEVELOPING ELIGIBILITY CRITERIA FOR
DAYLIGHTING STREAMS AS APPLIED
TO DALLAS MILL CREEK

by

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ABSTRACT

DEVELOPING ELIGIBILITY CRITERIA FOR DAYLIGHTING STREAMS AS APPLIED TO DALLAS MILL CREEK

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Daylighting is a deliberate act of exposing the full or partial flow of previously buried rivers, creeks and streams into restored surface waterways. Human development has encroached upon natural streams and confined them in concrete channels and pipes, covered them partially or fully, and altered their natural courses. This has caused reductions in flow capacity, increase in flow velocity, and water pollution, leading to floods, erosion, and loss of natural resources.

Stream daylighting is in a developmental phase, meaning that most of the daylighting projects have been undertaken without rigorous hydrological, geomorphological, and ecological assessment or knowledge of the outcome. Daylighting projects need to be more carefully engineered into storm-water management systems.

Few design standards, construction details, and references have been published on daylighting of streams to help professionals assess and plan for the rehabilitation of urban streams. This research identifies common denominators in the daylighting processes based on a literature review and the study of fifteen completed daylighting projects in North America.

The focus of the research is on the issues of stream daylighting surrounding Mill Creek, a buried stream in Dallas, Texas. Mill Creek—once the longest and deepest creek in the city of Dallas—played an important role in the city’s early development. However, over several decades, the creek became an open sewer carrying human and industrial waste. The riparian system which enveloped the creek was removed as the developing urban framework encroached upon the stream.

In 1910, the Dallas Park Board authorized city planner George Kessler to prepare a master plan for the city. According to Kessler’s plan, parkways were called for alongside Turtle Creek, Mill Creek, and Cedar Creek, within the Dallas city limits. Rather than following this plan, however, the City decided in the 1930s to bury Mill Creek in underground storm sewers. Events in the past decade, including violent floods in the residential neighborhoods and the Baylor University’s medical complex, revealed the extent of the subsurface drainage problems of the historic creek. According to the City’s Master Drainage Plan for Mill Creek (2005), partial daylighting has been proposed to mitigate these problems.

Preliminary daylighting criteria have been synthesized based on review and analysis of available literature and information. Based on Mill Creek study results using Geographic Information Systems (GIS), analysis of interviews and correspondence with

the city officials and daylighting experts, historical/cultural values and thoroughfares have been established as key considerations for the daylighting Mill Creek. These results were based on issues of decision making for daylighting streams, rather than a detailed step-by-step protocol for stream daylighting implementation.

Roadways/thoroughfares are a key infrastructure in today's urbanized areas. They are important criteria for daylighting streams in highly urbanized areas like Dallas, Texas. Secondly, Mill Creek has played a key role in establishing Dallas as an important transportation and economic center in north-central Texas, beyond the provision of providing a drinking water. Enhanced eligibility criteria for daylighting Mill Creek have been developed by adding these two key criteria to the preliminary criteria. The study has also shown that partial daylighting is feasible in the Mill Creek watershed and would be a better choice than replacing the old and under-capacity drainage system of the Mill Creek watershed. Property values in the Mill Creek watershed will likely increase after daylighting.

Stream daylighting offers viable solutions to address the problems of flooding, erosion, and loss of natural resources and provides benefits including the improvement of water quality, reestablishment of aquatic/riparian habitat and wildlife corridors, and restoration of natural resources. While this research does not suggest daylighting the entire historic run of Mill Creek, it shows the benefits of partial daylighting of the buried creek. It provides the context for selection of potential daylighting sites in Dallas, and can be useful in formulating a city-wide stream-daylighting policy in Dallas. This report will also serve as a reference for future planning efforts in the Mill Creek watershed.

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CHAPTER 1

INTRODUCTION

“They aren't supposed to be sewers, but since they are underground;
we tend to think of them that way”

- Clarence Burley, quoted in Klesius, 1999.

1.1 Background

In 1910, City of Dallas master planner George Kessler proposed developing East Dallas' Mill Creek, along with Turtle and Cedar Creeks, into tree-lined parkways (Kessler 1911). Rather than following this plan, however, the City of Dallas decided in 1930 to bury Mill Creek in underground storm sewers. Mill Creek, which flowed as a perennial creek prior to urban development (Pratt 1992) is now an underground storm sewer that drains over 3.5 square miles of East Dallas and South Dallas between Mockingbird Lane and the Trinity River (Halff Associates 2005).

The 1995 and 2005 flood in Dallas, Texas, brought attention to this much forgotten creek. There were thirty-nine reports of flooded structures (Baeck 1998), including Baylor Hospital's Emergency Room. The flood also resulted in loss of life, as the current Mill Creek pressure sewer could handle only one third of the design runoff from a 100-year storm.

1.2 The Concern and Stormwater Issues

Cities are dependent on rivers and river systems for water as primary resources for their citizens, wildlife and vegetation. With the modernization of cities, water

resources have been transformed from sources of clean water to navigation channels, to other functional applications and ultimately to drainage channels. This resulting configuration has led to water quality deterioration, stream habitat degradation, and an increase in flooding (Newbury 1998). For example, an estimated 700 miles of historical creek that once flowed through Dallas until the late 1800s is now reduced to approximately 600 miles because of stream modification (Figure 2.7).

Riley (1998) notes that “many cities regret loss of their streams and rivers as historical, aesthetic and environmental assets and are trying to undo some of the damage” (p. 11). Hence, a new paradigm is needed for integrating streams with the fabric of cities over the current model of relegating streams to “industrial drainage ditches” (Owens-Viani 1997; Moses and Morris 1998). “The newly emerging science of urban stream daylighting ...” (Buchholz and Younos 2007, p. 4) is becoming a viable choice to alter the traditional view of urban streams and to overcome the stated problems.

Underneath the city of Dallas, there is a vast network of utilities that supports the residents’ quality of life through which untreated storm water flows into creeks, rivers, and lakes (City of Dallas 2006). The Mill Creek watershed in Dallas, Texas faces persistent flooding. During wet weather, storm-water runoff exceeds the capacity of the existing drainage system which is undersized for a 100-year flood event. Approximately 147 acre-feet of storm-water gets stored in the low-lying areas of the Mill Creek watershed.

Stream daylighting is one of the “low impact design (LID), Best Management Practices (BMPs), Green Infrastructure techniques” which can be effective to integrate “...urban stormwater into its built environment...” (San Francisco Public Utilities Commission 2007, 2). Stream daylighting can help address significant challenges facing the City of Dallas’s storm-water infrastructure today.

1.3 Research Purpose and Objectives

The purpose of this study is to test eligibility for daylighting Mill Creek, Dallas, Texas. Preliminary daylighting criteria have been synthesized based on review and analysis of available literature. Using preliminary criteria, the enhanced eligibility criteria have then been developed through interviews. The enhanced eligibility criteria include design criteria and non-design criteria (Appendix D). Spatial analysis of Mill Creek using Geographic Information Systems (GIS) has also been performed to test design criteria for daylighting Mill Creek, Dallas, Texas.

The primary objectives of this research are to:

1. Explore the reasons of transformation of streams into sewers, to study the impact of urbanization on urban streams, to understand the factors involved in stream restoration and daylighting, and to observe how viewpoints have changed toward the value and function of streams in an urban environment in Dallas, Texas.

2. Establish preliminary criteria for stream daylighting based on review of the existing literature and information in the field of stream daylighting.

3. Perform a spatial analysis using Geographic Information Systems (GIS) for the Mill Creek watershed. Evaluate Mill Creek for daylighting against preliminary criteria based on key professionals' interview/perspectives.

4. Using the results of (3) above develop enhanced eligibility criteria for daylighting the Mill Creek to see how the Mill Creek project is different from the (reviewed) completed daylighting projects.

1.4 Primary Research Questions

The primary research questions that this research addresses are

1. What are the key criteria for determining eligibility for daylighting streams?
2. Does Mill Creek achieve that eligibility?

1.5 Definitions of Terms

Bellevue Pressure Sewer: It is designed to discharge a capacity of about 2400 cfs, which starts at the intersection of Ervay Street and Bellevue Street and continues along Bellevue Street to the Trinity River (Halff Associates 2005).

Best Management Practices (BMPs): They are techniques used to control stormwater runoff, sediment control, and soil stabilization, as well as management decisions to prevent or reduce nonpoint source pollution (U.S. EPA 2008)

Channel geometry: A catch-all term referring to such characteristics of a stream channel as its depth, width, sinuosity, meander wavelength and amplitude, and other measurable dimensions (Newbury 1998).

Combined sewer overflow (CSO): The release of excess water from a combined sewer system (a system carrying storm runoff and sanitary sewage together) that occurs

at a regulator structure designed to overflow when the system reaches capacity in wet weather (Butler and Davies 2000).

Combined sewer system: A combined system where storm run-off as well as sanitary sewage is collected by the same system (Butler and Davies 2000).

Storm sewer system: In City of Dallas, there is no combined system where storm run-off as well as sanitary sewage is collected by the same system. However, in North Texas region, storm drain pipes are also known as storm sewers (Patel 2008).

Daylighting: It is a deliberate act of reexposing the lost creeks, streams, rivers and storm-water drainages from the pipes and concrete channels in which they were enclosed (Pinkham 2000).

Fluvial geomorphology: The study of how landscape and moving water interact and influence the formation and stability of stream channels (Newbury 1998).

Hydrologic storm sewer design (HSSD): A computer program used to analyze existing storm drainage system of the Mill Creek watershed (Halff Associates 2005).

Hydraulics/hydraulic: The study pertaining to the behavior of water flowing in channels or pipes (Newbury 1998).

Hydrology/hydrologic: The study pertaining to the amounts and movement of water in the environment, for example in a watershed (Newbury 1998).

Mill Creek: Mill Creek, which years back flowed as a perennial creek (Pratt 1992), is now an underground storm sewer that drains over 3.5 square miles of East Dallas and South Dallas between Mockingbird Lane and the Trinity River (Halff Associates 2005).

Soil rehabilitation: Aeration and the addition of organic matter and dense vegetation increase infiltration rates into soil (Newbury 1998).

Trinity River Sump “A”: Mill Creek discharges storm water into the Sump “A” then to Trinity River via Interstate Belleview Pressure Sewer (Halff Associates 2005).

Rapid Bioassessment (RBP): Sampling technique as well as habitat assessments and water quality sampling (City of Dallas 2006).

Limnology: The scientific study of the life and phenomena of fresh water, especially lakes and ponds (Newbury 1998).

Low Impact Design (LID): It is a stormwater management approach that aims to re-create and mimic these pre-development hydrologic processes by increasing retention, detention, infiltration, and treatment of stormwater runoff at its source (U.S. EPA 2008, para. 1).

Morphology: The geometry of a stream channel and flood plain (Newbury 1998).

Watershed: All the land that drains to a given stream or low point; a drainage basin defined by topographic divides (Newbury 1998).

1.6 Overview of the Study

Daylighting not only significantly reduces peak flow and volume of storm runoff, it also increases the storm-water carrying capacity of the system (Pinkham 2000; Halff Associates 2005). It can provide opportunities to reconnect fragmented open spaces and add green amenities like recreational facilities and a site for environmental awareness and education.

Owing to the above concerns, the overriding objective of this research has been to evaluate Mill Creek for daylighting and develop enhanced eligibility criteria for daylighting Mill Creek in Dallas, Texas.

The research begins by exploring the influence of urban storm-water management in the United States and how early decisions have changed the treatment or outlook towards the value and function of streams in an urban environment in Dallas, Texas. Chapter Two includes literature review and analysis of documents related to stream daylighting and its criteria. Chapter Three briefly presents the historical background of Mill Creek, Dallas, Texas. The research methods used in the research are outlined in the Chapter Four and these include interviews of key professionals and a detailed study of Mill Creek, Dallas, TX. Chapter Five discusses the interview data, spatial inventory and analysis of Mill Creek using geographic information systems. Chapter Six of the study provides the conclusion and suggestions for the future research.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

“Nothing historic ever happens in these recollected creeks. But their persistence in memory suggests that creeks are bigger than they seem, more a part of our hearts and minds than lofty mountains or mighty rivers.”

- Peter Steinhart 1989, 22-23

In his article, "Devil Creek" Jim Schutze makes the reader aware of how isolated we have become from nature. Nature is too big and powerful to be controlled by us. It is very important to our survival to maintain harmony between nature and the city (Ian McHarg 1967) in order to avoid the environmental consequences.

Devil Creek by Jim Schutze in Dallas Observer:

For decades we buried our streams beneath concrete. Now they're baaaack.

Years ago--I don't remember how many; I was young myself, that's how long--an old guy pointed a line across my neighborhood with a chopping motion of his arm and told me it was where the creek bed must have been.

His theory was based on a series of houses on three blocks that suffer perennial foundation problems, and he had some notions about the lay of the land that I couldn't quite follow.

In '95 and again in this recent one, I watched the water crashing into the neighborhood from Live Oak, the big street just northwest of us. The waves came toward us on Glendale and crashed against a corner lot just across from our house on Bryan Parkway, right into the opening where the city guy had told me the huge holding tank was. But this time instead of flowing into the opening, the water shot straight up out of it..... But it never occurred to me that any of this could impinge on my property, which I believed to be high and dry, far from any water.

It took some searching (well, I have to say that, don't I), but at last I found the creek beautifully hand-tinted in blue on some of the maps, wide as a street in places. The maps show Mill Creek and branches of Mill Creek--a small river, really--winding through streets all around me, at Worth Street and Prairie Avenue, barely three-quarters of a mile from my house at Ross and Fitzhugh avenues, then all through the area where Baylor is now and over by Old City Park and finally through the southwest end of downtown to the Trinity.

At Monticello Avenue and Alderson Street, 1.4 miles from me, the elevation is 592 feet above sea level. At my house the elevation has fallen to 515 feet. Less than a mile away from me at Ross and Fitzhugh, the point closest to my house where I was able to find Mill Creek on the old maps, the elevation is 509 feet. At Baylor it's 464. At Old City Park, 420. Where Mill Creek reaches the Trinity River, it is 385 feet above sea level.

I have always thought of myself as living on flat land. But that's a drop of more than 200 feet--the height of a 20-story building--in five and a quarter miles as the crow flies. No wonder that water gets in a hurry.

As we have rebuilt the land, that rain fell on huge new expanses of impermeable McMansion rooftop, shot straight down the streets, smashed into the 75-year-old brick-walled conduits and holding tanks we haven't cleaned out or kept up in decades and then went angrily looking for its own way to the river.

I stood on the corner of our street and watched the water thrash against curbs, leap around tree trunks, hurl automobiles out of its way--an enormous angry snake writhing, a demon up out of the earth howling, "Where is my creek?"

We are foolish ants who think we have made the river disappear beneath our mound. Oh yes, and I almost forgot: those hundreds of millions of dollars we're going to pour into decorative suspension bridges as part of our "flood control" program downtown? Think of me doing the chimpanzee jumping-jacks thing right now.

Figure 2.1 Newspaper Article - Devil Creek

Source: Jim Schutze, Dallas Observer (2006)

2.2 A Hidden Resource: Streams to Sewers

2.2.1 Early History of Urban Drainage

Human settlements have identified the closeness to streams, river or other bodies of water as a source for their sustenance. Historical evidence indicates usage of drainage conduits in the Tigris and Indus river basins dating back to 3000 B.C.

Artificial drainage systems were developed soon as humans attempted to control their environment. Archeological evidence reveals that drainage was provided to the buildings of many ancient civilizations such as the Mesopotamians, the Minoans (Crete) and the Greeks (Athens). The great sewer (*cloaca maxima*) built in the sixth century B.C. to drain the Forum in Rome remains in use today (Butler and Davies 2000).

Across the millennia leading to an era where the practice of sewerage or drainage followed essentially the philosophy, that is, sewers were built to drain only runoff from storm water and waste water in separate sewer (Adams and Papa 2000). So strictly this practice was followed that in Roman times, laws were enacted to specifically prohibit the entry of anything but rainwater into the sewer systems. Thus, sewers were put in place largely for convenience to minimize the detention of water and roadways and other surfaces in wet weather (Adams and Papa 2000; Butler and Davies 2000).

2.2.2 19th Century City Improvement Programs in the United States

Hopey (2002) says, “Many of the streams haven't seen the light of day for hundred years or more, victims of decisions in the late 1800s to build combined sewers that carry storm-water and human waste rather than separate storm and sanitary sewers. Others were buried by industrial or housing projects that created flat land for development by cutting off hillsides and filling in valleys” (p. 1).

In the nineteenth century water was feared as a source of parasites and epidemics, and thus it was insulated from the urban ecology. During the late nineteenth

century, water-borne diseases were reduced by protecting water supplies, conveying wastewater away from ground water sources, and by increasing awareness of public sanitation. Death rates, which decreased due to improved water supply systems, began to rise in about 1815 due to polluted water (James 1998). Combined sewer systems were developed from the 1850s on, and continued to be built until the Second World War. Between 1860 and 1910, most of the sewer networks were built to channelize waste water and storm water in order to improve urban sanitation. Historically, waste water and storm water were either combined (combined sewers) or kept separate (separate sewers) (Adams and Papa 2000). Much of today's urban water management and technology was developed in the nineteenth century.

Before the Second World War, streams had become an integral part of the urban infrastructure, serving as rights-of-way for sewage and drainage or as corridors for parks and trails. Water supply and wastewater management programs grew rapidly in the early part of the twentieth century. But the real advances in water quality control date from after the middle of the twentieth century, with significant federal legislation and local regulations being implemented from the 1970s on. Sanitary and storm sewers were typically separated (Adams and Papa 2000; Butler and Davies 2000).

2.2.3 The Impact of the Environmental Movement in the United States

James (1998) as rightly points out one of root cause of the environmental damage: “Water resources engineers are indeed the unwitting, primary agents in the long-term, inexorable destruction of the world” (James 1998).

In the 1970s and 1980s, advancements in environmental regulatory law, including the National Environmental Protection Act, the Water Quality Act (NEPA), and the Endangered Species Act established in order to protect the waterways from the impacts of urbanization. With the environmental movement of the 1970s, the recognition spread in United States that economic development, urbanization, and population growth came at a heavy cost to the natural environment. The twenty-first century opened with environmentally sensitive programs such as wetland protection, mitigation banking, floodplain management, and watershed planning (Riley, 1998).

Cities are often thought to be separate from nature, but recent trends in ecocriticism (Bennet and Teague 1999) consider them a part of the total environment. Burying streams is now recognized as a practice with environmental costs, and communities are seeking to rediscover buried channels. For example, a group in Toronto has produced maps showing hikers the location of buried streams, inviting them to take “lost river walks” (Toronto Green Community). Another example that shows the time is right for a change in the way we think about streams: Since 1988, as a part of “The Zurich Stream Daylighting Program”, the city of Zurich in Switzerland daylighted approximately 10 miles of streams in more than 30 projects. The credit to this tremendous success goes to the “stream working group”, which always collaborated closely with the population, politicians, city departments and specialists (Conradin 2004; France 2008). After the success of the Strawberry Creek daylighting in Berkeley, California, an ordinance was passed to protect the streams from any new culvert construction or confinement (Pinkham 2001).

2.3 Streams in Urban Context

Streams in an urban landscape (Paul and Meyer 2001) are highly impacted by the processes as of urbanization (Karr and Chu 2000). For example, it disturbs the hydrology, geomorphology, water quality and ecology (Schueler 1996; Karr and Chu 2000; Paul and Meyer 2001) of cities, and degrades the downstream water systems at the regional level to the extent that professionals are facing tremendous challenges to mitigate the environmental damage (Schueler 1996).

The Texas Natural Resources Conservation Commission (TNRCC) has identified toxic metals, siltation, nutrients, bacteria, and organics among the top pollutants causing impairments to urban stream corridors (TNRCC 2001; USEPA 2000). If the impacted media (soil, groundwater, or surface water/sediments) exceeds the ecological benchmarks of these pollutant loads (TNRCC 2001) it may pose a threat to the health of cities using the water (Paul and Meyer 2001; TNRCC 2001). This makes nonpoint source (NPS) pollution ecologically more important than point-source pollution, which generally comes from wastewater discharged from the pipes of industrial facilities and municipal sewage treatment plants into urban streams (Paul and Meyer 2001). Research has demonstrated the physical, hydrological and biological differences between urbanized streams and their natural (rural) counterparts (Riley 1998; Schueler and Brown 2004). So, it is essential to study the issues of daylighting against the backdrop of past trends of urbanization (Pinkham 2000).

2.4 Impact of Urbanization

More than three-quarters of the U.S. population now lives in urban areas. The impervious land cover common to urban areas affects storm-water runoff. An increase of 10 to 20% of impervious surfaces increases runoff by twofold; an increase of 35 to 50% in impervious surface increases runoff by threefold; and at 75 to 100% impervious surface, runoff goes up by fivefold (Paul and Meyer 2001). The accompanying pollutant loads to a greatly influence physical, chemical, biological, and ecological processes, which in turn impacts stream health (House et al. 1993; Schueler 1996; Paul and Meyer 2001). This has resulted in huge ecological losses in the form of reduced fertile cover for malnourished aquatic organisms, increased sedimentation, and lower volumes of serviceable drainage (Riley 1998). Indeed, mapping the type of land cover is more important than mapping land use from a hydrological point of view (Riley 1998).

A startling collective report on stream channelization revealed that by 1972, over 235,000 miles of stream had been manipulated in some way (Little 1973 cf Wesche, quoted in Lewis 1985). A stream in the process of evolution evolves through erosion, transport and deposit of materials in its watershed basin (Ferguson 1991b). Nature has evolved its own dynamic equilibrium, matching inflow with the carriage and the outflow and is bounded by the parameters of dynamic discharges and channel morphology (Newbury 1998).

The negative impact of human encroachment on streams is obvious in the unstable urban watershed. The ninetieth and twentieth centuries have witnessed the

manipulations of these waterways to serve the infinite need for buildable land. Such activities have taken a toll on our streams, and they lay polluted, straightened, diverted and confined in concrete channels. This has also resulted in the abuse of the associated wetlands and once thriving ecosystems in the name of flood control and public safety. Such blatant encroachments are supported by engineering marvels, which have disguised the impending threat. Floodplains are bypassed by engineered infrastructure, and are filled and built upon. Over 80,780 miles of streams and rivers in the United States are impaired by urbanization (USEPA 2000). Such ill-advised human intervention has turned waterways from a boon to a liability, especially in the urban landscape (USEPA 2000).

In a 2002 EPA study, 19% of the nation's three million six hundred ninety-two thousand eight hundred thirty miles of rivers and streams were observed and assessed. The primary focus was the perennial streams. Streams were critically observed in terms of ecology, watershed, riparian corridor, genetic species supported and urban runoff. The USEPA (2002) statistics reveal that only 55% of streams fully support their designated use, while 45% for are impaired to some extent. The report also states that 4% of streams are "good but threatened," precariously poised to impair aquatic life (USEPA 2002).

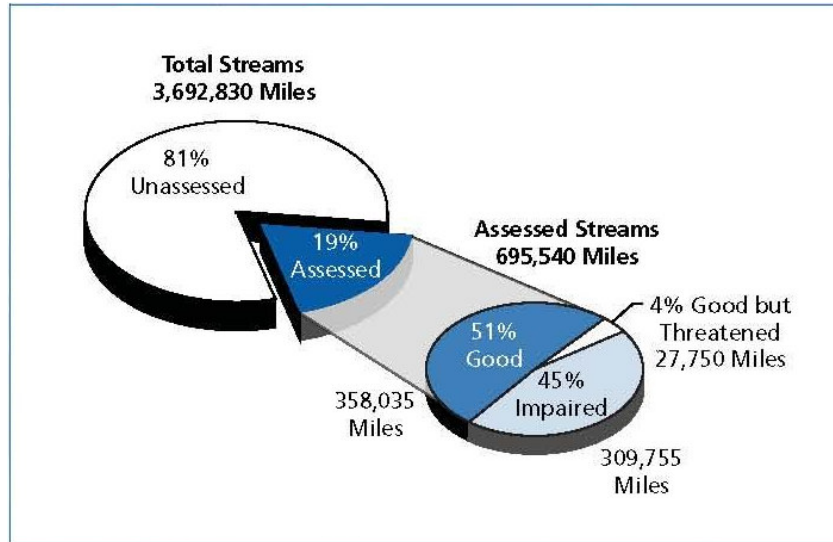


Figure 2.2 Water Quality Assessed River and Stream Miles
 Source: USEPA (2002)

Table 2.1 Individual Water Use in Assessed River and Stream Miles

Designated Use	Assessed Miles	Percent of Total U.S. Stream Miles	Percent of Waters Assessed		
			Good	Threatened	Impaired
Fish, Shellfish, and Wildlife Protection/Propagation	596,433	16%	55%	4%	41%
Recreation	321,750	9%	64%	3%	33%
Agricultural	189,332	5%	92%	<1%	7%
Aquatic Life Harvesting	186,721	5%	57%	16%	27%
Public Water Supply	150,492	4%	81%	2%	18%

Source: USEPA (2002)

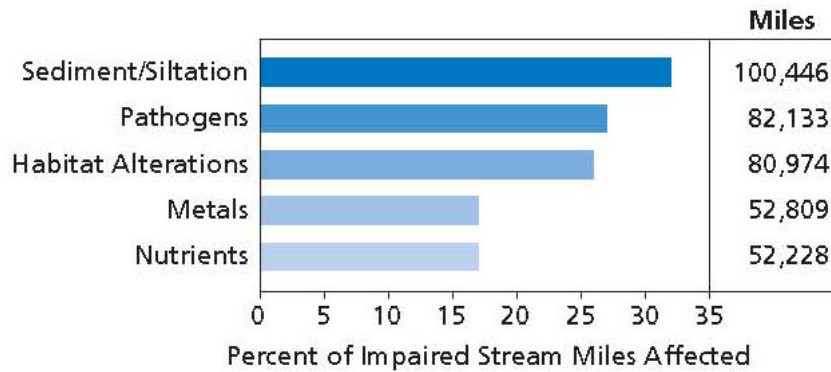


Figure 2.3 Top Causes of Impairment in Assessed Rivers and Streams
 Source: USEPA (2002)

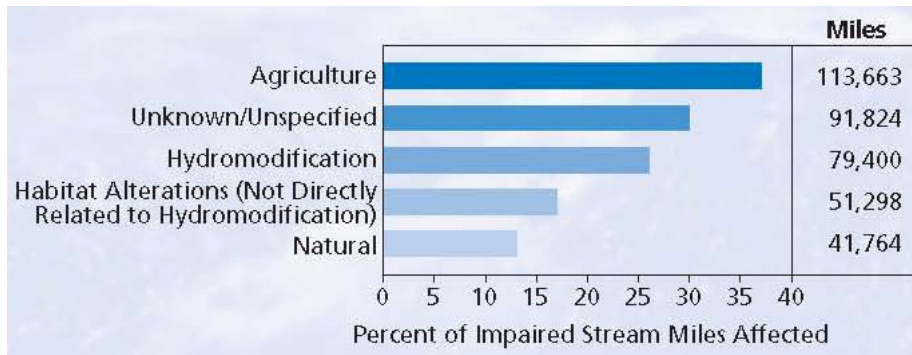


Figure 2.4 Top Sources of Impairment in Assessed Rivers and Streams
 Source: USEPA (2002)

2.5 Streams in Dallas: An Urban Context

Underneath the City of Dallas, there is a vast network of utilities that improve the quality of life. A water, sanitary sewer, and storm drain system presently runs below Dallas’s streets and buildings. Moreover, some of that infrastructure dates back to the origin of the City. A separate set of pipes has been built to handle rain water. When it rains, the storm-water runoff flows through the streets into a unique set of storm drain pipes. Unlike water from a reservoir (treated in the water treatment plants before consumption and use) and wastewater (treated before being discharged to the

surface waters), storm water goes with the flow untreated into our creeks, rivers, and lakes (City of Dallas, 2006). Within the City of Dallas there are currently 308 miles of perennial streams, 148 miles of intermittent streams, while approximately 194 miles of streams are in artificial paths, connector and canals/ditches (Figure 2.6). This figure shows the effect of stream channelization and culvertization in Dallas, Texas. Between 1899 and 2002 over 100 miles of stream channel are lost in the city.

Table 2.2 Texas Assessed Waters Overall Water Quality Attainment for Rivers and Streams

Attainment Status	Miles	Percent of Assessed
Good	15,937.58	78.53
Threatened	.00	.00
Impaired	4,357.47	21.47
Total Miles Assessed	20,295.05	100.00

Source: USEPA (2002)

Table 2.3 Stream Quality Assessment: City of Dallas

Attainment Status	Miles	Percent of Assessed
Nonimpaired	214	44.39
Slightly-Impaired	112	23.23
Moderately-Impaired	00	.00
Total Miles Assessed	482	100
Total Miles	601	

Source: City of Dallas, 2000 (Figure 2.5)

In the past, channelization was a common stream management practice. The increase in storm-water runoff and the loss of headwater streams has led to dramatic changes to the remaining unchannelized streams. In order to prevent channel erosion and to move stormwater out of urban areas as quickly as possible, streams were straightened and channelized using concrete and rip-rap. While this may have solved a

problem along an individual reach, it resulted in much greater problems downstream. In the years 2004-2005, The City of Dallas assessed fifty-five sites on forty-nine creeks using habitat assessments and water quality sampling. Twenty-four of these sites were assessed using a modified rapid bioassessment (RBP) sampling technique as well as habitat assessments and water quality sampling (Figure 2.5 and Figure 2.6).

Water quality parameters routinely tested included field parameters of pH, temperature, specific conductance, dissolved oxygen, total dissolved solids (TDS), total suspended solids (TSS), and turbidity. Water chemistry performed in the laboratory included nitrates, nitrites, total phosphorus, copper, iron, chemical oxygen demand (COD), and fecal coliform analysis. These parameters were compared to benchmark values established using guidelines from EPA and Texas Surface Water Quality Standards (TSWQS) (TNRCC 2001). Fourteen sites had fecal coliform values greater than 200 colonies per 100 ml. Thirteen sites had dissolved oxygen concentrations lower than the standard of 5.0 mg/l. Four sites had chlorine levels of greater than 0.2 mg/l (City of Dallas 2006).

Habitat assessments were performed on all streams and given a score based on thirteen habitat parameters, which included epifaunal available cover, embeddedness, velocity/depth regime, sediment deposition, channel flow status, channel alteration and sinuosity, pool variability and substrate type, frequency of riffles, bank vegetation cover, riparian zone width, and bank stability. Seven sites were rated as “optimal,” thirty-one sites were rated as “suboptimal,” sixteen sites were rated as “marginal,” and one site was rated as “poor” for habitat availability (City of Dallas 2006).

CITY OF DALLAS STREAM QUALITY (2004-2005)

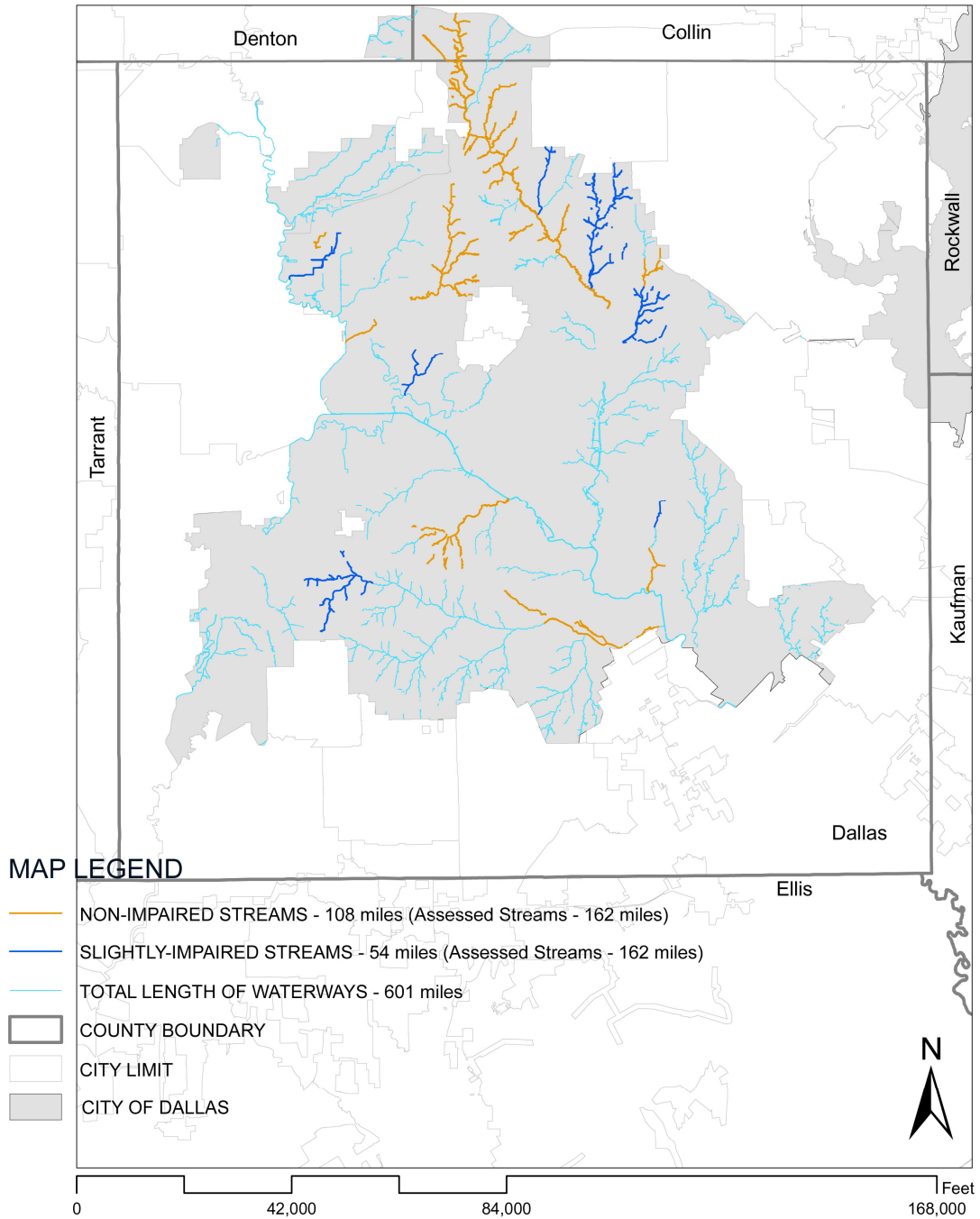


Figure 2.5 Stream Water Quality of City of Dallas Map
(Data Source: City of Dallas, 2000)

CITY OF DALLAS HABITAT RATING (2004-2005)

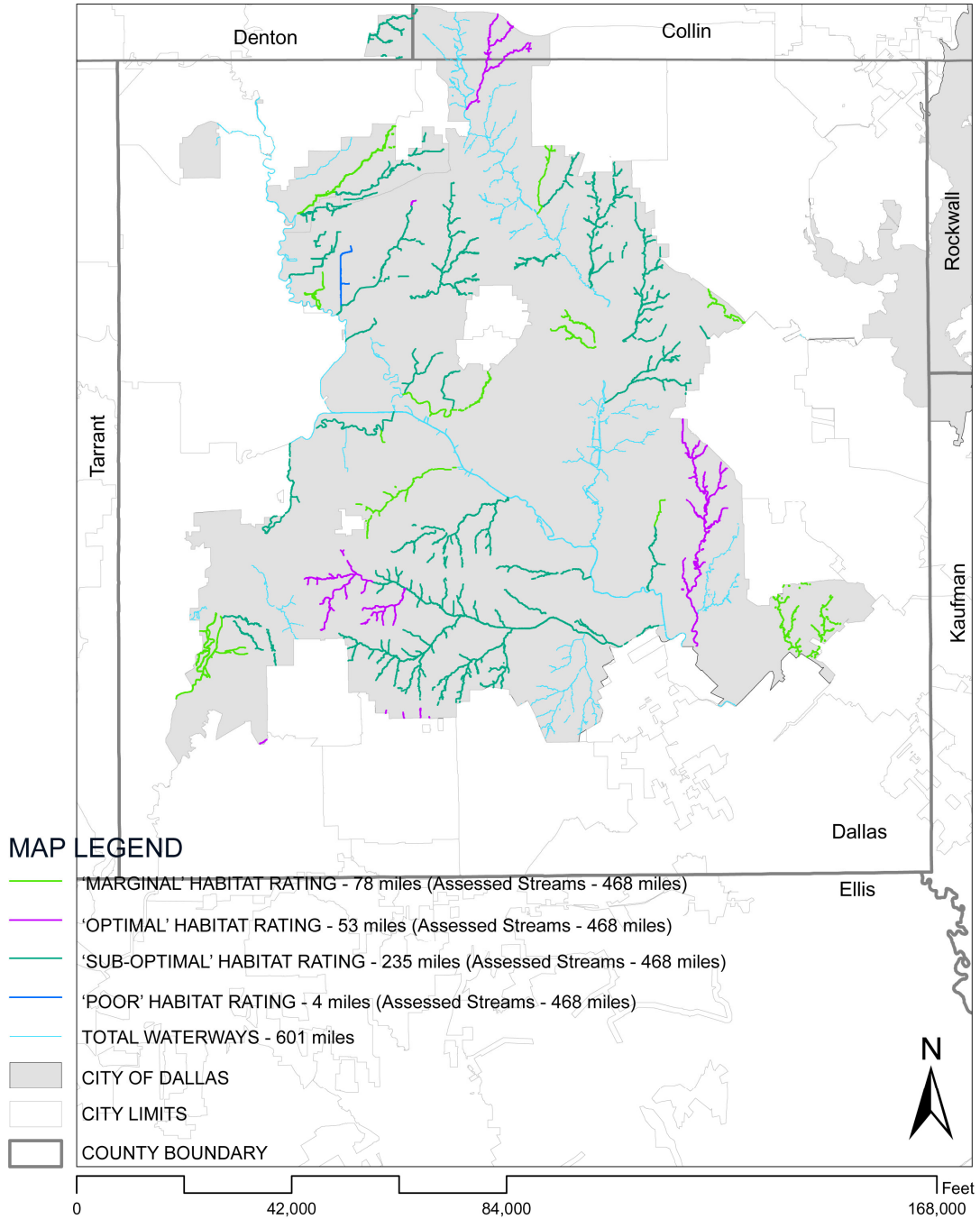


Figure 2.6 Stream Habitat Rating of City of Dallas
(Data Source: City of Dallas 2000)

CITY OF DALLAS CREEKS AND STORMSEWER FLOW PATH

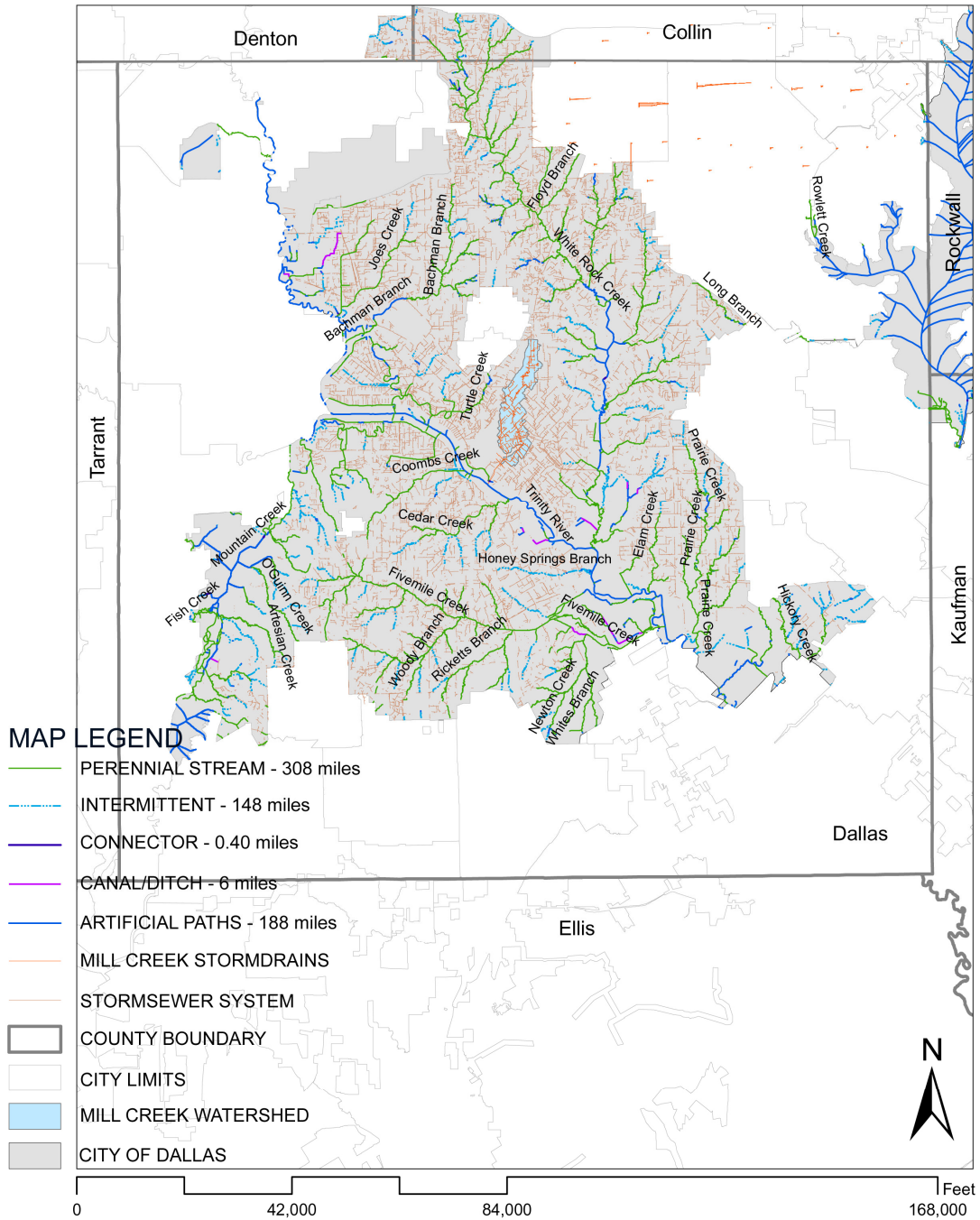


Figure 2.7 City of Dallas Stormsewer Flow Paths
 ((Data Source: City of Dallas 2000))

CITY OF DALLAS CREEKS AND STORMSEWER FLOW PATH

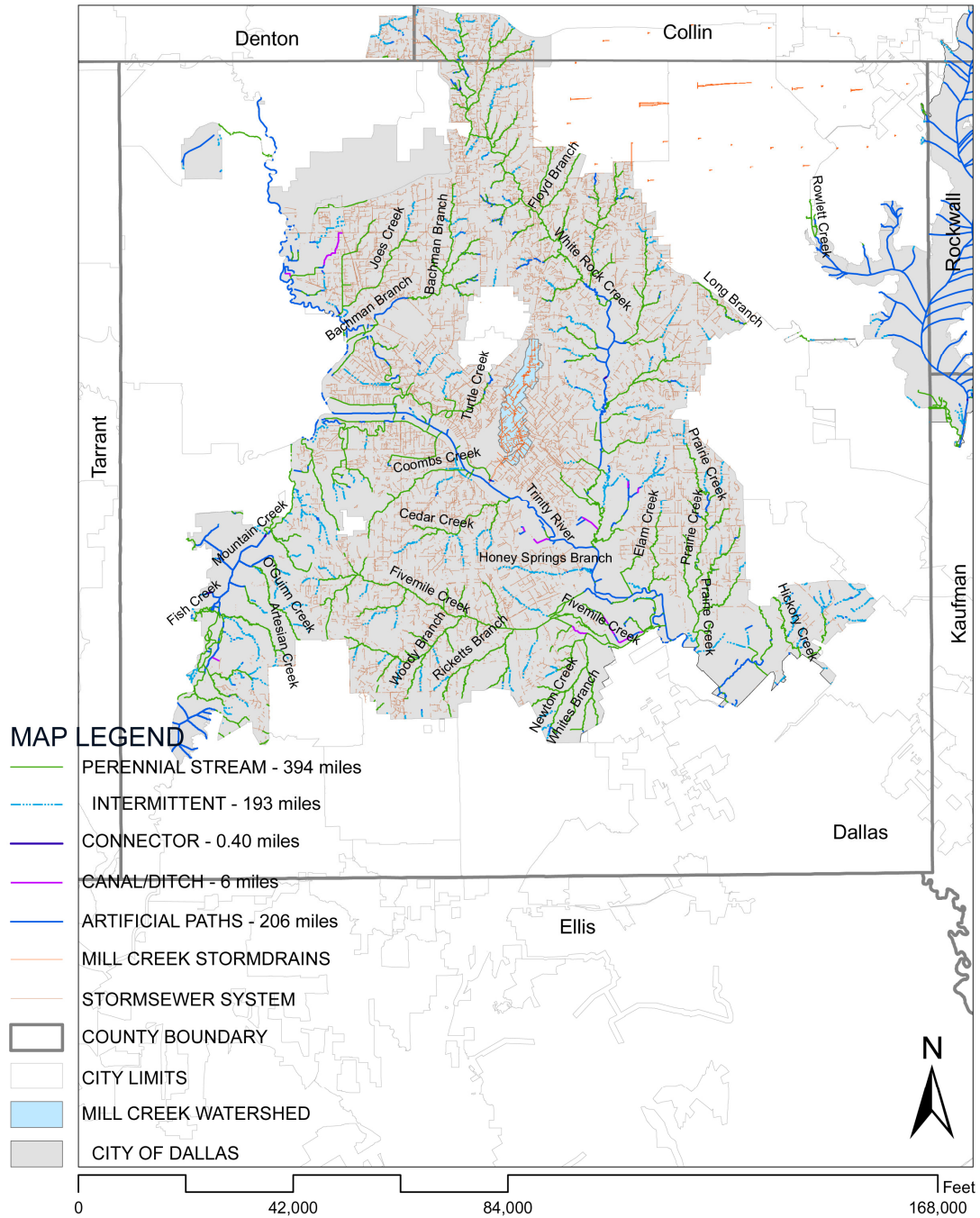


Figure 2.8 City of Dallas Water Conduits – Pipes, and Current and Historic Creeks
 ((Data Source: City of Dallas 2000))

Most of these waterways have disappeared. They have been buried in culverts, diverted and filled in during the course of urban advance.

“..., nearly all have been reduced in volume and depth by the natural silt, the annual washing down of hills, by the demands of industry for water-power, the construction of mill-dams and mill-races and bridges, the emptying of manufacturing refuse from factories, saw-pits, and tan-yards, and by the grading and sewerage necessary in the building of a great city” (Levine 2005).

Instead of addressing the source of these problems, decisions were made to bury creeks. Technological advancements have thus detached the Dallas population from nature.

The impact of the loss of small streams on ecosystem processes and stream biota is unstated. Many miles of headwater stream channels have been enclosed in pipes and culverts in urban subwatersheds across the country. Many of these streams were enclosed to eliminate floodplains, create more buildable land, or simply because that is the way things are done.

2.6 Summary

Linear corridors cutting through the urban fabric or urban framework play an important role in urban development and influence a city’s urban landscape pattern (Trancik 1986). The research on the stream restoration, presents a bleak picture of the state of our waterways. It reinforces the urgency of initiating effective steps towards daylighting or otherwise restoring streams. Restoration approaches need to be appropriate, to suit the degree of damage or deficiency for each stream. They can include varied measures and actions such as;

1. Active intervention: (physical alterations of the stream corridors).

2. Active restoration: (removal of stressors, minimizing negative human impact, bank stabilization, removal of dams, reestablishment of channel sinuosity and riparian zone).
3. Restoration and enhancement: (To make a positive impact on the ecology) (Riley 1998; Newbury, 1998).

Since 1990's, people are realizing the social, economical, ecological value of storm-water.

“. . . The notion that man can be safely shut off from nature has its problems. Many of the problems that arise within city limits would arguably not take place in other surroundings. If people were spaced out more over the landscape, there would not be as many possibilities for conflicts to erupt. I am not suggesting that we should burn our cities, abandon technological advancements, and run back into the forest. Instead, the benefits from living in a natural landscape can and should be transferred to the city itself” (Hubbard, 1994).

2.7 Urban Stream Restoration

“Living Stream” channels, rivers and other waterways are dynamic systems (Newbury 1998; CWP 2001) and provide wonderful opportunities for revitalizing cities. Centuries ago, rivers, streams were considered to be a nuisance when it came to the development and growth of a community, so they were hidden away by culverting them deep underground (Colvin 1948; Owens-Viani 1999; Pinkham 2000).

Consequently, in most parts of the country, living streams have become a primary focus of restoration efforts. Policy makers and community organizations have recognized the value of urban waterways and are working to revive them (Pinkham 2000; CWP 2001). However, while major efforts are now being mandated to improve

urban storm-water management up gradient of streams, no such directed program exists for stream restoration. Despite the fact that the stream renovation can immediately increase the water quality and reduce quantity impacts (through bank stabilization, flood storage on reconstructed floodplains, floodplain filtering) (Schueler and Brown 2004).

Riley (1998), a pioneer in the urban streams movement, details the history of the stream restoration movement in the United States from its beginnings through to the present. The emerging concept of “green infrastructure” (Benedict 2001; McMahon 2001) is not a new phenomenon. It dates back to the nineteenth century works of the visionary landscape architect Frederick Law Olmsted, and the writing of the Depression-era government in the early twentieth century on restoration techniques. Since the 1900s, sport fishing organizations in the United States have been involved in stream restoration programs. In order to investigate the cause of decline in fisheries, Congress passed the Fish Commission Act creating the U.S. Fish and Wildlife Service. Later in 1937, the Wildlife Restoration Act made federal assistance available to acquire and restore wildlife habitat. The era between the 1940s and the 1950s is called the era of concrete, since concrete was considered to be the most suitable material for construction of a project. Lately, we have realized its drawbacks for stream restoration projects (Riley 1998).

In the 1970s, the stream restoration projects in Napa, California, and Urbana, Illinois, kindled the urban stream movement throughout the country, with the goal of resurrecting hidden waterways (Pinkham 2000). Over the past decade, numerous

projects have been undertaken with the goal of restoring urban streams, and various studies are monitoring the effectiveness of a variety of different stream restoration practices (bank protection, grade control, flow deflection, and bank stabilization) (CWP 2001).

In the Dallas/Fort Worth area, the “Stream Team” is among the very few groups which offers free technical expertise and recommendations concerning methods for flood control, erosion control, stream restoration, and other types of stream corridor projects to developers and local governments. Technical staff from the U.S. Environmental Protection Agency, U.S. Army Corps of Engineers, Texas Parks & Wildlife, U.S. Fish & Wildlife Service, Natural Resources Conservation Service, U.S. Geological Survey, Federal Emergency Management Agency, and North Central Texas Council of Governments participate in the Stream Team (NCTCOG 2005). Stream corridor restoration uses a wide range of stream repair practices in order to bring back the lost appearance, structure or function of the urban living streams (Brown and Schueler 2004).

2.8 Stream Daylighting

Pinkham (2000) says “The modern era has not been kind to streams. We have redirected them with all manner of modern engineering--diverted them, straightened them, filled them in, dammed them, and rendered them unrecognizable” (p. iv). The answer, he says, is daylighting, which he defines as bringing to the surface some or all of the flow of a stream, creek, or storm-water drain previously buried in a culvert or pipe (Klesius 1999).

Stream “daylighting” is an effective way to restore, establish, enhance, and preserve (Pinkham 2000) hidden historic streams by opening up the underground drainage pipes and culverts (Mason 1999; Pinkham 2000; Brown and Schueler 2004). “Stream daylighting is moving from pure science to an engineering practice that uses and respects science,” (Matlock 2005; McGowan 2005) and has become a popular trend in urban ecology and urban planning (Wenk, William, and Gregg 1998; Mays 1999; Vernon 1999).

Despite the plethora of literature on urban stream restoration, the practice of daylighting, the most profound form of stream restoration (Pinkham 2000), remains poorly studied and described. Several researchers have suggested that the key to effective, environmentally sound water management (Mason 1999) is daylighting the surface waterways where “nothing” exists now (Pinkham 2000).

In 1984, the success of the daylighting of Strawberry Creek in Berkeley, California, became the epitome of the “daylighting movement” in urban and suburban areas. The concept of daylighting spread and various daylighting projects were subsequently carried out in the Pacific Northwest, Georgia, Illinois, and Minnesota (Klesius 1999; Pinkham 2000). Since then, numerous stream daylighting projects have been designed and constructed with various motivations and objectives including storm-water management, mitigation, education, connecting people and nature, creating wildlife habitat and improving aesthetics (Pinkham 2000). Social, institutional and technical issues and challenges are associated with reintroducing an urban stream (Pinkham 2000). Germany, Switzerland, Oregon, Delaware, and Canada are among the

places where the success of daylighting has been demonstrated (Klesius 1999; Pinkham 2000; France 2008).

2.8.1 Benefits

One major, overwhelming reason why we are
running out of water is that
we are killing the water we have
- William Ashworth 1982, *Nor Any Drop to Drink*, 145-146
(Karr and Chu 2000)

In *Nor Any Drop to Drink*, William Ashworth, an author and an active environmentalist, writes, “Children of a culture born in a water-rich environment, we have never really learned how important water is to us.”

“...ignoring the ancient lesson that a deluge is just compensation for human sins, they still build walls to contain the rivers. Yet without the endless cycle of water, human and other life on Earth would simply cease” (Karr and Chu 2000). Pinkham (2000) says the answer is Daylighting for liberating the forgotten waterways, “which have been channeled, rerouted, paved over, transformed into storm sewers, or in case of wetlands, obliterated” (Cairns and Palmer 1995). Klesius (1999) states the importance of flowing water in an urban environment. “There's psychic value to urban water, and the more urban the area, the higher the value. The functional value of daylighting and restoring the natural systems of hydrology are important and real. But there's something deeper going on; many people are discovering the deep desire to set things right that were wronged long ago. It's a radical concept, daylighting. I think it reflects how people are taking that deeper view” (Klesius 1999).

Table 2.4 points out the various intangible and tangible benefits by summarizing many case studies on stream daylighting projects in the US and internationally (Pinkham 2000).

Table 2.4 Benefits of Daylighting

<ul style="list-style-type: none">* relieve choke points and flooding problems caused by under-capacity culverts;* increase hydraulic capacity over that provided by a culvert, by recreating a floodplain;* reduce runoff velocities--thus helping prevent erosion--as a result of natural channel meandering and the roughness of the stream bottom and banks;* replace deteriorating culverts with an open drainage system that can be more easily monitored and repaired;* cost less, or only marginally more, than replacing a culvert;* divert urban runoff from combined sewer systems before it mixes with sewage, reducing combined sewer overflows and burdens on treatment plants;* improve water quality by exposing water to air, sunlight, vegetation, and soil, all of which help transform, bind up, or otherwise neutralize pollutants;* recreate aquatic habitat and improve fish passage;* recreate valuable riparian habitat and corridors for wildlife movement;* provide recreational amenities, such as a challenging new water hazard on a golf course, a place for children to play, or a streamside bench for people to relax upon;* create or link urban greenways and paths for pedestrians and bicyclists;* serve as an "outdoor laboratory" for local schools;* beautify neighborhoods, perhaps serving as a focal point of a new park or neighborhood revitalization project;* allow businesses to cut costs and increase profits while benefiting neighborhoods and the environment;* increase property values;* benefit nearby businesses by creating a new amenity that attracts people to the area;* create jobs or job-training opportunities in building and maintaining the stream or park;* build civic spirit and relationships as local residents, businesses, and governments come together to create the project;* reconnect people to nature through the look, feel, and smell of open water and riparian vegetation, and through contact with aquatic and streamside creatures;* give people a sense of "setting right something we messed up."

Source: Pinkham (2000), quoted in Lewis, 2003

2.8.2 Implications

The daylighting of living streams can occur in several ways. Various implications of creek daylighting are discussed by Brown and Schueler (2004), Pinkham (2001), Wolfe and Mason (1999). They include:

1. Architectural/ Channelized Stream: The surface of the stream is restored by opening-up an underground channel, culvert or pipe. It does not function as a stream but instead moves water in a concrete canal or a similar engineered structure. This is done in highly urbanized areas or where it is important to prevent erosion caused by upstream discharges (Pinkham 2001; Lewis 2003; Brown and Schueler 2004). There are some benefits of this daylighting alternative such as improvements in storm-water management and in aesthetic quality, water quality, and in-stream habitat. It has the same general qualities as nonsupporting streams (Brown and Schueler 2004).

A) In-stream habitat: The stream channel is still confined by hard structures, but has a scoured gravel bed typical of a natural river. Vegetation, flow deflectors, check dams and energy dissipaters are incorporated in-stream to provide habitat, aeration and to slow stream velocity by providing roughness.

B) Riparian Buffer: Natural stream banks are incorporated and emergent vegetation and streamside canopy is restored. Sinuosity has been created within the stream's course allowing pool and riffle habitat, point bars and undercut banks.

C) Best management practices (BMP's): BMP's are sited in conjunction with the daylighted channel accepting storm water discharge from the storm water/ sewer system and adjacent impervious surfaces. A wider riparian buffer of 75 feet is required at storm water outfall locations to accommodate BMP's. (Lewis 2003).

2. Naturalization: This daylighting alternative restores natural features such as stream banks, a stable streambed, and "normal" stream geometry by representing meanders, riffles, pools, and habitats. Riparians and natural wetlands are created. In this case the stream bottom and stream banks are permeable to water and are vegetated (Pinkham 2001; Lewis 2003; Brown and Schueler 2004).

3. Symbolic or Cultural representation: This symbolically acknowledges the buried streams by various options like educational or interpretive signage, tile marking

or fountains to show the path of the historic buried stream and the stream's present situation, and also provides physical and cultural information (Pinkham 2001; Brown and Schueler 2004).

2.9 Criteria

The literature details various social, economical, ecological benefits of stream daylighting. However, there are no published papers uncovered in this research dealing with the criteria to daylight streams. Most of the daylighting projects were undertaken on a “trial and error” basis, without proper hydrological, geomorphological and ecological assessment or predictors of the outcome (Buchholz and Younos 2007; Matlock 2005; McGowan 2005).

“There are underlying assumptions about daylighting, however, and they influence attitudes and decisions regarding their long-term impacts on streams” (Buchholz and Younos 2007). For example, a growing body of research shows that daylighting in an urban drainage of more than 60% imperviousness, with an objective of aquatic diversity (especially that targeting sensitive fish species), is unrealistic (Moses and Morris 1998; Schueler and Brown 2004).

Municipalities and organizations might take away financial resources from other kinds of habitat improvement with daylighting projects if they see failures in their intended objectives. So, it becomes imperative to clear up such misconceptions by evaluating the daylighting potential of the stream.

Brown (2000) selected four dimensions or attributes to include in the assessment of the function and performance of urban stream restoration practices:

structural integrity, effectiveness/function, habitat enhancement, and vegetative stability (Kitchell 2004; Schueler 2004). In some cases the water flow was measured. Then the need for space, legal and technical aspects, and other arguments were considered (France 2008). In his discussion of the possibilities of daylighting streams, Klesius (1999) listed seven parameters: available space, soil and water contamination, financial resources, safety issues, and public opinion or attitudes towards environment. Moses (2003) also listed several physical, cultural, political, economical factors along with the preferences of landowners and institutional bodies which govern the objectives and style of the restoration.

A good candidate stream for daylighting can be determined by assessing projected costs, site conditions, and even political struggles and public resistance (Buchholz and Younos 2007). A recent study by Buchholz and Younos (2007) examined nineteen completed daylighting projects selected from across the United States. Post-daylighting monitoring was explored to evaluate the predaylighting goals. Five trends were observed from the stated goals: Creation of Park Amenity, Economic Development/Flood Reduction, Ecological Restoration, Creation of an Outdoor Classroom/Campus Amenity, Residential Daylighting (Buchholz and Younos 2007).

Kitchell and Schueler (2004) have formulated an Outfalls Assessment Form (OT form) in the Unified Stream Assessment (Manual 10) to determine the best candidates for daylighting. However, the paper lacks in-depth information on the criteria for daylighting streams.

In his report on stream restoration and daylighting, Pinkham (2001) briefly listed “negative” and “positive” screening criteria for daylighting streams:

- a. “Negative” screening criteria:
 - i. extensive infrastructure and buildings over the culvert or areas of possible stream relocation;
 - ii. “capture” of streams by combined sewers (daylighting projects must divert stream water above inflows to combined sewers);
 - iii. high land values that preclude open space uses;
 - iv. steep slopes that would result in overly erosive stream velocities;
 - v. high discharge rates, due to upstream conditions (e.g. imperviousness), that cannot be managed given stream corridor constraints imposed by surrounding urban land uses; and
 - vi. sunk costs in recently culverted streams.
- b. “Positive” screening criteria:
 - i. Local support: Are neighbors, local citizen groups, and local agencies likely to actively support a project? Are any likely to oppose it?
 - ii. Funding opportunities: Are one or many angles to grants or other potential funding programs likely? Could a daylighting project at this site be an adjunct to some other existing or likely project by public or private parties with interests in development, parks, transportation, water management, or other areas?
 - iii. Technical feasibility: Are the potential technical challenges at this site likely to be manageable? Is a project here likely to be robust (unlikely to impair other values or otherwise fail)? Does a project here seem “doable?” (p.19).

Existing handbooks or guides are inconsistent and fail to document all the parameters necessary for daylighting an urban stream. By expanding Pinkham's (2001) criteria, surveying texts on stream restoration and reviews on completed daylighting projects, four broad categories of criteria were chosen in order to evaluate the feasibility of daylighting streams in an urban built environment.

1. Technical factors
2. Urban economics and politics
3. Institutional

4. Ecological

The literature review of these four categories follows. Based on these parameters, the success of an urban stream daylighting project may be determined. Following these steps may also help prepare proponents to present the project to the public and/or city officials.

2.9.1 Technical Factors

Historically, most stream restoration projects have been done from the perspective of landscape architecture or restoration ecology. As a licensed engineer and registered ecologist, Matlock is one of the few academic researchers nationwide who is qualified to design stream-restoration projects from an engineering perspective. In applying the science of ecology to engineering practice, he and his research team design natural streams that interact with people and function in an urban environment (Matlock 2005).

2.9.1.1 Land Use

One of the most vital considerations for daylighting is location (Moses 2003) because historically watercourses have been altered tremendously by human interference in urban areas “built environment” (Pinkham 2002).

a) Buffer Width: In an urban site, sufficient stream buffers are required along the channel for revitalizing the altered landscape or for greenways (Moses and Morris 1998). This will ensure that there is enough floodplain storage to reduce flood hazards downstream, promote healthy stream function (natural channel geometry and stream gradient) and sustain a properly vegetated riparian corridor (Pinkham 2000, 2002;

Moses 2003). However, just prescribing wide buffers may not be enough to significantly improve stream quality (Riley 1998; Moses and Morris 1998; Moses 2003). As a recent example of a successful buffer acquisition, a three hundred foot storm sewer culvert—once a tributary to Flint Creek in Barrington, Illinois—was daylighted on a semiindustrial site and a new wetland was created. John Heinz, public works director for the Village of Barrington, credits the success of the project to the fact that the land was confined by railroad tracks from all the sides and hence was inexpensive and unattractive to developers (Pinkham 2000). As noted before, Flint Creek, Illinois was successfully daylighted due to the undesirability of the land. The town was able to condemn the land relatively cheaply and easily because the property was surrounded by railroad lines (Pinkham 2000).

b) Distance of Unobstructed Pipe: The underground storm-water pipe will ideally travel unobstructed from surface obstructions (for example, topographic confinements (Moses 2003), buildings, roads crossings, utilities, mature forests or other land uses) and underground obstructions as they would make excavation impractical disrupts the natural hydrologic functions of channels and floodplains (Moses and Morris 1998; Schueler and Brown 2004) and Stream restoration (daylighting) and engineering solutions (culvert) can be used in combination where topographic, land use and infrastructure constraints are present in the watershed (Pinkham 2000; Halff Associates 2005). For example, high imperviousness and lack of space in the watershed of Phalen Creek, St. Paul, Minnesota, led to insufficient storm-water storage, so a new reinforced concrete culvert had to be installed (Pinkham 2000).

c) Widths of Drainage Easement or Right-of-Way: Most enclosed storm drains have an aboveground drainage easement or right of way that allows a municipality access to repair the pipes. The width of the right of way corridor is an important daylighting design parameter, as it governs how much space will be available for the new channel (Schueler and Brown 2004).

2.9.1.2 Topography and Slope

A culvert on higher-gradient stream reach can alter the channel morphology through bank widening or incision (Moses and Morris 1998; Newbury 1998), resulting in stream bank erosion due to increased volume or erosive downstream flooding. It also creates fish barriers (Ferguson et al. 1974; Moses and Morris 1998; Schueler and Brown 2004). A substantial drop between the pipe outlet and the downstream channel can be neutralized by regrading with lower angles. This can provide enhanced flood storage, flood flow conveyance, and a more natural channel appearance. Conversely, a culvert on a low-gradient area can result in channel sedimentation and aggradations deposits (Moses and Morris 1998).

2.9.1.3 Depth of Overburden

The depth of soil or overburden above the storm drain pipe is an important determinant of the cost of excavation (offsite hauling and disposal of overburden) and can make the project infeasible. Before digging the site, it is crucial to know what is underneath (Pinkham 2000; Schueler and Brown 2004). For example, in the case of Codornices Creek, Berkeley, California, there was a gas pipeline running across the

creek which had to be moved in order to create a proper channel section (Pinkham 2000).

2.9.1.4 Invert of Outfall in Relation to Stream

The difference in the stream channel elevation between the stream and invert of the outfall pipe can result in a steep stream gradient, which can require extensive grade controls in order to control the stream velocity and improve the channel geometry (Pinkham 2000; Schueler and Brown 2004). A flat slope increases the feasibility of excavating the pipe and exposing the stream to its natural condition.

2.9.2 Urban Economics and Politics

Thompson (1973), quoted in Lewis (2003), explains the imperfect measures used by The Gross National Product (GNP) which measure the nations economic welfare through totaling the value of goods and services produced by a nation;

“The Gross National Product (GNP) subtracts the costs of pollution abatement but does not accredit a market value to ecological infrastructure or the mitigation of a pollution problem. Furthermore, the manufacturing processes and consumer activity increases the GNP while directly contributing to the waste stream and pollution” (p. 51).

Thus, the GNP influences the economic considerations for daylighting projects. Further, Lewis (2003) states the cost benefits of daylighting: “Stream daylighting represents an energy efficient, environmentally responsible infrastructure that is sustainable over a long period of time and is therefore independent of fluctuations in the market economy” (Lewis 2003,).

Daylighting projects can be expensive. According to the Rocky Mountain Institute, it involves “Technical studies, design work, property acquisition, excavation

and rough grading, hauling of fill, materials for the streambed and in-channel structures, landscaping materials, hand labor for final grading and planting, and more” (Pinkham 2000, 2001). As noted, Flint Creek, in Illinois was successfully daylighted due to the undesirability of the land. The town was able to condemn the land relatively cheaply and easily because the property was surrounded by railroad lines (Pinkham 2000). Property tax revenues to the city from the redevelopment zone have increased from sixty thousand dollars to four hundred thousand dollars annually. Activities at the new festival site by the stormwater pond generate an estimated twelve million dollars annually in sales and payroll for local businesses (Pinkham 2000).

Good design, donations of services and materials, and volunteer labor can keep costs low if projects are expertly facilitated. Collaboration has been a key element in fundraising for projects of this kind (Pinkham 2000).

2.9.2.1 Increase in Property Values

There is no denying the attraction of water in the landscape. Property adjacent to water—whether a pond, lake, stream, or ocean—is often more expensive (Dornbusch et al. 1974). In recent decades, many cities have invested in waterfront revitalization projects to create commercial attractions. In many places waterfront areas have also been developed as greenways, providing opportunities for walking and biking as well as observing nature (Kaplan and Kaplan, and Ryan, 1998). Bringing streams to the forefront of development criteria and restoring them to a natural state will yield long-term economic benefits for cities and health benefits for the people (Pinkham 2002; Moses 2003; Matlock 2005; Buchholz and Younos 2007).

Many studies have found that property values increase closer to greenways highlighting the value of unprogrammed open space as opposed to recreational facilities (NPS 1995). Property values are positively influenced by the size of the restored water body, access, and community involvement in the restoration process (Dornbusch et al. 1974).

Arcadia Creek was daylighted for flood relief in downtown Kalamazoo, Michigan. Planning began in 1986 for a 13-block redevelopment project intended to attract business to the rundown portion of downtown. An important goal of the redevelopment effort was to reduce flooding by increasing the creek's capacity. Engineering studies revealed that an open channel could provide the necessary flood capacity at relatively low incremental cost over improving and reburying Arcadia Creek's aging culvert. Part of has been transformed into a festival site. Several sources cited long term economic benefits of daylighting streams. So, it becomes important to review the economic aspects of design and installation.

2.9.2.2 Comparison of Cost of Daylighting and Cost of Repairing an Aging Culvert

Daylighting becomes a cost effective solution to reduce flooding when compared to replacing an undersized or deteriorated culvert (Pinkham 2000; Owens-Viani 2000) which would otherwise produce backwater effects that result in channel sedimentation (Moses and Morris 1998).

2.9.2.3 Outfall Pipe Diameter

The most cost-effective outfall pipe candidates typically range from 24 to 60 inches in diameter. These normally drain catchments ranging from 25 to 400 acres,

depending on the degree of upstream development. Smaller outfall pipe diameters normally drain such a small drainage area that they cannot support perennial flow, and larger diameter pipes may be too expensive or constrained to daylight. Short lengths of large diameter pipes or culverts that “interrupt” two healthy reaches of perennial streams should always be investigated for daylighting (Schueler and Brown 2004). In the cases of Shoal Creek Tributary in DeKalb County, Georgia and Darbee Brook in Roscoe, New York, daylighting the streams was less costly than replacing the deteriorated culvert (Pinkham 2000) and becomes a viable solution.

Table 2.5 Costs of Stormwater Pipeline Components

Material	Cost
Median dia. 24” corrugated metal pipe	\$30.10 / linear feet
Median dia. 36” reinforced concrete pipe	\$74.40 / linear feet
Excavation of clay soil trench at 1:1 ft ratio	\$7.09 / cu.yd.
Bedding costs for trench 24” dia. x 4 ft. wide	\$8.52 / feet
Manhole 4ft. dia. x 4 ft. deep	\$1,860.00 / feet
Paving Costs:	
Prepare and roll subbase. 2500 sq.yd.	\$0.88 / sq. yd.
Base course (3” crushed stone)	\$3.39 / sq. yd.
Asphalt pavement (3” binder course)	\$5.91 / sq. yd.
Asphalt pavement (2” wearing course)	\$4.52 / sq. yd.
Curb and gutter (24” dia. concrete)	\$6.95 /linear foot

Source: USEPA, quoted in Buchholz and Younos 2007

Table 2.6 Stream Daylighting Average Cost Breakdowns by Length

Natural Restoration Small Scale = < 250 linear feet	
Average length	144 linear feet
Average cost	\$9,800
Cost/in. foot	\$68.05

Medium Scale = 250 linear feet – 1,000 linear feet	
Average length	480 linear feet
Average cost	\$48,250
Cost/in. foot	\$100.50

Architectural Restoration Large Scale = < 250 linear feet – 1,000 linear feet	
Average length	2,287 linear feet
Average cost	\$1,857,250
Cost/in. foot	\$812.09

Source: Buchholz and Younos 2007

2.9.2.5 Inclusion in a Park

Most daylighting stream projects are intended to create park amenities for human use (Pinkham 2000; Buchholz and Younos 2007). Incorporating a physically accessible park in daylighting projects makes the daylighting process much easier from a legal perspective (Pinkham 2000; Buchholz and Younos 2007). The storm-water system thus becomes an integral part of the parks and open-space network (Wenk, William, and Gregg 1998; Pinkham 2000).

This makes the entire daylighting process much easier from a legal (land tenure) view. A review of completed projects demonstrates that although the preferred outcome of many daylighting projects is to improve the environment, the reality is that most

efforts focus attention on aesthetic appeal and public enjoyment of the new waterway (Mason 1999; Pinkham 2000).

2.9.3 Ecological

“The main point here is, we have a lot of ways to meet our energy needs ...these salmon only have one river forever. If we do not support them, they will go extinct.”
-Todd True, quoted in "Agency sued over putting hydropower ahead of fish"
Seattle Post-Intelligencer, 4 May 2001

An urban water system differs largely from suburban or natural watersheds in terms of physical, hydrological, biological and water quality attributes (Pinkham 2000; Lewis 2003; Schueler and Brown 2004; Buchholz and Younos 2007). Pinkham (2000) states that “among the “doable” projects, not every one can be highly naturalized” (p. 6). According to the ICM (Imperviousness Cover Model) developed by the Center for Watershed Protection (CWP 2003), urban streams can be classified based on their stream health and future restoration potential in four categories: sensitive streams, impacted streams, nonsupporting streams and urban streams (Schueler and Brown 2004). Sufficient stream buffer or land is required in order to have a naturalized stream corridor (Moses and Morris 1998; Pinkham 2000; Schueler and Brown 2004) in an impacted or nonsupporting stream (Schueler and Brown 2004). Stream restoration projects have become increasingly common, and the need for systematic post-project evaluation, particularly for small-scale projects, is evident. This study describes how a seventy meter restored reach of a small urban stream, Baxter Creek (in Poinsett Park, El Cerrito, California), was quickly and inexpensively evaluated using habitat, biological

criteria, and resident-attitude assessments. The restoration involved opening a previously culverted channel, planting riparian vegetation, and adding in-stream step-pool sequences and sinuosity. Replicated benthic macroinvertebrate samples from the restored site and an upstream unrestored site were compared using several metrics, including taxa richness and a biotic index. Both biological and habitat quality improved in the restored area compared with the unrestored section. However, when compared with a creek restored 12 years earlier the habitat condition was of a lower quality in the recently restored creek. A survey of the neighborhood residents indicated that, overall, they were pleased with the restored creek site. The approach used in this demonstration project may be applicable to other small-scale evaluations of urban stream restorations (Purcell, Friedrich and Resh 2002).

In spite of public resistance and other technical difficulties, both the Blackberry Creek project in Berkeley, California and Cow Creek in Hutchinson, Kansas were successful in their daylighting effort. However, resulted from an increased human use and decreased flooding, not in reestablishing the original ecological function of the stream (fish passage, habitat and water quality). In Blackberry Creek, the stream banks were restored through a variety of bioengineering solutions such as gabion walls and channelization (Wolfe and Mason 1999; Lewis 2003). On the other hand, after daylighting of suburban Darbee Brook in Roscoe, New York and Jenkins Creek in Maple Valley, Washington, follow-up monitoring revealed the clear movement of fish and improvement of stream habitats for spawning salmonids (Pinkham 2000; Buchholz and Younos 2007).

Ecological improvements (e.g. bank protection, water quality) are important to make streams accessible for public use for recreational purposes (Schueler and Brown 2004). The philosophy behind many urban ecological movements is to promote an individual's role in their environment and cultivate a sense of geographic place (Lewis 2003).

2.9.3.4 Water Quality Renovation and Habitat Improvement

“Man is a complex animal; he makes deserts bloom and lakes die.”
-Gil Stern, quoted in *Texas Environmental Almanac*, 1995

The primary sources of pollutants (nutrients, siltation, metals, and pathogens) are urban area runoff, storm sewer discharges, fertilizers and land disposal of waste. This results in water quality impairment and risks to public health (Riley 1998; Paul and Meyer 2001; USEPA 2008). It is important to determine which daylighting features (architectural restoration, instream habitat, riparian buffer, best management practices (BMP's), riparian floodplain and natural wetlands) (Lewis 2003) can mitigate pollutants to improve water quality and wildlife habitat (USEPA 1995; Lewis 2003).

In order to design holistically, nonpoint source problems should be identified and tested with a number of water quality parameters. The final design must address those problems. Lewis (2003) qualitatively compares the five alternatives of stream daylighting project in order to examine their effectiveness in improving storm-water quality and sustainable habitat for urban wildlife. Stream daylighting can control the quantity and velocity of stream flow, thereby reduces habitat deterioration (Riley 1998; Newbury 1998; Moses and Morris 1998; Lewis 2003). Lewis (2003) observes that

various stream daylighting alternatives resulted in a variety of variables for water quality and habitat improvement. Out of five alternatives, BMPs and natural systems provided water quality renovation and habitat improvement, while others exacerbated water quality issues and created only marginal habitat (Lewis 2003).

Communities need the ecological services that streams provide, such as disinfection and processing of nutrients nitrogen and phosphorous. Allowing streams to perform these natural functions can decrease the extent to which cities or other local governments can have to treat water artificially, which is an expensive process (Matlock 2005).

Ken Hall, a UBC environment chemist, expresses his concern for stream habitat by writing that it will not be easy “to simply carve-out a long-buried creek and send out invitations to salmon in search of a new spawning address” (p.4) But he optimistically adds, "There's always a way to do it if there is political will with money behind it" (quoted in Kirkby 1997).

2.9.3.2 Soil Suitability

The modification of soil over the years of human habitation is typical of old established urban places. It is important to do a detailed soil survey and together geologic data before undertaking a stream daylighting project this to ensures it's suitability for riparian vegetation and determines its hydrological importance (Schueler and Brown 2004; Kitchell and Schueler 2004).

Chemical residues vary widely in urban sites, as the soil properties (pH of soil, organic matter, other ions present in solution, vegetation and rainfall) affect the

bioavailability and concentrations of contaminants (such as metals, organic matter, pesticides, nutrients and other ions) and thus their toxicity (Cunningham 1997, quoted in Williams 2001; USEPA 2005). Mike Abbaté, former principal of Green Works, a landscape architecture firm in Portland, Oregon, gives two reasons for the unfeasibility of daylighting Tanner Creek. One was the presence of century-old industrial contaminants on the site, which would require intensive soil capping. Sealing off the soil from infiltration would impair the nearby Willamette River by transporting contaminants. Second, Tanner creek was 30 feet below ground and it would require excavation and extensive gradient change which proved to be neither economical nor ecological (Abbate 2006).

Federal and state governments and other research agencies such as Natural Resources Conservation Service (NRCS) and Agricultural Research Service (ARS), have been working toward improving soil quality for many years by encouraging best management practices (BMPs). The USDA (2001) states that:

“...achievement of water quality, air quality, and carbon sequestration goals rely on improving soil quality. For example, one typical method for improving soil quality by increasing organic matter involves reducing tillage, a fundamental practice for reducing erosion. Decreasing erosion improves water quality by reducing sediment runoff. In areas subject to wind erosion, conservation tillage reduces the amount of particulate matter in the air. Thus, reducing tillage to improve soil quality also benefits erosion control, air quality, and water quality goals” (USDA 2001).

2.9.3.4 Presence of Perennial Flow

Outfall pipes usually have some dry weather flow during most of the year. It is important to make sure that the flow from the pipe is truly derived from groundwater

and not produced by an illicit discharge from an upland pollution source (Schueler and Brown 2004).

2.6.3.5 Connection with Existing Stream Network

“Outfalls are preferred if they are directly connected to the existing perennial stream network and expand the length of the stream corridor, which can eliminate fish barrier” (Schueler and Brown 2004).

2.9.4 Decision Makers

2.9.4.1 Public Support and Community Involvement

In *Landscape Architecture* magazine, Thompson (2006) describes Portland as a “leader in the design and implementation of fully functioning constructed wetlands” (Thompson 2006). Also describing Portland, Abbate reasons that “the political will is here in our part of the country to make these new landscape typologies more functional, visible, and prevalent” (2006,).

Ken Sweeney, planning and environmental manager for The Port of Port Angeles (quoted in Pinkham 2000, 38-39) suggested the importance of getting the support of the community, relevant agencies and local government in order to expedite the regulatory and planning process. This contributes to the success of daylighting projects. For instance, the daylighting of Valley Creek, Port Angeles, Washington, took longer for permitting, because of the proponent's unreasonable demand to increase the mitigation ratio (two or three times habitat ratio) in the mill pond which had a very low habitat ratio (Pinkham 2000).

In the report *Urban Stream Daylighting: Case Study Evaluations* (2007), Buchholz and Younos concluded that the finished daylighting projects were originally intended to improve the environment, but they gradually came to focus on aesthetic appeal and public enjoyment. Waterscapes have always fascinated human beings. Nearness to water is greatly preferred for its restorative effect (Pinkham 2000; Kaplan et al. 1998).

Stakeholders are becoming interested in the water features in the urban landscape. However, with people's different agendas, technical backgrounds and preconceptions can hinder efforts to get anything done (Moses 2003). Stakeholders interested in the rehabilitation of urban streams need both a profound appreciation of the nature of human alterations to urbanized landscapes and acceptance of the need to meet human objectives in these projects. Because cities and suburbs are fundamentally human habitats, it may be more important to focus on amenities than on fish habitat in many urban stream rehabilitation projects (Moses 2003).

Public resistance can be the biggest hindrance to accomplishing daylighting goals. In order to get public support, it is important to make people aware of the benefits of open water systems—of the fact that in most cities, sewers are running right below their feet which were once streams (Pinkham 2000). Communities have created “lost stream maps” to gain a better understanding of the present situation of urban waterways (Pinkham 2000). As Pinkham rightly said, “Look, if people don't even know it is there, we can't get the public support to clean it up. Daylighting would provide that. It is all about the three A's: Awareness, Appreciation, and Action” (2000,)

For instance, some the residents of The City of El Cerrito, California, were concerned about the safety issues and the preservation of the existing lawns as the city's conceptual design for the retrofitting of a storm-water drain had to change due to a small piece of land on the property that was on high slope (250 feet in length by 75 feet in width). The cross-slope height was about three to four feet creating the creek's banks and retention basins steeper and deeper than originally planned (Owens-Viani 1997). This is also a good example of how the slope (physical constraint) plays an important role or a key factor in daylighting a stream.

“Streams are not supposed to be sewers, but since they are underground, we tend to think of them that way. There is a fragile river ecosystem running beneath our town” (Klesius 1999). There is a growing concern about the deteriorating condition of urban waterways among the common people (Karr and Chu 2000).

There are common challenges faced by proposed and implemented daylighting projects. Initially, the community, including some representatives of the municipality, does not fully understand the concept and can only see the problems that a buried creek might pose if it is brought back to the surface. After these qualms are settled and a buried creek is raised, the project can begin to do what it was designed to do.

On her proposal for the “daylighting” of the Meadow Creek project, Mary Hughes (2000), director of the project and landscape architect for the University of Virginia, said she hopes the project will help the University community "reconsider the way we think about water at the University. People see storm water as a necessary evil, a product of development that you just want to get away from the site, out of your

consciousness as quickly as possible. This plan takes a different attitude -- [that] water is a resource that we should use as quickly as possible while it is on our land” (Simson 2000). This shows a change in attitude of institutions towards the waters under their sites because of daylighting.

2.10 Summary of Literature Review

The review of literature has revealed that it is important to combine the science of ecology with the process of engineering to solve complex ecological problems. Retrofit and redevelopment projects that are technically and economically feasible can improve the value and livability of the city while effectively restoring the watershed's natural functions. The technical key to doing so involves removing storm water from sewer systems and reintroducing it to the soil and vegetation. The humanistic and economic key is to integrate infrastructure improvements, community development desires, and ecosystem needs. This phenomenon is known as “daylighting”.

After expanding Pinkham’s (2001) criteria, surveying texts on stream restoration and reviewing completed daylighting projects in United States, four broad categories of criteria were chosen in order to evaluate the feasibility of daylighting streams in an urban landscape.

1. Technical factors
2. Urban economics and politics
3. Institutional
4. Ecological

These four broad categories are further sub categorized into the preliminary daylighting criteria (Appendix A) which can help in making decisions to daylight streams. Based on the above parameters, the success of an urban stream daylighting project can be determined. These steps will also help prepare proponents to present the project to the public and/or city officials.

CHAPTER 3

HISTORY OF MILL CREEK, DALLAS, TEXAS

3.1 Introduction

In Dallas' early days, Mill Creek, a tributary of the Trinity River, flowed from the Park Cities (east of S.M.U. and south of Lovers Lane, flowing southward through East Dallas), turned westward on the present Farmers Market/Old City Park, roughly following the present route of Interstate 30 along the south side of downtown Dallas before discharging to the Trinity River near the present Dallas Convention Center and Reunion Arena.

Along the Mill Creek course, Browder Springs was located a mile southeast of the Dallas County Courthouse. It became the first principal source of water for the Dallas in 1872 and at the same time City of Dallas captured the Texas & Pacific railway in Dallas area (Hazel 1952). It had attracted people of the town because it's a popular site for picnics in 1876 and it became Dallas' first public park (present Old City Park). By 1878, a waterworks system was installed on Browder Springs which was purchased by Dallas Water Supply Company (privately owned) along with two surrounding acres of land for water supply development (Hazel 1952; Prejean 2004). After a disastrous flood in 1908, the Park Board hired City planner George E. Kessler (Dallas' first city planner) to develop a city plan for Dallas (McElhaney and Hazel 1952).

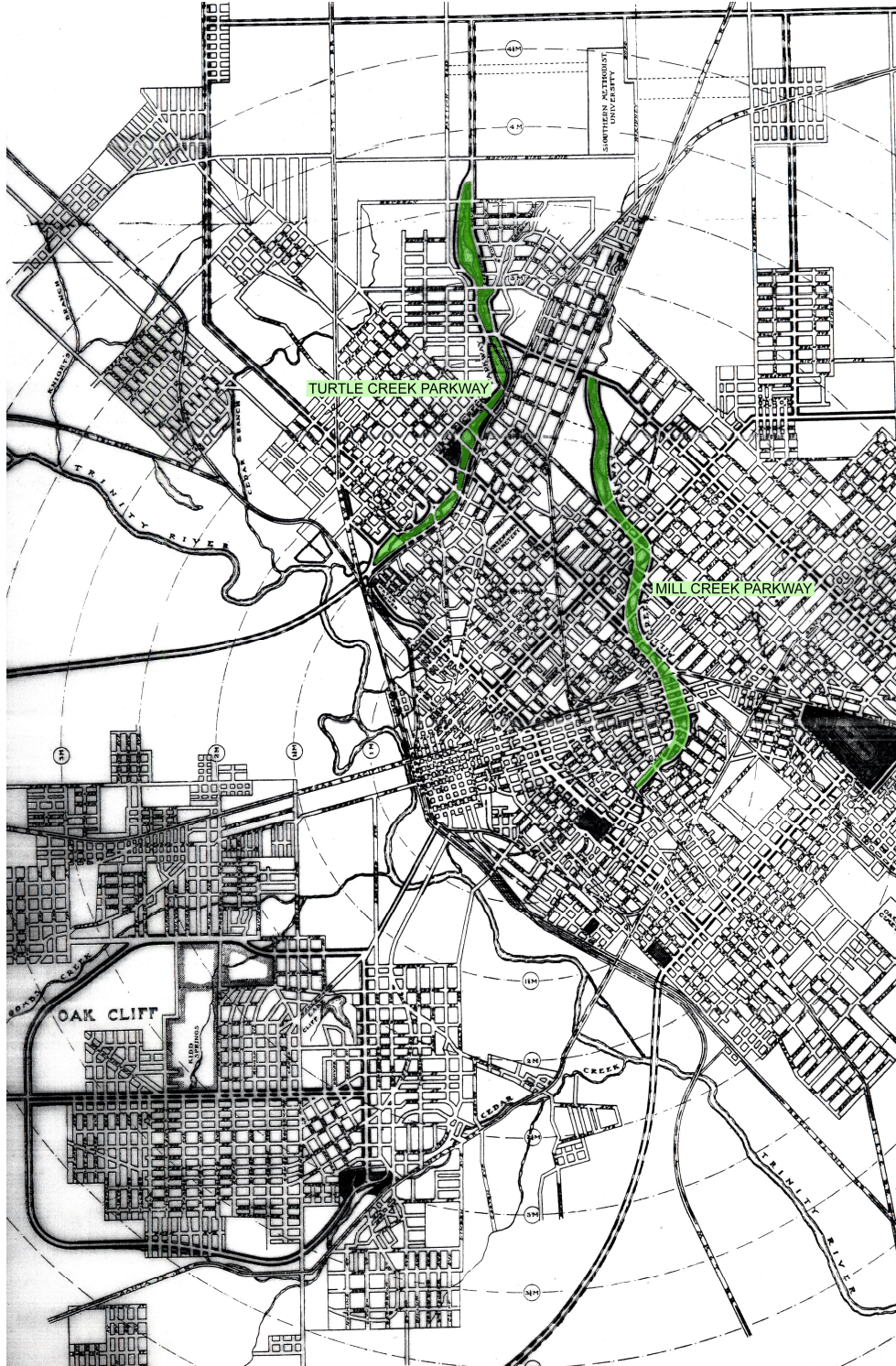


Figure 3.1 Mill Creek Parkway and Turtle Creek Parkway (1911)
Source: Dallas Public Library

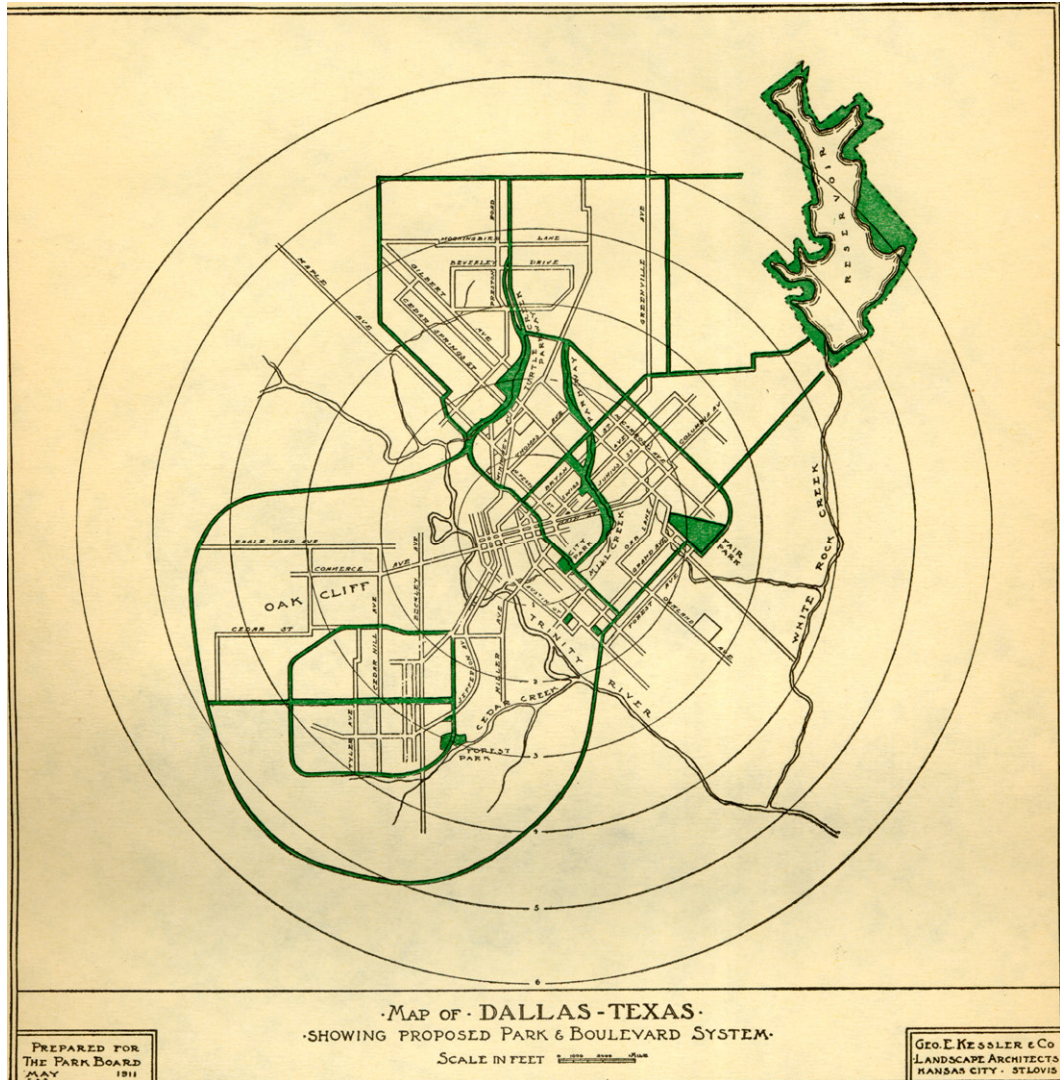


Figure 3.2 Kessler Greenbelt Plan (1911)

Source: Dallas Public Library

According to the Kessler plan, parkways were envisioned along Turtle Creek, Mill Creek, and other streams in Dallas as a part of city beautification. However, this vision was compromised in favor of the industrial needs and a decision was made in the 1930s to bury Mill Creek in underground storm sewers to drain over 3.5 square miles of East Dallas (land between Mockingbird and the Trinity River) and South Dallas which

now flows through the residential property in the upper region and dense community and industrial properties in the areas immediately surrounding Interstate 30.

In the 1950s, two diversion structure was constructed to reroute flows from the portions of the Mill Creek watershed to the Turtle Creek and Dallas Floodway Sump “A”. In 1997, retrofit work occurred on the existing Mill Creek Storm drainage system to provide diversion chambers to divert storm flow into the Cole Park Detention Facility west of the Central Expressway. The Riparian system which enveloped the creek was removed as the developing urban framework encroached on the stream periphery in the name of progress. Ever since, the creek has continued to run and exit to the Trinity River through culverts.

In an ironic situation, in 1920s, San Antonio city leaders also considered covering over their waterway as the river was subjected to flooding. Fortunately, local community opposed and succeeded in stopping the plan and with the help of the federal Works Progress Administration, San Antonio river beautification started based on Robert H.H. Hugman “dream river improvement plan” in the late 1930s (Noonan-Guerra 1978).

Today, San Antonio River has become a famed The San Antonio River Walk, an asset to the city, attracting hundreds of thousands of tourists (Noonan-Guerra 1978); on the other hand, the entire Mill Creek became the Mill Creek drainage system and is now comprised of underground conduits carrying runoff into the Trinity River.



Figure 3.3 City Park, Dallas, Texas (1910)
Source: Dallas Public Library



Figure 3.4: City Park Scene (1914)
Source: Dallas Public Library



Figure 3.5 Frame House Beside a Creek - South Preston Road
by Old City Park (1930) *Source: Dallas Public Library*

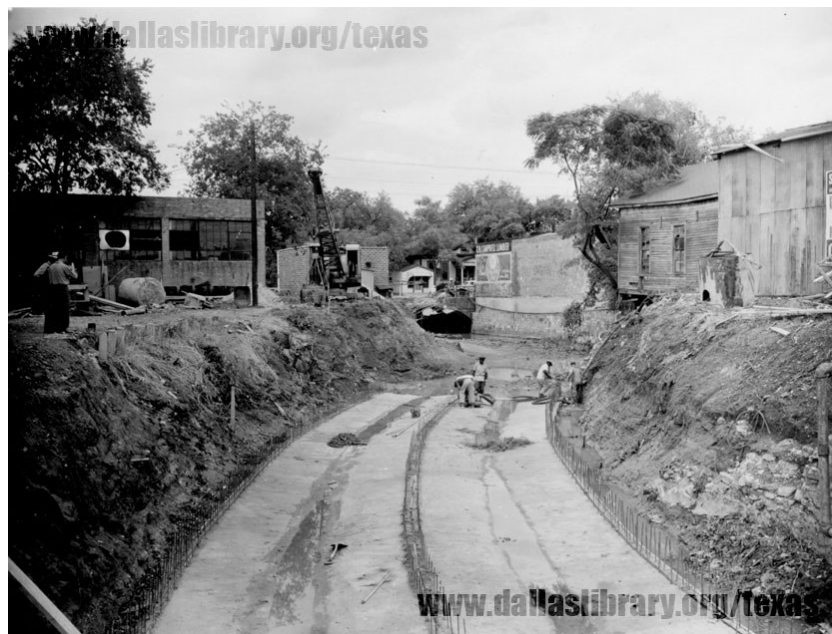


Figure 3.6 Mill Creek Stormsewer Construction (1950)
Source: Dallas Public Library

The May 5, 1995, storm flood impacted both public and private properties which include Baylor Hospital Emergency Room, Old City Park historic structures and their contents. The IH-30 closed due to high water and Sump A flooded over Industrial Boulevard with loss of life. Throughout the watershed, excessive storm-water runoff turned rainstorms into raging floodwaters. In parts of Dallas, the rainfall intensity exceeded the 100-year frequency event, completely overwhelming many storm sewer systems, channels, creeks, and other drainage facilities. In order to determine alternative storm drainage solutions a Mill Creek Master Drainage Plan study was conducted by the City of Dallas.

3.2 Ongoing Stormwater Improvements in Mill Creek Watershed

3.2.1 Current Storm Drainage System and Constraints

In the Mill Creek Master Drainage Plan Study, a Hydrologic Storm Sewer Design (HSSD) model was used to develop the hydrology for this study. Using this model, peak runoff from each subbasin, flow exchange between street and sewer system, storm duration, depth, and surcharge-induced inundation of low lying areas were computed. The study resulted in watershed-wide storm water Comprehensive Management Plan with nonstructural and structural flood control options.

3.2.2 Alternatives

Initially, several infrastructure options “Storm sewer relief systems”, “Pressure sewers”, “Underground detention”, and “Creek restoration” were evaluated to provide 100-year flood protection in the Mill Creek watershed. The evaluation criteria for discarding the single alternative were estimated cost, maximize flood control; ability to

be independently phased in construction; impact to thorough fare traffic; reduction in volume to Sump A .

Many of the alternatives with combined options were then studied. Four Combined Alternative Strategies were developed by the City of Dallas and Half Associates to improve the main trunk capacity and/or reducing peak flows in the Mill Creek drainage system. These four alternatives included different combinations and applications of Storm sewer relief systems, Pressure sewers, underground detention and creek restoration which were based on using specific infrastructure options in different segments of the basin.

CHAPTER 4

RESEARCH METHODS AND DATA ACQUISITION

4.1 Introduction

The overriding objective of this research was to evaluate the proposed Mill Creek Project, using the Preliminary Daylighting Criteria (Appendix A) to determine feasibility for its daylighting. The literature review yielded a list of recommended criteria for deciding to daylight streams. The list is labeled Preliminary Daylighting Criteria (Appendix A). However due to lack of literature on stream daylighting, key daylighting experts' interviews have been used to revalidate the list of Preliminary Daylighting Criteria. Review and enhancement of the preliminary criteria are needed to assure viability and integrity of daylighting the Mill Creek in view of different geographic location and hydrologic, political, and/or regulatory contexts within Dallas, Texas. Accordingly enhanced daylighting criteria are formulated after analysis and review of interviews, and Mill Creek study results using Geographic Information Systems (GIS). Data acquisition includes primary research through phone interviews and e-mail correspondence with city officials and stream daylighting experts, and secondary research through review of The Mill Creek Master Drainage Plan, reports and Internet research.

For the purpose of this research, qualitative approaches of content analysis, in-depth interviewing and review of the completed projects have been conducted.

Because the literature was inadequate, it was determined that the best way to gather information on the feasibility of daylighting streams was by interviewing experts involved in the daylighting projects. The interviews brought out a full range of perspectives about the daylighting of streams (Bodgan and Taylor 1994). Eight interviews were conducted either in person, via telephone, or e-mail. A variety of projects with differing designs have been considered to examine the concept of stream daylighting. These projects are summarized in Appendix A.

4.2 Research Design

4.2.1 Preliminary Daylighting Criteria

In order to create a list of preliminary daylighting criteria, a review of relevant literature, encompassing a wide range of disciplines are needed. The criteria are a set of parameters to be used to evaluate the possibility of daylighting a creek. These criteria for daylighting streams have been developed through a review of completed daylighting projects in the United States and by reviewing several texts on daylighting streams and stream restoration. The literature review includes references of relevant journal articles, local newspaper stories, magazine articles, Web sites and stream restoration agency manuals. From these sources, a matrix of salient characteristics of fifteen completed daylighting projects in United States has been prepared (Appendix A). Characteristics are basic information about these projects such as location, length of daylight segment, stated goals, land use characteristics, hydrologic and hydraulic study of the watershed, topography and slope study, ecological study, project cost, and various decision makers.

4.2.2 Project Review Selection

The concept of creek daylighting is examined through the analysis of various completed projects; however, no single project answers all the research questions. Pinkham (2000) and Buchholz and Younos (2007) are the main sources for the review of the completed projects in the United States. These projects are summarized in Appendix A. The projects have been selected on the following basis:

1. The projects provided a balanced representation;
2. These are projects that have data available regarding budgets, sizes, and objectives; and
3. The projects are considered to be the most successful according to the literature.

4.2.3 Content Analysis for Criteria Selection

Marshall and Rossman (1989) explain, “Content analysis is a process for making inferences by objectively and systematically identifying characteristics of messages...the major point of content analysis however, is that it allows researchers to analyze systematically some dimensions that appear in written form” (quoted in Henderson 1991, p. 95). Textual analysis or hermeneutics looks for “...patterns and understanding within texts that have been written. It is a method grounded in experience and emphasizing meaning. As in the other methods, it utilizes similar qualitative techniques for data discovery and interpretation” (Henderson 1991). Hermeneutics analysis is used in the literature review to find different parameters under which a stream can be daylighted or not. A list of Enhanced Daylighting Criteria was then

formulated after analysis and review of interviews and Mill Creek study results using Geographic Information Systems (GIS).

4.2.4 Data Acquisition and GIS Process

For concluding the spatial analysis of Mill Creek watershed, Geographic Information System (GIS) has been used. As the data for Mill Creek watershed are compiled from different sources, those data are available in the geographic information systems. The GIS helped to eliminate the cumbersome review of maps with different scales, and it accelerated the site-analysis process because data can be layered for analysis in geographic information system. GIS allows for overlapping the historic path of the creek with present land use, slope classes, and other screening parameters for site analysis.

In order to understand the site condition of the Mill Creek watershed, spatial data are compiled using the City of Dallas Storm Water Management Geographic Information System (GIS) database and Halff Associates' geographic information system database for the Mill Creek watershed. The data layers gathered from the City of Dallas Storm Water Management Geographic Information System (GIS) database are land use, soil, topography and slope, thoroughfare, Mill Creek watershed boundary, existing storm-water pipe dimensions, estimated flow rates, flood-prone areas, and low-lying areas of the watershed have been collected from Halff Associates geographic information system database. The historical Mill Creek path has been divided into four segments based on land use and urban conditions (Figure 5.17). Through the

preliminary daylighting criteria developed from the literature review, these factors contributed to the site analysis.

The historic maps of Mill Creek, Dallas, Texas, were collected from the Dallas Public Library and later the streams of City of Dallas were digitized in Arc View GIS 9.2 as the streams data layer in digital form from the City of Dallas could not be retrieved. This effort was made to see the old path of Mill Creek, along with other historic streams which are now buried. Figure 2.6 shows the current stream condition of Dallas, Texas.

4.2.5 Interview with Key Informants

An open-ended, standardized interview method used “...the exact wording and sequence of questions for each interview although the interviewee may respond in whatever way she/he wishes” (Henderson 1991, 73). The “...assumption in these interviews is that the researcher already has a sense about the types of information that is to be discovered” (Henderson 1991, 74).

Initially fifteen key experts were contacted via e-mail and asked if they would like to participate in the interview for research purposes. For this study, interviewees were selected from references in literature, as well as inquiries from professional whom they considered important sources. A brief explanation of the research was provided in the e-mail. Upon agreement, time and locations have been set for a face to face interview. Where face-to-face interviews were not possible, a telephone interview was conducted. Out of the fifteen experts contacted, eight agreed to be interviewed. Two out of the nine are e-mail replies as the subjects have been comfortable in responding to

the questions through e-mails, which limited scope for the follow-up questions. Two sets of interviews were conducted during 2008. Key informants (interviewees) have been divided in two groups.

Group 1

Stakeholders, public agencies and professionals involved in the implementation of completed projects were interviewed. A set of open-ended interview questions was used to seek the following information:

1. The key parameters considered before daylighting a stream.
2. Who was involved in the decision-making process on daylighting?
3. When is a combination of strategies pursued? (Partial daylighting)
4. Decision on which parts to leave buried and which to resurrect.

Group 2

The lack of documentation of stream daylighting presented the opportunity to interview local professionals to find their views on the daylighting of Mill Creek. The professionals who are familiar with and involved in the proposed Mill Creek daylighting have also been interviewed. They are from different backgrounds but connected with landscape architecture. They have worked in stream restoration projects and not necessarily daylighting streams.

The objectives of the interviews were

1. To seek their views on daylighting streams.
2. To determine who (professionals, political agency, organizations, public) favors the idea of day lighting.

3. To examine if there is a lack of daylighting streams in Dallas, Texas.
4. To determine what political motivations are needed for daylighting Mill Creek.

The criteria for selecting the interviewees were

1. Their position within a relevant professional society or organization.
2. Their knowledge, experience and understanding of the subject matter and issues explored in this study.
3. Recommendations by professional landscape architects of their peers who are articulate spokespersons about their point of view.
4. Their willingness to contribute to this study.

The interview questions (Appendix A) were chosen for the interview process based on the literature found on stream daylighting issues, trends, and challenges, along with reviews of case studies of completed daylighting stream projects. The interviews were taped and later transcribed. These transcriptions can be found in Appendix C.

4.1.6 Study Participant

Group 1

Jorgen Blomberg, MLA, an Associate Principal, a Creek Restoration Team Coordinator at Philip Williams & Associates, San Francisco, CA. He is a Landscape Designer and an environmental hydrologist specializing in creek and wetland restoration projects.

Jim Figurski, ASLA, CLARB, LEED®, Principal of GreenWorks, PC. He is a Technical Director and a Principal at GreenWorks. He has over twenty years of professional experience: eleven years in parks and recreation planning, community involvement, design and project management.

A.L. Riley, Ph.D, is the watershed and river restoration advisor for the San Francisco Bay Region Water Quality Control Board, Oakland, CA. She is regarded as a national expert in the field of river restoration.

Group 2

Robert Prejean, AICP, an urban and regional planner and economic analyst in the Dallas-Fort Worth area with more than sixteen years of experience in planning, design and project management. Currently, he is working as a senior planner with Wilbur Smith & Associates in Dallas, Texas. His work today mostly focuses on comprehensive plans and comprehensive planning ranges from small community plans to regional planning and analysis.

Richard Westsmith, P.E., Vice President of Halff Associates, Richardson, Texas. He is a hydraulic engineer by background. He has been working in the firm for about twenty nine years.

Jack Tidwell, AICP, Manager of Environment & Development in North Central Texas Council of Government (NCTCOG). He has been employed with NCTCOG for about eighteen years.

Yogesh Patel, P.E., a Senior Engineer/Project Manager in the Public Works Department (PWT) in the City of Dallas. He has been working with the City of Dallas for over twenty three years.

James Pratt, FAIA, an architect based in Dallas, Texas. He is the principal of the firm James Pratt Architecture / Urban Design, Inc. His principal areas of practice are urban design, architecture, historic preservation and interiors.

4.3 Limitation

This research establishes preliminary criteria for daylighting streams in United States through an examination of completed daylighting projects review and the surveying several texts on daylighting streams and stream restoration. Much is known and has been written about stream restoration. However, much less is published about stream daylighting.

The information concerning daylighting projects featured in periodicals, newspaper and Web sites seem too frivolous to qualify as an academic or professional database. The reports are notable for their inclusion of technical aspects of construction, anecdotal descriptions about habitat restoration and water quality improvement but without applying an established method of analysis for a prerestoration and postrestoration review.

4.4 Delimitation

The scope of the study was delimited in a number of ways. Subjects from Group 2 were restricted to professionals who are well aware of the Mill Creek watershed in Dallas, Texas. Other professionals, who are doing stream restoration projects in the city and not daylighting, could have added a different perspective to the topic.

There is no completed project on daylighting streams found in Dallas, Texas. Also, there is no case study found which is similar to the geographic, hydrologic, political, and/or regulatory contexts within Dallas, Texas. So the review done on the completed stream daylighting projects were based on secondary data, primarily the book by Pinkham (2000).

4.5 Summary

Preliminary daylighting criteria were synthesized based on review and analysis of available literature and information. The results of the analysis of interviews and correspondence with city officials and daylighting experts and a comprehensive spatial inventory and analysis of Mill Creek using Geographic Information Systems were used

to test the preliminary daylighting criteria in order to ascertain the viability of daylight
Mill Creek.

CHAPTER 5

INTERVIEWS, SPATIAL INVENTORY AND ANALYSIS

5.1 Introduction

The enhanced eligibility criteria for Mill Creek were developed in two steps. First, the preliminary daylighting criteria (Appendix A) were synthesized based on review and analysis of available literature in Chapter Two. Secondly, the proposed Mill Creek project was evaluated against preliminary daylighting criteria using interviews and enhanced eligibility criteria for daylighting Mill Creek, Dallas, Texas (Appendix D) was then developed. Then spatial inventory and analysis was performed using Geographic Information Systems (GIS) to test Mill Creek achieved “design criteria” eligibility for daylighting or not. The spatial inventory and analysis and interview data analysis were discussed in the following enhanced eligibility daylighting criteria of Mill Creek, Dallas, Texas.

5.2 Enhanced Eligibility Daylighting Criteria of Mill Creek, Dallas, Texas

5.2.1 Historic and Cultural Perspectives

Interestingly, the historic and cultural significance of the creeks were not specified as daylighting criteria in any of the completed daylighting projects in the United States. From *Group Two*, two out of five experts pointed out the historical value of the Mill Creek as one of the important criteria for daylighting.

“Mill Creek is the one creek that has always flowed in the olden times and it never stopped even in the drought. The springs that fed it were that strong that mills could be put on it so that they could run them around. Other creeks in Dallas dried up in drought times but this one did not. That’s why it is called Mill Creek” (Pratt 2008).

Ar. James Pratt stresses the history of Mill Creek;

“... If you get into history of creeks, Mill Creek is a very good one to talk about because it was gradually changed from the open creek to the current condition. Originally, water from the Mill Creek was pumped to Harwood at Main Street to the standpipe to flow out to the city in the 1880s and gradually it was closed up. It was very famous in the sense that Browder Spring fed Mill Creek and Old City Park and it was the criterion for the Texas and Pacific railroad through North Texas. A legislator wrote the law that permitted the railroad to come and it had to cross the Trinity River within so many feet of Browder Spring. Nobody knew where Browder spring was. But that’s a part of Old City Park so that was an important milestone. It provided the location for the first bottling works for the city that sold bottled drinks. It provided the first location for Fair Park...It also provided a location for a meat processing plant when there was no such facility in Dallas and it needed water to clean the meat...When the city wanted to assemble troops to go to the Civil War they chose a site along Mill Creek to assemble the troops so that they would have water...Mill creek was the border for the eastern hardwood forest surrounding downtown Dallas and big black land prairies to the east of the city in the olden times. It was border between the two” (Pratt 2008).

Mr. Prejean expressed a strong opinion about the historical value of Mill Creek. He called Mill Creek an “historic legacy” of Dallas. Further, giving an example, he said “there was Browder Spring along Mill Creek in Old City Park...” Browder Spring, a natural spring, was a source of drinking water for the city of Dallas until 1888 (Hazel, 1952). Also in 1872, Browder Spring “...was used as a reference point in getting the Texas & Pacific Railroad line through Dallas back in 1872...Certainly in the legislature, no one knew where the Browder Spring was...later the city officials realized what

happened. Nevertheless, it played a very important role in establishing Dallas as the important transportation and economic center in the north-central Texas growth...It's a shame that it got buried" (Prejean 2008).

5.2.2 Technical feasibility

5.2.2.1 Land Use

The eight experts involved in daylighting stream projects interviewed have stressed that site location and land availability are the key requirements to daylight a stream. Ms. Riley, who has been involved in daylighting and stream restoration projects for over twenty-five years, writes about availability of "width of drainage easement or right-of-way" as one of the essential criteria to decide which streams to daylight.

There should be enough width to enable a real functioning stream to be restored. This means that there needs to be enough width or right of way for the active (or bankfull) channel an adequate meander belt to accommodate the historic sinuosity (the actual historic platform does not need to be restored but the channel length should be restored...the right-of-way should also accommodate enough space so that there won't be flooding issues by allowing a natural—again functional—dense vegetative growth. (Ann L. Riley, 2008, e-mail message to the author)

Spatial data from the GIS analysis suggest that nine miles of primary creek channel is thought to have existed in the Mill Creek watershed before the stream was buried (Figure 5.5). Today, however, no exposed creek segment exists in the Mill Creek watershed. Citywide, an estimated 700 miles of historical creek may have once flowed through Dallas until the late 1800s (Figure 2.7).

The Mill Creek watershed is now primarily comprised of residential property in the upper region ('M' Streets to Henderson). Commercial and Institutional zoned land is found in the lower middle Region (Exall Park to Interstate 30). Industrial and commercial properties are found in the lower region, immediately surrounding Interstate 30. Some vacant lands are typically found between industrial pockets and commercial land use near Interstate 30 (Figure 5.2).

Notable landmarks (Lynch 1960) in the Mill Creek watershed include Baylor Hospital, which is now the cornerstone of a huge healthcare complex and which occupies a prominent height above the adjacent commercial development upstream of Deep Ellum (Figure 5.2). Old City Park, now a thirteen-acre museum of the architectural and cultural history of the North Texas (Handbook of Texas Online) is in the lower region of the watershed. Interstate 30 and Interstate 75 define the western man-made edge (Lynch 1960), and the Trinity River creates a natural southern edge (Lynch 1960) in the watershed.

Open space/Parks/Pedestrian access—There are no significant open spaces or parks in the Mill Creek watershed. In the Mill Creek watershed, streets tend to be the predominant public space, in addition to a few fragmented parks (Cochran Park, Exall Park, Samuell Park). The largest footprints reflect residential, commercial, and industrial construction. Several disjointed trail grids exist in the Mill Creek watershed. Interstate 30 and the industrial sites separate Old City Park from the residential community (Figure 5.3).

LOCATION PLAN

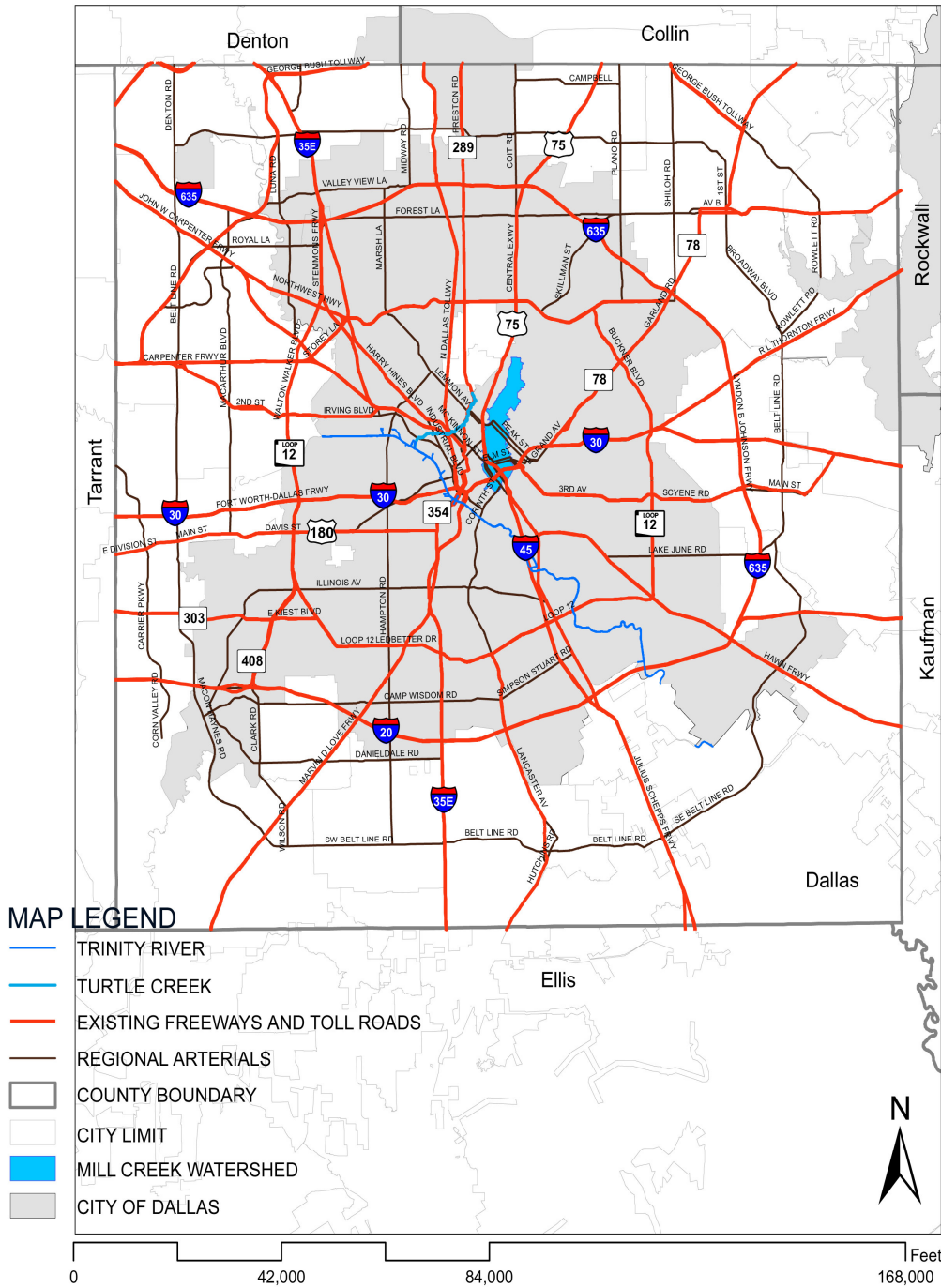


Figure 5.1 Location Plan of Mill Creek Watershed
 ((Data Source: City of Dallas; North Central Texas Council of Government 2000))

LAND USE

- MAP LEGEND**
- SINGLE FAMILY
 - MULTI FAMILY
 - MOBILE HOMES
 - GROUP QUARTERS
 - OFFICE
 - RETAIL
 - HOTEL MOTEL
 - INDUSTRIAL
 - INSTITUTIONAL
 - TRANSPORTATION
 - AIRPORT
 - RUNWAY
 - UTILITIES
 - WATER
 - EXPANDED PARKING
 - PARKING GARAGE
 - PARKING (CBD)
 - FLOOD CONTROL
 - LANDFILL
 - PARKS AND RECREATION
 - VACANT LAND
 - UNDER CONSTRUCTION
 - MILL CREEK STORM DRAINS
 - MILL CREEK WATERSHED

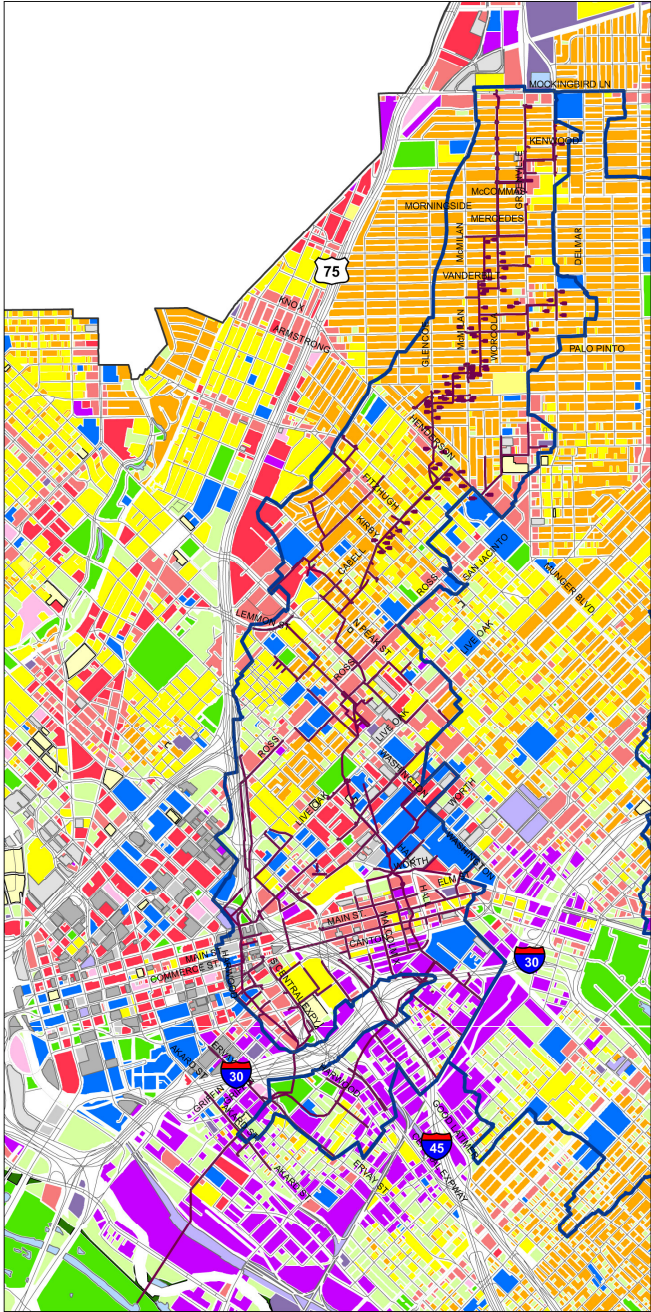


Figure 5.2 Mill Creek Land Use
 ((Data Source: City of Dallas; Half Associates 2000))

EXISTING AND PROPOSED DEVELOPMENTS

MAP LEGEND

- MILL CREEK WATERSHED
- MIXED USE DEVELOPMENT
- LANDMARKS
- BIKE TRAIL
- + + + RAIL LINE (2008)
- MILL CREEK STORM DRAINS
- ~ TURTLE CREEK
- PARKS
- TRINITY RIVER
- REGIONAL ARTERIALS
- MINOR ARTERIALS
- STREETS
- HASKELL CROSS TOWN CONNECTION
- PEGASUS PROJECT
- ~ BAYLOR BOULEVARD
- ~ FAIR PARK LINK
- TRINITY RIVER PARKWAY
- ~ OLD CITY PARK RELIEF STORM SEWER
- PRESSURE SEWER
- ~ CREEK RESTORATION
- RELIEF STORM SEWER



Figure 5.3 Existing and Proposed Developments in Mill Creek Watershed (Data Source: Half Associates 2005; North Central Texas Council of Governments 2008)



Figure 5.4 Glencoe Street – Looking North from North Henderson Avenue, Dallas, TX
Source: Google Earth 2008



Figure 5.5 North Peak Street – Looking NorthWest from Live Street, Dallas, TX
Source: Google Earth 2008



Figure 5.6 Fuqua Street – Looking NorthEast from Fitzhugh Avenue, Dallas, TX

Source: Google Earth 2008



Figure 5.7 Ross Avenue – Looking SouthWest in Vicinity of North Peak Street,

Dallas, TX. Source: Google Earth 2008



Figure 5.8 Southern Corner of Exall Park, Dallas, TX



Figure 5.9 SouthEast Corner of Exall Park –Looking towards Baylor University Medical Center, Dallas, TX



Figure 5.10 Baylor University Medical Center – Intersection of Worth Street and Hall Street, Dallas, TX



Figure 5.11 Looking towards Baylor University Medical Center Emergency Room – Intersection of Worth Street and Hall Street, Dallas, TX



Figure 5.12 - SouthWest Corner of Old City Park, Dallas, TX
Source: Google Earth 2008



Figure 5.13 – Looking towards Samuel Beaumont Park on Beaumont Street, Dallas, TX



Figure 5.14 – Interstate 30 – Looking Down on South Ervay Street, Dallas, TX



Figure 5.15 – South Ervay Street – Looking towards Downtown Dallas, TX

“Developers have shown interest in enhancing the area in Deep Ellum adjacent to Hall Street by incorporating a creek restoration project or surface detention project in this segment of the watershed. This enhancement would offer open space as well as reducing downstream flows due to the detention” (Halff Associates 2005, p. 37).

5.2.2.2 Slope

Jorgen Bloomberg, who has been involved in creek and floodplain restoration, gives an example of a stream restoration project which is in a very steep location (6 to 9% slopes). He further adds,

Daylighting work can occur in just as creek restoration in any type of systems...we do creek restoration, creek enhancement designs that are very steep...we are working with the University of California, Berkeley right now in botanical gardens on a creek restoration project and not a daylighting project but the profile of that stream is in the order of 9%. It is in a very steep upper watershed section in a redwood growth. So we are looking to develop some significant cascade and step pool features to help stabilize the stream. And my feeling is that if the stream had been in a pipe under the same conditions we probably could have removed that pipe and developed an appropriate stabilized design to daylight as well.

He also points out that “there is probably a point from an engineering perspective and cost benefit perspective it may not be feasible to daylight a creek over a certain slope profile.” Riley also consider slope as less essential criteria for a stream daylighting project. “Acceptable side slopes up to grade can vary from 1:1 to 3:1 or more. There is no reason you can not have vertical side slopes if it is designed well into the site and is safe” (Ann L. Riley, 2008, e-mail message to the author).

TOPOGRAPHY AND SLOPE

MAP LEGEND

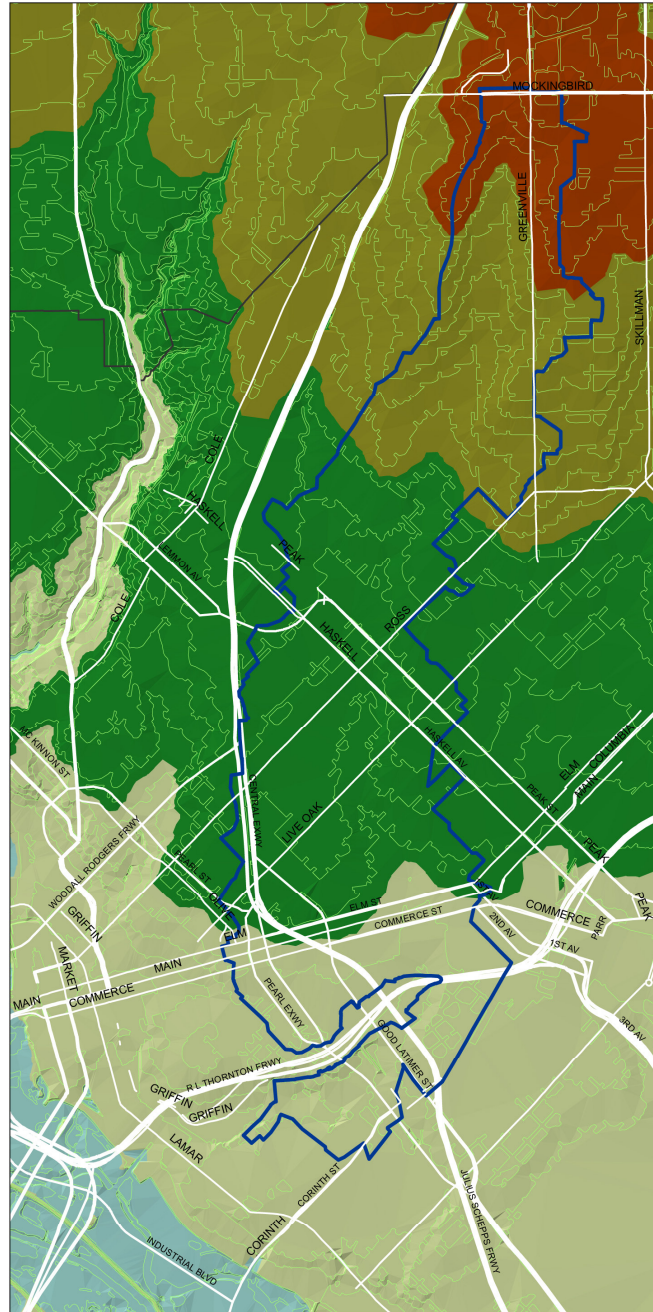
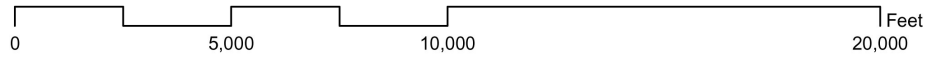
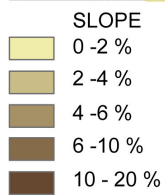
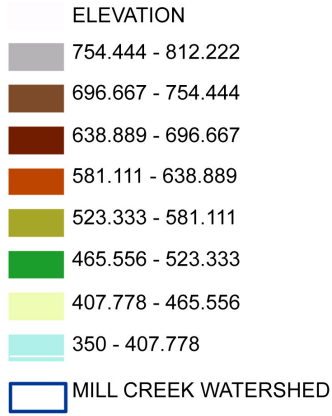


Figure 5.16 Topography and Slope
 (Data Source: Texas Natural Resources Information System, Austin, TX 1999)

5.2.2.3 Hydrology and Hydraulics

Mr. Firguski, who has been actively involved in daylighting projects in Portland, Oregon, posed a significant question which should be considered for daylighting streams: “If the stream has been piped underground, is there still sufficient water within the pipe to recreate a surface stream? Often storm water is diverted through other pipes and systems depleting or even completely negating the original flow” (Firguski 2008). Mr. Westsmith has also mentioned that stream flows are perennial or seasonal pattern should also be considered as a significant factor before daylighting a stream (Westsmith 2008).

5.2.2.4 Mill Creek Storm-Water Collection System

The Mill Creek system collects storm-water runoff from an approximately 3.5 square mile area of East Dallas (Pratt 1992). The area includes land between Mockingbird Lane and the Trinity River, as shown in Figure 5.2. This underground collection system routes its storm flow from Mockingbird Lane to the Trinity River and discharges to an outfall structure, the “Bellevue Pressure Sewer” at Bellevue Street just south of Lamar Street. The existing Mill Creek storm drain system is comprised of storm sewers; approximately 90 different laterals feeding into the trunk, 5500 linear feet of curb inlets, 1000 square feet grate inlets, box culvert, Horseshoe Storm Sewer, Horseshoe Pressure Sewer with approximately 28 miles of pipe, ranging in size from 30 inches to 192 inches diameter (Halff Associates 2005).

In Dallas, during a 100-year storm event, 7000 cubic feet per second (cfs) of peak stormwater discharge is generated by the Mill Creek watershed. However, with the

existing Mill Creek drainage system, 2000 (cfs) discharges into Interstate 30 resulting flood depth of more than six feet. The Belleview pressure storm sewer starts at the intersection of Ervay Street and Belleview Street and continues along Belleview Street to the Trinity River and is designed to discharge a capacity of about 2400 (cfs), which leads to surface ponding upstream. The water surface elevation at the Trinity River is 399.91 Mean Sea level (MSL) which is five feet higher than the lowest inlet elevation located south of Interstate 30 near Old City Park. This configuration causes back flow from the Trinity River to the Sump A . The effect of the above under-capacity storm sewer system was evident in the 1995 flood. There were thirty-nine reports of properties flooded including Old City Park building, Baylor Emergency Room and Interstate 30 and those were closed for several weeks. The properties damage was estimated at five million dollars (Halff Associates, 2005).

The Mill Creek watershed is highly impervious with land uses roadways, rooftops, parking lots. Polluted storm water is piped and dumped into the Trinity River. Water flowing directly into the Trinity River has some opportunities to be naturally filtered. However, for the most part, there is little natural buffer between the urban hardscape and the Trinity River. The impervious surfaces are too dense to absorb water and the pollutants are deposited directly into the waterway.

5.2.2.5 Invert of Outfall in Relation to Stream

The difference in the stream channel elevation between the stream and invert of the outfall pipe can result in a steep stream gradient, which can require extensive grade

HYDROLOGY

MAP LEGEND

- MAJOR ARTERIALS
- EXISTING FREEWAYS AND TOLL ROADS
- ▭ MILL CREEK WATERSHED
- MINOR ARTERIALS
- HISTORICAL PATH OF MILL CREEK (1890's)
- STREETS
- ▭ MILL CREEK STORM DRAINS
- ▭ PARKS

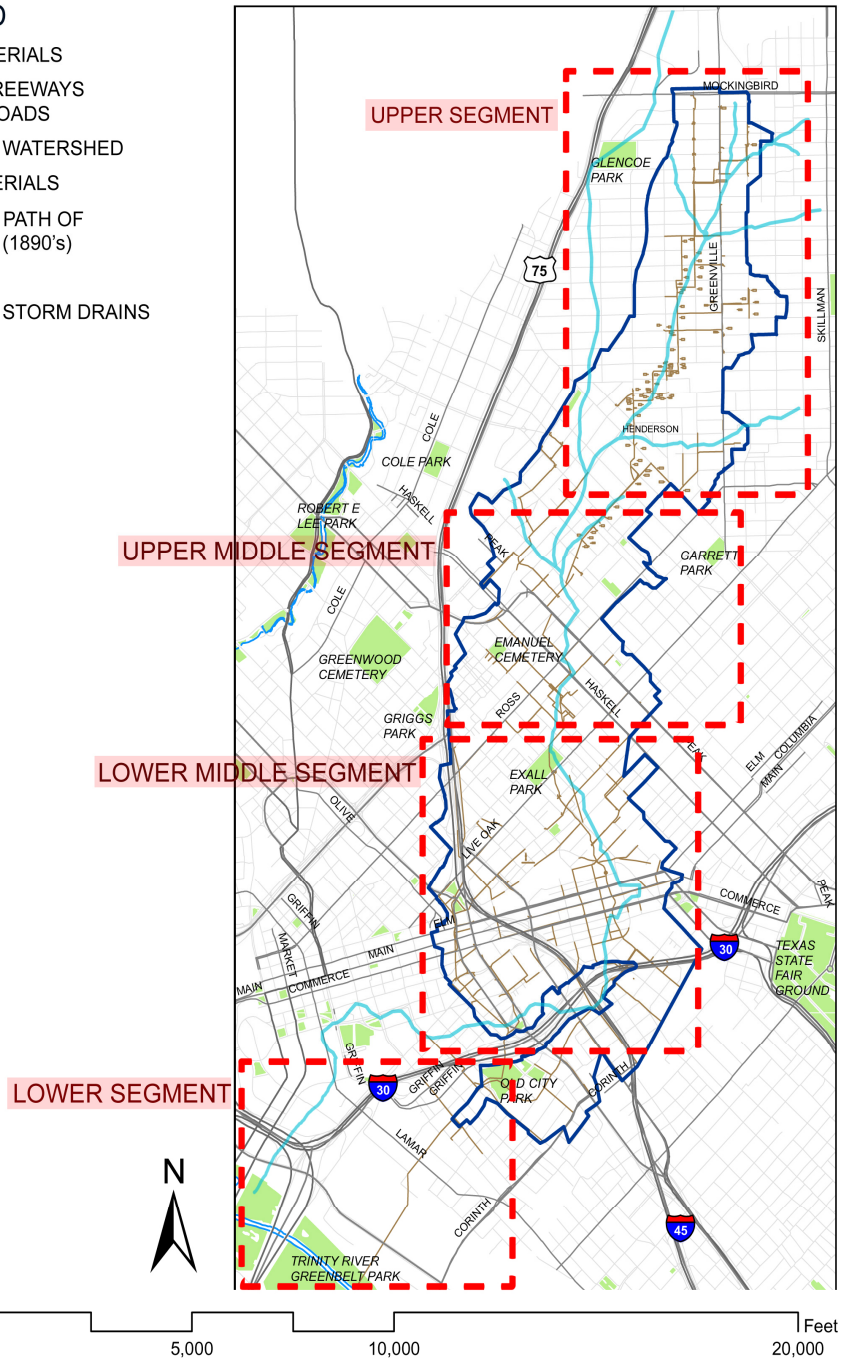


Figure 5.17 Hydrology (four segments) of Mill Creek
(Data Source: Half Associates 2005)

STORMWATER HAZARD AREAS

MAP LEGEND

- STORMWATER HAZARD AREA
- FLOOD DEPTHS (OVER 3 FEET)
- MILL CREEK WATERSHED

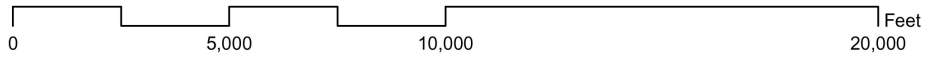
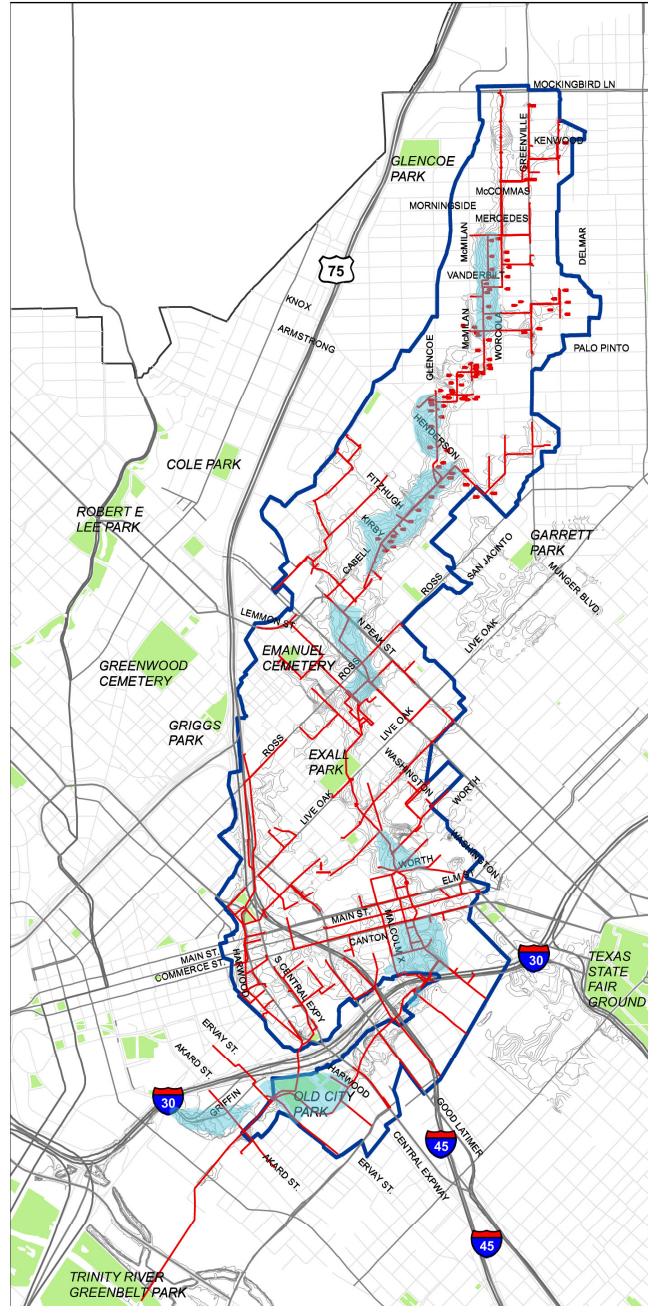


Figure 5.18 Stormwater Hazard Areas
(Data Source: Half Associates 2005)

controls in order to control the stream velocity and improve the channel geometry (Pinkham 2000; Schueler and Brown 2004).

5.2.3 Thoroughfare

Interstate 30, Interstate Highway 45, and U.S. Highway 75 (North Central Expressway) are primary corridors connecting the Mill Creek watershed with Downtown Dallas, Fair Park, Dallas Central Business District, and suburbs like Mesquite and Richardson. U.S. Highway 75, a North-South freeway starting in downtown Dallas, passes through popular districts and high-income neighborhoods like Highland Park. Along U.S. Highway 75, the DART rail service has many major city stations (Figure 5.20).

Impact on thoroughfare traffic needs to be addressed while daylighting a stream, including "...conflicts with street patterns...the handling of crossing of the city streets and knowing where their utilities where they intersect to the creek" (Pratt 2008). Impact on thoroughfares can be assessed based on peak hour traffic volumes for the major thoroughfares in the Mill Creek watershed (Halff Associates 2005). It is estimated to be \$2,200 for a traffic control device. For example, between Carroll and San Jacinto Street in the Mill Creek watershed, six traffic control devices are required in order to control the traffic during construction (Halff Associates 2005).

THOROUGHFARE

- MAP LEGEND**
- DART RAIL STATIONS
 - +— 2008 DART RAIL LINE
 - ▭ MILL CREEK WATERSHED
 - MAJOR ARTERIALS
 - MINOR ARTERIALS
 - EXISTING FREEWAYS AND TOLL ROADS
 - BIKE TRAIL
 - STREETS

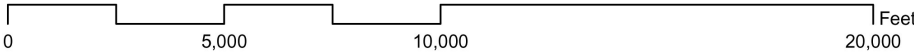
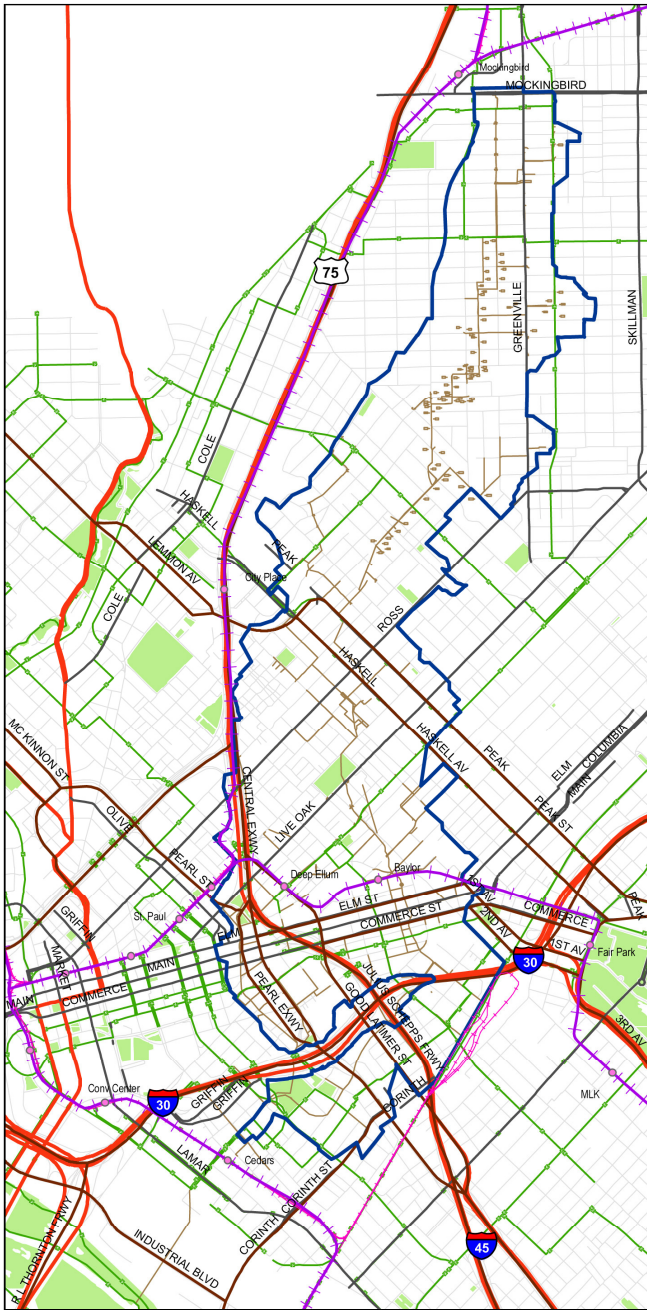


Figure 5.19 Mill Creek Watershed: Thoroughfare Plan
 (Data Source: City of Dallas 2000; Half Associates 2005)

Mr. Prejean suggested some alternatives to minimize impact on the traffic while daylighting Mill Creek.

I saw some opportunity where the land could be somehow gathered along the Santa Fe tracks, to rebuild the freeway over that direction. Basically what I am suggesting is moving a transportation land use over to the train track for the freeway. Build that freeway through there and building this way would not be disturbing the current traffic discipline along the canyon of east R.L. Thornton Freeway. Once that is complete, then you ship the traffic patterns to the new roadway and then the old right-of way of the old canyon can then be turned around to use to open up Mill Creek. That's the area where Kessler proposed the parkway...I was offering that kind of a suggestion (to) the city. Also, looking at the land that's a very costly thing I suggested. (But)... what land values are doing currently along Interstate 30 in that area south of downtown and what would happen if you had a park corridor...green amenities have a very positive impact because again people are attracted to living near (green) spaces, especially linear ones with a creek running through it. (Prejean 2008)

“...They are not taking it seriously in any way because they are looking it as multi million dollar freeway redo of this whole area. Basically The Texas Department of Transportation (TXDOT) is for the road building business there. City of Dallas is in favor of trying to make a community there, but thinking about money to buy that land along the Santa Fe tracks corridor to put a freeway in place” (Prejean 2008).

During a 100-year flood event, the depressed section (canyon) of Interstate 30 floods over a depth of six feet. In order to meet public safety requirements, the Texas Department of Transportation (TXDOT) is required to rebuild Interstate 30 (Halff Associates 2005). TXDOT is looking at expanding Interstate 30 (Westsmith 2008) “...also known as ‘the canyon’ because it is the lowest surface along the south side of downtown Dallas” (Prejean 2008). The proposed 500 million dollar Pegasus widening project will create several highway tunnels and provide the surrounding areas with

better access to the downtown area. Planners desire to eliminate the complicated maze of ramps and overpasses that connect the Central Business District with Old City Park and the lower Mill Creek basin. A number of options are being considered that would add space to crossover bridges to attract pedestrian traffic, including parks on top of tunnel sections (Halff Associates 2005).

Mr. Pratt also notes that “It can be done very easily along the sides of the railroad right of way on the Santa Fe running through Fair Park down to the river, but that’s a big political issue. If you consider widening the Interstate 30 in the present situation it would be much cheaper on the Santa Fe” (Pratt 2008). However, a further study is required to estimate the costs of buying this land and rebuilding a whole new freeway in the Santa Fe right of way. Also, the benefit of doing the freeway over the Santa Fe track should be compared with the Pegasus project. During construction of the freeway on the Santa Fe, the existing Interstate 30 freeway would continue to do what it is doing right now, without any traffic disruption (Prejean 2008).

5.2.4 Economic Considerations

5.2.4.1 Comparison Between Cost of Daylighting and Cost of Repairing an Aging

Culvert

Mr. Ferguski asks, “Are the benefits of daylighting justified by the cost?” About 50 to 60% of all storm-water pipes are more than thirty years old. If built with the conventional pipe system, the life expectancy is estimated between thirty to forty years. This applies to the other collection system in Dallas, Texas (Patel 2008). Adding a relief structure to the drainage system is estimated to cost up to ten million dollars per

mile (Halff Associates 2005), Daylighting a 100 foot wide stream buffer to convey the upstream flows in excess of 2300 (cfs) in the upper middle segment (Henderson Avenue to San Jacinto Street), is estimated to cost thirty-two million dollars per mile (including property acquisition, relocation, demolition and moving expenses, but excluding any amenities) (Halff Associates 2005). Further study of the lifecycle costs of the current drainage system with a “low impact design approach” like daylighting can demonstrate the economic difference between the two approaches for urban storm-water management. Mr. Westsmith, Vice President and Project Manager for the Mill Creek Master Drainage Plan Study, said “We have not projected possible increases in property value with daylighting. We are just looking at the flood problem. We can state it as a benefit...the property value will go up to 50% or 5%...it’s sort of a ‘crystal ball gazing’ for an engineer” (Westsmith 2008).

Property in the City of Dallas in direct proximity to Interstate 75 where it follows the course of Mill Creek appraises for about eighty dollars a square foot, whereas property in the City of Dallas in direct proximity to Interstate 35 E near Turtle Creek appraises for about 120 a square foot. However, the normalization of the property values could provide useful economic data to more accurately assess the benefits and costs of urban stream daylighting (Dallas Appraisal District 2008).

5.2.5 Ecological

5.2.5.1 Wildlife Habitat and Water Quality Enhancement

Mr. Bloomberg notes that geomorphic setting is one of the essential criteria for daylighting streams. “How will the daylighted stream integrate with surrounding

ecosystem?” “How will a daylighting project potentially benefit or enhance ecosystem function...either by providing specific types of habitats or by providing connectivity for wild life to move through?” He further adds that “Flood protection and flood management considerations are critical in identifying an appropriate ecological values and habitat goals” in an urban and developing areas (Bloomberg 2008).

Mr. Firguski mentioned wildlife habitat and water quality enhancement as goals in daylighting projects (Firguski 2008). There are many ways that stream daylighting can be done with different outcomes for wildlife habitat and water quality enhancement.

Mr. Jorgen elaborates,

Whether daylighting a creek or doing full restoration, rehabilitation, enhancement, or naturalization, all of these have different implications in terms as to how streams function and what kinds of physical processes are allowed to actually occur and function within the site...When you take a creek out of a pipe, you daylight it and at that point consider what are you doing: Are you restoring it? Enhancing it or creating a naturalized waterway? All of which may have different flood function capacity, ecological values and recreational and educational values. (Jorgen 2008)

According to the Impervious Cover Model for urban streams (Schueler and Brown 2004) the Mill Creek watershed is classified as “urban drainage” because 60% of the watershed is impervious cover. Impervious surfaces provide an indication to the quality of water and health of a stream. High levels of imperviousness indicate environmentally detrimental levels of runoff (Schueler and Brown 2004).

So, an assumption or expectation of any kind of wildlife habitat and water quality enhancement outcome from daylighting Mill Creek may not be valid and needs to be tested. If in the Mill Creek daylighting, the goals are wildlife habitat and water

quality enhancement, then it is also imperative to test stream daylighting as an effective means for the cited goals. The project must be designed from the start with those goals in mind. Ms. Riley clearly stated, “Daylighting should restore creeks to natural systems... not dead creeks. We do not want to go to the expense of digging a pipe up if we are not providing a functioning stream. We don’t want to be creating canals” (Ann L. Riley, 2008, e-mail message to the author).

5.2.5.2 Soil Investigation

Out of eight experts, only two stated geotechnical/soil investigation as essential criteria before undertaking a stream daylighting project to ensure its suitability for riparian vegetation and its hydrological importance. Mr. Tidwell, who is actively involved in stream restoration projects, notes, “Knowing the soil characteristics of the channel that you are going to reestablish is important. Each soil type requires different slope and has different responses to erosive factors. To think that one soil equals another is not appropriate...another advantage of cement. The pipe removes that factor of uncertainty. For riparian vegetation, soil selection is also very important” (Tidwell 2008).

SOIL INVENTORY

MAP LEGEND

- AUSTIN-URBAN LAND COMPLEX
0 TO 2% SLOPES
- AXTELL-URBAN LAND COMPLEX
1 TO 5% SLOPES
- BASTSIL-URBAN LAND COMPLEX
0 TO 2% SLOPES
- EDDY-URBAN LAND COMPLEX
4 TO 8% SLOPES
- FRIO-URBAN LAND COMPLEX
- HOUSTON BLACK-URBAN LAND
COMPLEX, 0 TO 2% SLOPES
- LEWISVILLE-URBAN LAND COMPLEX
0 TO 4% SLOPES
- LEWISVILLE-URBAN LAND COMPLEX
4 TO 8% SLOPES
- SILSTID-URBAN LAND COMPLEX
0 TO 6% SLOPES
- TRINITY-URBAN LAND COMPLEX
0 TO 6% SLOPES
- URBAN LAND
- WILSON-URBAN LAND COMPLEX
0 TO 2% SLOPES
- CONTOURS (20'-0" INTERVAL)
- MILL CREEK WATERSHED

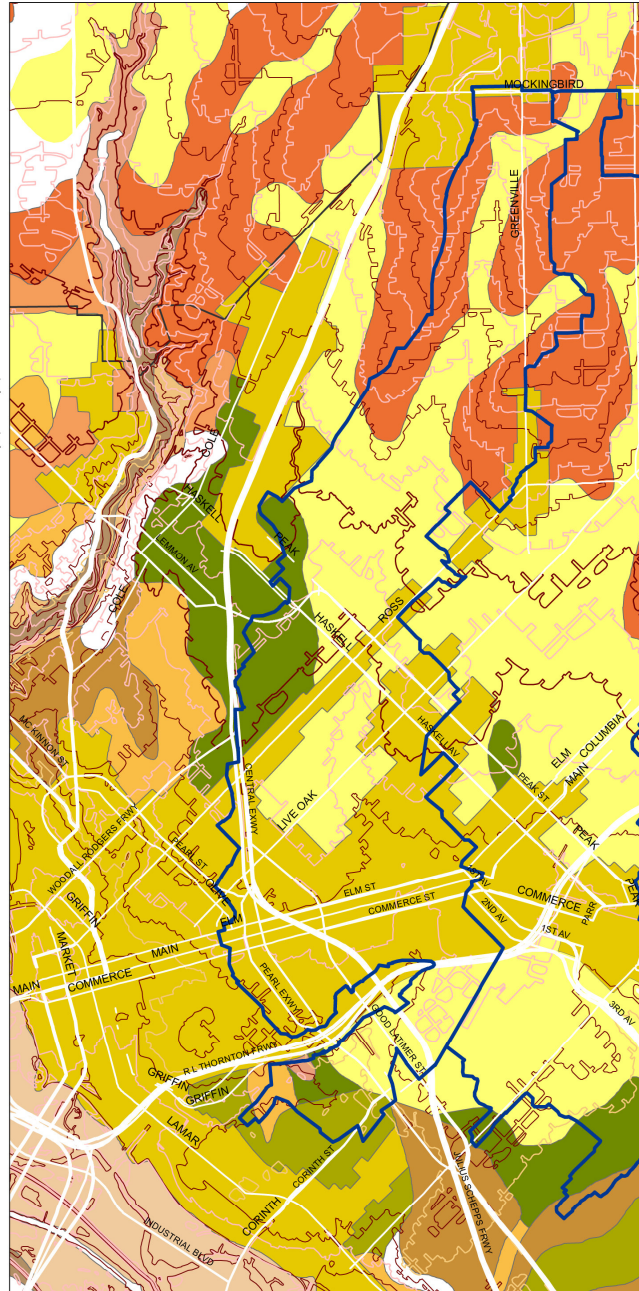


Figure 5.20 Soil Inventory
(Data Source: Natural Resources Conservation Service 2006)

Mr. Bloomberg adds,

We have had different experiences with soil conditions and soil quality. I think it's a part of the investigation of a given project where you do certain number of soil tests and geotechnical investigation to understand what substrate you are actually dealing with and also what the quality of that substrate is? We have had experiences where it is necessary to actually off haul and remove significant volumes of contaminated soils. These particularly occur in more industrial and developed areas that are being redeveloped for housing or for greenways...It's not a good idea obviously and there is lot of regulations around this to open up the contaminated soils that may allow for human contact as well for animals and other wildlife to come in contact with contaminants, as well potential mobilizing of those contaminants through the daylighting project itself. So it's very important to know what you are dealing with when you start digging the site (Bloomberg 2008).

A geotechnical study was done by Terra-Mar, Inc., Dallas, Texas, for the Mill Creek Master Drainage Plan Study. The study was done in order to investigate the subsurface condition of the Mill Creek watershed. The purpose of the study was to look at drainage improvement feasibility, including storm-water detention basins at Garrett Park, Cochran Park and Exall Park. The study also included the proposed storm drain alignments along and within the Mill Creek watershed. A depth to the top of Austin Chalk Limestone within Mill Creek watershed was investigated. The ground surface at the boring locations was typically paved with asphaltic concrete underlain by Portland cement concrete. Clays, sandy clays and sand can be found in the Mill Creek watershed ranging from depths of approximately 6 inches to 13 feet (Halff Associates 2005). This study provided depth of different layers of soil in the Mill Creek watershed. However, further soil quality/contamination study is suggested in order to assess the feasibility of daylighting in the Mill Creek watershed.

5.2.6 Decision Makers

“Though it is not a design criterion” (Ann L. Riley, 2008, e-mail message to the author) all the experts shared their views, provided information and insight on how different decision makers can be a significant factor in deciding on feasibility of stream daylighting. The following section elaborates on decision related issues for stream daylighting.

5.2.6.1 Who Should be Involved in Decision Making about Stream Daylighting?

The experts pointed out some key players in the decision-making process of stream daylighting, based on their experience with stream daylighting and stream restoration. They are categorized into four broader groups.

Public interest and community involvement: In order to make stream daylighting a success Mr. Tidwell suggests “Having an aggressive public involvement strategy...you are letting people know what you are doing. Reaching out to the property owners is particularly important because of the assumptions of the value that they have determined their property could be impacted” (Tidwell 2008).

Bloomberg elaborates on the community interests as very important criteria for even imagining daylighting project, “The daylighting project in more urban areas, I think that community interests having an abundance of inspiration and vision for a creek could be very important. My experience is that there has to be an investment from the community side which actually drives a town or a city or a municipality, government agencies to take on the project. It has been my experience that the projects undertaken by the government are in fact initiated by a committed and energized

community” (Bloomberg 2008). Ms. Riley adds “Daylighting only occurs because there are community advocates for it. The neighborhood or merchants group located at the site must want it, organize for it and find funding for it.” (Ann L. Riley, 2008, e-mail message to the author).

Safety issues (flooding, maintenance and the fear of children drowning) with open channels can be a big concern to the public and city officials. As Mr. Tidwell of NCTCOG puts it, “There are public safety issues because “out of sight, out of mind” has some advantages to it” (Tidwell 2008).

Technical advisory groups: Mr. Bloomberg notes that “It is important to include a technical advisory group that includes the appropriate type of professional expertise: engineers, geomorphologists, landscape architects, public access (experts) and people who can help the stakeholder group which is trying to make decisions about creek daylighting process. You need to have an appropriate level of advice and technical input to help translate typically some complex technical issues to support the decision-making process. So having a good organized design team I think is very important as well” (Bloomberg 2008).

Regulatory agencies: The experts have cited some of the important regulatory agencies which can be involved in the decision-making process of stream daylighting: City public works and transportation departments, Army Corps of Engineers, planning department, economic neighborhood services, neighborhood associations along the stream corridors to be daylighted, leaders on board explaining economic potential as well as social and physical attributes would be positive for the community. Economic

groups such as Chambers of Commerce and specialized groups like historic preservation societies can also help project how daylighting can positively affect a neighborhood.

Mr. Prejean notes that “City leaders are more cautious because they have the public eye on them all the time as to what they do with the public fund. So they will be little hesitant to make any move on this” (Prejean 2008).

In the North Texas region: North Central Texas Council of Government (NCTCOG) is

providing and looking at the big picture throughout the region ...they have been heavily involved in the traffic solutions and traffic congestion solutions and alternatives, the big roads and big freeways type of projects. And they get lots of the federal grant money. They have developed Integrated Storm Water Management (ISWM) manual for the entire region to bring out the consistency and uniformity in addressing storm-water and its solution. I would say that the NCTCOG plays a bigger role and of course each state entity like TXDOT, local governments and departments handling the flood plain, drainage or storm water in each local government, those will be the real big players in the decision-making process said Mr. Patel. (Patel 2008)

Funding Resources:

Mr. Bloomberg notes that funders should be involved in the decision on daylighting projects. He gives an example, “Here in California, the state funds quite a bit of a creek daylighting and creek restoration work through the Department of Water Resources. They issue grants on an annual basis. And so typically...if their money is involved in a project... it’s reasonable to say that they should have some involvement in decision-making process. Other funders, if they are private funders they may have certain priorities as well with in a project” (Bloomberg 2008).

When asked about the funding resources for Mill Creek watershed, Mr. Westsmith said that “there is a possibility of outside funding. We did look at the TXDOT participation, Corps of Engineers possible participation. ...they showed interest but so far there is no money coming forth” (Westsmith 2008).

Mr. Patel positively states that the funding opportunity for daylighting streams in the North Texas region is “Federal grants or State funds in order to shape up this kind of projects” (Patel 2008). He further elaborates, “NCTCOG, regional mobility, the different Intermodal Transportation (ISTEA) federal grants, transportation. Those types of funds which Federal government passes on to the state and then the state shares that funding with the local governments and local governments also share some funding...another one would be the North Texas Tollway Authority (NTTA). NTTA has their own establishment and they handle the big tollways” (Westsmith 2008).

The alternatives in The Mill Creek Master Drainage Plan Study were presented to the citizens of neighborhoods that were affected by the flooding, the City of Dallas, TXDOT, DART, and Baylor Hospital. Mr. Westsmith said “We just explained everything to them and took their comments, moved back and reworked the report” (Westsmith 2008).

5.2.6.2 Lack of Daylighting Stream Projects in the North Central Texas

From the *Group 1* interviewed, all the experts agreed that there was a lack of daylighting projects here in Dallas, Texas. Mr. Prejean reasons, “Daylighting is an afterthought, it’s kind of a new subject.” “It needs some examples here...It’s a new concept...Houston, San Antonio, Austin they have seen water flow growing...it’s a

learning curve to this whole thing...having educated people why it would be beneficial to daylight a creek that would have economic possibilities. It's hard for the people to visualize what the future is going to look like...bringing out the natural asset which was buried in the past...there is a learning curve and economics to it" (Prejean 2008).

Stream daylighting was never on the agenda in any of the stream restoration programs in the North Texas region. Here in North Texas, stream restoration projects typically deal with concrete lined channels being restored to a more natural setting (Tidwell 2008). Mr. Tidwell noted that "...Several projects (are) going on in the Council of Governments...we are partnered with the Corps of Engineers on the cities' behalf. Actual daylighting a stream has never been identified as a particular project to pursue. We have worked with City of Dallas for example on the Trinity River program. The biggest and the most obvious project being pursued is the Trinity floodway" (Tidwell 2008).

Mr. Patel admits that in this region, "More focus has been given to the mobility, the transportation issues, development meeting the traffic needs...other than creek restorations" (Patel 2008). Mr. Tidwell adds, "We have stream restoration projects, concrete lined channels (being) restored to a more natural setting, which are not necessarily daylighting." He expresses strong reservations about stream daylighting: "The difficulty with stream daylighting is typically that the geography is so small...the ability to demonstrate a positive cost-benefit ratio in terms of the amount of dollars or resources that need to go into the project, have to be able to demonstrate that they are going to get as much benefit" (Tidwell 2008).

Mr. Prejean stresses the need to educate people about benefits of daylighting “How it will be if you have greenbelt? How it will be linked to other community assets in their area?” He further adds that “...other communities who are daylighting tend to be more in the East Coast and even in the West Coast as well. They are hard core people to imagine. Think about driving through East Dallas. Now when you are driving you come down to Ross Avenue or Live Oak. It’s kind of depression there. There is vacant property around there. You don’t really realize that there is a creek underneath this area...you have to visualize what this area could be like if that creek were brought out to live again and treated and can be an asset for the community” (Prejean 2008).

Mr. Patel sees a change in trend for the public demand towards water features and green amenities. “There is big push for water features, creeks, and trees. So at least developers and the users or buyers, condominiums, apartment, homes...everybody wants more features like trees and ponds...where they can go out and sit there...recreational opportunities...more and more for any new projects. Now the city needs these elements... they are going to be considered in greater depth...as a matter of fact it is happening right now...” Mr. Patel remarked (Patel 2008).

As Mr. Tidwell of NCTCOG puts it, “(With) the environmental sensitivity in the contemporary world, people recognize the importance of wetlands. We have done a good job of trying to educate people about this. I think there’s need for education, need for communication but also a need to reassess our regulatory programs we have put in a place just like we assess whether a public works project is causing any negative consequences” (Tidwell 2008).

5.3 Analysis Results

Initially, preliminary daylighting criteria have been synthesized based on review and analysis of available literature. Using preliminary criteria, the enhanced eligibility criteria (Appendix D) have then been developed after evaluating Mill Creek for daylighting against preliminary criteria based on interviews / perspectives from key professionals. A spatial analysis of Mill Creek, Dallas, Texas was performed using Geographic Information Systems (GIS) to test the Mill Creek eligibility for daylighting. The results were summarized thus:

1. Possibility of partial daylighting in the Mill Creek watershed.
2. Historic and cultural value and thoroughfare criteria of the proposed daylighting of Mill Creek make it different from the other (reviewed) completed daylighting projects in the United States.
3. Daylighting can be a viable choice over replacing an old and under-capacity drainage system of the Mill Creek watershed.
4. Lack of daylighting streams in Dallas, Texas.
5. Possibility of daylight other streams in Dallas, Texas
6. Possibility of increase in property value of the Mill Creek watershed when daylighted.
7. Possible connection to the proposed developments in and around watershed.
8. Daylighting as the low-impact design solution to storm-water management in the watershed.

9. Opportunities to connect with the proposed developments in the Mill Creek watershed.
10. Daylighting is not envisaged in the Integrated Storm Water Management of Dallas, Texas.

CHAPTER 6

CONCLUSIONS

“As in most cases, we are unsuccessfully trying to replicate a service that nature provides for free: the management of storm water. And, as in most cases, nature does it better.”
-Anonymous

This research deals with current status, scope, benefits and feasibility requirement of daylighting of Mill Creek, Dallas, Texas. It provides insight about daylighting for landscape architects, engineers, city planners, city activists and other professionals who are daylighting streams or involved in decisions about daylighting. Enhanced eligibility daylighting criteria for Mill Creek, Dallas, Texas has been developed based on the analysis and review of the interviews. Spatial analysis using Geographic Information Systems (GIS) was done to test Mill Creek feasibility for daylighting.

Two criteria Historical/Cultural values and Thoroughfare have been added to the Preliminary Daylighting Criteria in order to formulate Enhanced Eligibility Daylighting Criteria for Mill Creek, Dallas, Texas. Roadways/thoroughfares are a key infrastructure in today’s urbanized areas and are considered important criteria for daylighting streams in a highly urbanized area such as Dallas, Texas. Experts stress the significant historical and cultural importance of Mill Creek. Mr. Prejean called Mill Creek a “historic legacy” of the City of Dallas. It played a key role in establishing Dallas as the important transportation and economic center in the north-central Texas

region, as well as providing a source of drinking water (Prejean 2008). Therefore, historical and cultural values are included as important criteria for Mill Creek daylighting. These criteria distinguish Mill Creek from the other (reviewed) completed daylighting projects in the United States.

In the Mill Creek Master Drainage Plan Study the following were proposed for the upper segment—storm sewer relief systems; upper middle—creek restoration; lower middle and lower segment—pressure sewer and storm sewer relief systems. However, the proposals were based on single objective assessments—to control flood water in Mill Creek watershed. Water quality, wildlife, social values and other downstream effects were not taken into account. As discussed in Chapter Five, upper middle segment and the lower segments of Mill Creek have been identified as the potential daylighting sites in the watershed (Figure 5.17).

Experts have revealed that there is a lack of daylighting of streams in Dallas, Texas. Daylighting is not envisaged in the *integrated* Storm Water Management (ISWM) program of North Central Texas Council of Governments. However, the goals of the ISWM program are mutually synergistic with daylighting: “Conservation of natural features and resources, lower impact site design techniques, reduction of impervious cover, utilization of natural features for storm-water management” (Tidwell 2008; Integrated Storm Water Management). Daylighting can be the low-impact design solution to the storm-water management in the watershed.

Stream daylighting offers viable solutions to address the problems of flood, erosion, and loss of natural resources, and benefits water quality and the reestablishment

of aquatic/riparian habitat and wildlife corridors. Therefore, daylighting can be a viable alternative over replacing an old and under capacity subsurface drainage system of the Mill Creek watershed.

There are opportunities to connect proposed daylighted segments of Mill Creek with the existing and proposed developments in and around the watershed, as shown in (Figure 5.3). While this research does not indicate that the entire segment of Mill Creek is suitable for daylighting, it shows the viability of partial daylighting of the buried creek.

6.1 Relevance of Study

Manual 10 of the Unified Stream Assessment asks, “Given that many post-industrial waterways are now in pipes underground, why would it be considered worthwhile to dig up a culvert and restore its original surface stream? What makes a storm water outfall a good candidate for stream daylighting? When is stream daylighting *not* recommended?” (Kitchell and Schueler 2004). Little research was found that addresses this topic.

This study presents a preliminary site study, analysis of requirements, and specifications for the Mill Creek watershed, which can be used as a reference for future implementation by the City of Dallas on other daylighting projects. These general criteria will help the decision making process for the daylighting of streams. In order to start a daylighting project in Dallas, Texas, all these criteria need evaluation for maximum benefits. The intent of the study is to present information from past events, decisions, and perspectives regarding daylighting to landscape architects, city planners,

city activists and other professionals who are daylighting streams or are involved in the decision-making process. It provides the context for selection of potential daylighting sites in Dallas, Texas, and can be useful in formulating a city-wide stream daylighting policy in Dallas.

6.2 Role of Landscape Architects

Stream daylighting projects call for participation and support from citizen activists, government authorities, institutions and concerned professionals such as ecologists, hydrologists, engineers and landscape architects. Landscape architects need to take a leading role as facilitators, administrators and designers of interdisciplinary projects to mobilize support and participation of all concerned and to arrange for funding sourcing for stream daylighting projects. Landscape architects should also assume the role of stewards for the environment, to preserve the health of natural systems, and secure a renewed quality of life in the human landscape.

6.3 Future Research

This paper provides some initial estimates of approximate locations and capacity requirements of a potential Mill Creek daylighting project. Several topics for future research have emerged from the discussions. Based on the Enhanced Daylighting Criteria, the middle and lower middle segments of Mill Creek have been identified as potential daylighting sites. However, more detailed hydrologic modeling is advised before implementing the actual projects. For example, the difference in the stream channel elevation between the stream and invert of the outfall pipe in the Mill Creek watershed needs to be studied to determine the feasibility of daylighting.

Studies so far have not acknowledged the variables that influence the efficacy of improving water quality and habitat. The reports are notable for their inclusion of technical aspects of construction and anecdotal descriptions about habitat restoration and water quality improvement, but fail to apply an established method of analysis for a prerestoration and postrestoration review. Comparative analysis is needed for the small number of contemporary daylighting projects. There is a significant void in the reviewed literature in terms of measurable outcomes such as details of habitat population restored and water quality improved. In-depth study needs to be conducted to firm up the scope and requirements to achieve goals such as habitat restoration and water quality improvement.

The daylighting choice is largely dictated by cost. Further study of the lifecycle costs of the current drainage system versus the low-impact design approach of daylighting will demonstrate the economic differences between the two approaches for urban storm-water management.

According to the Kessler Plan of 1911, Mill Creek and Turtle Creek were intended to be the centerpieces for urban parkways. But only the Turtle Creek parkway was implemented, while Mill Creek was buried underground. Partial daylighting of Mill Creek can be a viable choice both technically and economically to address flood problems and other socio-economic issues. A comparative study of Mill Creek (buried) and Turtle Creek can be done to estimate the impact of daylighting on property values. One of the benefits from the daylighting is the increase in property value; which also increases the property taxes of the site (Pinkham, 2000). However, that can result in

displacement of lower-income groups and businesses from the daylighted site. Further study on the gentrification issue of the completed daylighting projects in United States is needed before proposing daylighting. Synthesis of information from experts in the fields of fluvial geomorphology, water quality science, hydraulic engineering, limnology, soil science, planning, social sciences, landscape architecture and economic development can establish the feasibility criteria, and suggests the technical and financial requirements for a daylighting project.

Stream daylighting promises health, safety, natural beauties and numerous other benefits of green spaces for neighborhood, hospitals, and entertainment venues. Therefore, it is imperative to move in this direction in order to create a new lifeline of green in an environmentally degraded part of Dallas. With an intricate and socially complex web of benefactors and beneficiaries, the whole exercise calls for collaborative efforts by all concerned.

APPENDIX A
PRELIMINARY DAYLIGHTING CRITERIA

APPENDIX B
INTERVIEW QUESTIONS

Interview Questions:

Group 1 (These subjects are not familiar with Mill Creek):

1. What are the key parameters to be considered before daylighting a stream?
2. Are there criteria for deciding which sections of a stream should be left buried or which should be resurrected?
3. Are there any new daylighting projects coming up in the near future?
4. Who should be involved in decision making about stream daylighting?

Group 2 (These subjects are experts in stream daylighting and may or may not be familiar with Mill Creek):

1. Tell me what you know about Mill Creek, Dallas, Texas?
2. Is this project well conceived?
3. Have you been involved in any daylighting projects or stream restoration projects in Dallas?
4. Is there a lack of daylighting stream projects in this region?
5. Who should be involved in decision making about stream daylighting?
6. What are the pros and cons of daylighting streams?
7. What are the key parameters that should be considered before determining which streams to daylight?
8. Are there criteria for deciding which sections of a stream should be left buried or which should be resurrected?
9. Are there any new daylighting projects coming up in the near future?

APPENDIX C
SAMPLE INTERVIEWS

(Group 1) Jorgen Blomberg interview Sept. 25, 2008

Q.1 What are the key parameters to be considered before daylighting a stream?

My experience is that there are a number of important parameters and they shift depending on where the project is, who is involved in it and what the goals are. With daylighting project in more urban areas, I think that community interests having an abundance of inspiration and vision for a creek could be very important. My experience is that there has to be an investment from the community side which actually drives (say) a town or a city or a municipality, (or) government agencies to take on the project. It has been my experience that the projects undertaken by the government are in fact initiated by a committed and energized community. So I think community interests are critical for even imagining daylighting projects. As I said, that location(al) understanding...what is possible within a creek daylighting project ...a lot of that is driven by the project within the watershed. One is its geomorphic setting and how will the daylighted stream integrate with surrounding areas. There are lot of concerns obviously around...flood function, flood conveyance, flood protection and management, in particular in urban and developing areas, but also consideration of surrounding ecosystems and how a daylighting project will potentially benefit or enhance ecosystem function, either by providing specific types of habitats or providing connectivity for wildlife to move through. That's also a very important consideration. I also mentioned about flood protection management. I think it's very important for any daylighting project to meet or exceed the existing flood function of the pipe. But my experience is that people are careful of the floods and the dangers of property damage and what not. That perception can be a critical factor, or I should say, misconception can be a critical factor in defining whether or not a project will have the necessary support to move forward. So being certain that you can provide the appropriate level of flood protection and conveyance capacity is also very important. What we have found is that in daylighting projects you often have the opportunity to improve flood protection both on the site specifically, but also within the overall system because you are encouraging infiltration and percolation of water on site. You are reducing the flashiness of the stream. And by doing so, in many ways (you're) providing the added value in terms of reducing the erosion and flooding downstream of the site. So flood protection management considerations are critical in identifying appropriate ecological values and habitat goals. I think it's very important in considering daylighting projects (to state) what you are hoping to reestablish within a project and making sure that you are very clear about what is possible and how the project can be monitored to be deemed as success in a long term. [But daylighting projects can be...] I think, as I said, focus on various specific species or they can also be looked at a broad perspective in terms of enhancing ecosystem function. Public access and recreation of this kind refers to the first point I made about community involvement. I think daylighted projects offer a really rich opportunity for bringing people to these natural resources ...hoping to interpret and educate people and communities about the values of these systems in our

society. So (a goal would be) being able to identify ways to incorporate meaningful public access and educational opportunities. Perhaps even stewardship opportunities (would be) other important criteria for moving ahead with a daylighting project. And I said this because there isn't a great investment on the community side. What we often see is that these projects won't be taken care of the way they need to be. And so having an active participation by the community tends to really help these projects evolve in the landscape over time and become important places within those communities. Understanding the very real monitoring and management requirements when you open up a pipe and bring flow back in the restored creek channel... It's very important to be clear about the long term management expectations and requirements that are necessary to maintain this project...that is, that you know with limited resources. For instance urban and suburban projects have certain important hydraulic functions and conveyance capacities that often means some level of vegetation management. It is also important to consider vegetation management from the perspective of invasive exotic species which typically colonize riparian areas. So being able to not only to identify what your monitoring management requirements are, but also be able to commit to some level of program that will help (at) some level to maintain (it) over time...is important. Maybe in some ways most importantly is cost. How the project can be paid for? What kind of funding sources does the community or a town project leader have in terms of funding (the) design and construction (of the) project. Implementation, and as I was just talking about, the monitoring and maintenance of the project. So really trying to provide clarity in terms of realistic costs estimates. What it takes to carry out the project is very important.

Q.2 Are there criteria for deciding which sections of a stream should be left buried or which should be resurrected?

I think this is kind of an interesting question. (On) the project we are working on in the Portola Valley, we had exactly that issue come up and there are 630 feet of pipe on the project site. However, with the town center project there are number of program elements that are also needed to be fitted into this site. It's a 7 acre site. As a result, some of the program elements were competing with one another, especially on the site. So for example there was a need for a new soccer field, a new baseball field, and emergency vehicle access. (There was) a need for a meadow area, and also existing resources such as mature redwood trees and oak trees that were on the site. So there is definitely in many projects a point where compromise becomes an important element to the design ...understanding that if you are going to have a daylighting project it may have to scale back to certain extent in order to balance goals of the diverse community and a multi-objective project. So in this case in Portola Valley, the town decided to go ahead and daylight the lower half of the project and maintain the upper half of the stream in the culvert. But I think what was interesting in terms of the Portola Valley is that they developed a master plan which ultimately shows the entire section of the creek being daylighted and restored. And (this) now serves as a guide or vision document for

future phases of work. What does it essentially help the design team establish where certain elements on the projects could be located and still at some future point potentially be refigured to allow for a complete daylighting project to be implemented. In terms of partial daylighting, I think we should be clear about what is it you are asking there. Either you bring the creek to daylight or you don't. But maybe there is also a discussion about how, in daylighting a creek, whether or not (you're) able to do full restoration of the creek or rehabilitation or enhancement or naturalization. All of which have different implications in terms of overall how streams function and what kinds of physical processes are allowed to actually occur and function within the site. So in opening a creek...my feeling is when you take a creek out of a pipe you daylighted it and at that point...what are you doing? Are you restoring it? Are you enhancing it? Are you creating a naturalized waterway? All of which may have different flood function capacity, ecological values while keeping recreational and educational values. We have had different experiences with soil conditions, soil quality. I think it's a part of the investigation of the given project where you do certain number of soil tests and geotechnical investigations to understand what substrate you are actually dealing with and also, what the quality of that substrate is? We have had experiences where it is necessary to actually haul off and remove significant volumes of contaminated soils. These particularly occur in more industrial and developed areas that are being redeveloped for housing or for greenways. But it's a very important consideration in developing a project. It's not a good idea obviously and there are a lot of regulations around this... open(ing) up contaminated soils that may allow for human contact as well for animals and other wildlife to come in contact with contaminants, as well potential mobilizing of those contaminants through the daylighting project itself. So it's very important to know what you are dealing with when you start digging. In terms of slopes, again I think there are a number of ways of looking at. How to stabilize both the creek channel itself that is a longitudinal profile of the creek as well as the bank profile? So we have been working in our designs here to look at...number one, primarily how can we reestablish the natural physical processes that would occur on a given site. First and foremost we try to have the geomorphology of the site drive both the plan form as well as the profile of the creek, and from that we are able to analyze and determine what kind of bank profiles are either necessary to fit in to a given project footprint or that are necessary to maintain stable slopes. We use lot of different materials, generally materials that are native to the area that we are working. So for example, linking creek Lincoln Creek is a very steep creek. It is on the order of a 5%-6% slope and in those conditions you would naturally find a of step pool type of geometry, a step pool system and riffle pool system. We used surveys of natural stable streams in the area as an analogy for our project. And that then allowed us to (create) construction documents for a large pool (and) step pools which help us to stabilize the profile of the stream. We often integrate bioengineering and biotechnical engineering as well as broader revegetation plans and applications, to integrate those with the more structural approaches we use. That may take advantage of rock material, large woody debris, and other things like that, that are more structurally focused.

Q.2a Is there any benchmark for slopes? Is there any literature on that?

I would say there are probably...I haven't come across any literature myself, either and I don't think it would be applicable. I think that creek restoration, creek enhancement, (and) daylighting work can occur in just as creek restoration can occur in any number of type of systems. So we do creek restoration and creek enhancement designs in systems that are very steep, as I said Lincoln Creek is on order of 6%. There were sections of Lincoln Creek that were actually steeper, closer to 9%. So I think what is important is (that you're) able to develop appropriate, sustainable features within the creek that will persist under more dynamic hydraulic and geomorphic circumstances. But I feel that there is probably a point where from an engineering perspective (and) cost benefit perspective, it may not be feasible to daylight a creek over a certain slope profile. But you know in terms of our work it seems valid to consider being able to do daylighting in a number of different conditions. We are working with the University of California, Berkeley, right now on botanical gardens on a creek restoration project, not a daylighting project, but the profile of that stream is on the order of 9%. It's in a very steep upper watershed section in a redwood growth. So we are looking to develop some pretty significant cascades and step pool features to help stabilize the stream. And my feeling is that if the stream had been in a pipe under those same conditions we probably could have removed that pipe and developed an appropriate stabilization design to daylight as well. Is that making sense?

Researcher: Absolutely.

Q.3 Are there any new daylighting projects coming up in the near future?

There are number of projects. Right now the City of Berkeley is looking at daylighting a section of Strawberry Creek through downtown Berkeley. The project is right now in the planning phase/feasibility analysis phase, where the design team (that is) part of this is looking to determine what types of flows can actually be brought from the open section of Strawberry Creek down through the downtown and returned to the storm drain culvert several blocks away. So that the project is an exciting one, a lot of people are looking at it. It is associated with the broader development project that incorporates the new museum, the new university art museum as well as the new conference center. Both of which want the creek project to occur to help add value to other projects. That's a pretty interesting project. California State Parks is right now looking at a daylighting project on Schoolhouse Creek, in west Berkeley (which) is associated with the Eastshore State Park. Schoolhouse is a small stream that drains a fairly small basin in west Berkeley, but it drains directly to San Francisco Bay.... there has been a very successful daylighting project on another creek just north of it, where steelhead and other anadromous fish have been found in the stream occupying the restored area of the creek. State Park(s) are looking at the School Park as another option to

reestablish...brackish conditions with this daylighting project. There are other projects that are certainly being talked about but (not) at this point being formally pursued. What is interesting is here in California and in Northern California specifically...the communities are very supportive of creek daylighting and creek restoration as a whole. The communities up here are I think really recognize that living and functioning creeks provide a lot of values to these communities in terms of flood management, water quality, habitat values and just (plain) spiritual values. There is a very strong motivation here in California to do this type of work.

Q.4 Who should be involved in decision making about stream daylighting?

Well, I think it varies with the location of the proposed project. It's critical to have community involvement in creek daylighting work and creek restoration work. Often these projects are driven by a motivated community, and any appropriate government agencies at the municipal level, town council, city council and county representative are also relatively important. If they are where the land owner is, then obviously they need to have a representation, a technical advisory group that includes the appropriate type of professional expertise. So engineering, geomorphologist, landscape architecture, public access, people who can help the stakeholder group which is trying to make decisions about creek daylighting process. You need to have an appropriate level of advice and technical input to help translate typically some complex technical issues to support the decision-making process. So having a good organized design team, I think, is very important as well to support the decision-making process. But then also there are funders that should be involved. Here in California, the state funds quite a bit of a creek daylighting and creek restoration work through the Department of Water Resources. They issue grants on an annual basis. And so typically...if their money is involved in a project, I think it's reasonable to say that they should have some involvement in the decision-making process. Other funders, if they are private funders, they may have certain priorities as well with in a project. Then they are also very important regulatory (agencies)...be it the Department of Fish and Game, the U.S. Wildlife Service, the Army Corps of Engineers, or the regional water quality control board. All of those agencies have in many cases overlapping jurisdiction over the waterways here in California. So, mak(ing) sure that they are involved in providing comment and any input to the design and planning process is absolutely critical to expedite and facilitate a successful design. Richard Westsmith interview Sep 23, 2008

Q.1 What do you know about Mill Creek, Dallas, TX?

We have been studying this since 2003. We did a master drainage plan looking at a flooding problems occurring in the basin. (We) found out that the system was about a 2 year system...not able to carry the 100 year flow, which is a criterion for city of Dallas. So they asked us to come up with alternatives (of) how to solve the flooding problemwe looked at detention, reducing flow downstream; we looked at the conventional

storm sewer upgrade, making them larger...we looked at the pressure sewer outfall to the Trinity River. It's a deep tunnel, since it is a large storm sewer that would convey the flow past the flood areas. And we also looked at restoring part of the Mill Creek open channel...started out in the 30s as an open channel with a few culverts and there were some roads that went between...eventually it all got filled in with storm sewer so it is all underground.

Q.2 Is this project well conceived?

We were primarily looking for an engineering solution. We were just trying to reduce the flooding. The possibility came up of daylighting part of it. It's an area that's very congested. So there weren't too many properties we would have been able to buy for a reasonable amount of price as there are lots of businesses, there is a hospital that was flooded during the flood in 1995. So to buy a lot of these properties is not feasible...but we did find an area we could open up and create a new channel.

We looked at that, but the problem is that I-30 drains to one of the interior sumps in the Dallas floodway, and it doesn't have enough capacity for the flow that (it is) supposed to take care of. And the reason we didn't do anything downstream of I-30 was because there was no way to get water across I-30 without doing a deep tunnel, because it is depressed in that area. We could take a tunnel down to the sump...but then the sump has to be expensively upgraded.....

TxDOT is looking at the expanding I-30 and adding lanes to the I-30 which will use up most of the right-of-way. They bought enough right-of-way so they could widen it in the future, so if we took up that right-of-way for the open channel, they wouldn't be able to add that many lanes to the highway. Taking water down to Sump A was not feasible...there isn't enough property down by Sump A to buy up land and increase the volume in the Sump A ... it just not a feasible area. We did look at that. In fact, TxDOT maybe they would like to have an open channel over the highway...Sort of connecting the parks and Old City parks. We did look at that, but again it's a short distance and the expense outweigh.

Q.3 Have you been involved in any daylighting projects or stream restoration projects in Dallas?

We did a project, not necessarily a daylighting, but there was a stream restoration in Allen, Texas. There was an old dam that was getting washed away and crumbling. We did a nice job over there. But not as far as daylighting.

Q.4 Is there a lack of daylighting stream projects in this region?

I don't know any others but as far as possibilities. The adjacent watershed to Peak Branch...we are looking at that now. It's a little bit of a problem because the basin is so steep. So putting open channel in that...it's much better if we can get more storage where the creek is actually filled up, as opposed to being partially full. Then we worry about high velocities, kids getting into the open channel unless we slow it down.

Researcher: So slope is the main hurdle for Peak Branch?

Mr. Westsmith: That's the main part...again the upper part of the basin was probably more feasible for doing open channel except for the slope.

Researcher: Is there any benchmark for slope?

Mr. Westsmith: I don't have any number on top of my head.

Researcher: Ok.

Q.4 Who should be involved in decision making about stream daylighting?

Definitely the city...also property owners along the creek, or if they have a committee that's sort of looking at how to develop a particular area. We have done some presentations to some people who were trying to do master plan for Mill Creek and trying to decide what do they want to do with it.

Researcher: Who are those people?

Westsmith: That was the East Dallas development committee. I forgot its name.

Researcher: Were any landscape architects or planners were involved?

Westsmith: Not in the location of the daylighting. That was all hydraulic driven...trying to remove land from the floodplain and to inexpensively (relatively) try to solve the flooding problem and to reduce the flood downstream.

Researcher: What are the pros and cons of daylighting streams?

Westsmith: The pros are, it's environmental friendly. You can do water treatment. That (it is) also a neighborhood enhancement, if you add park land to it. It's more enjoyable. The cons are: It takes land out of the tax base, because you need more right-of-way for the open channel as compared to storm sewer.

Researcher : Did you see any other solution for Mill Creek?

Westsmith: Yes, we thought about taking the pressure sewer all the way past this and not daylighting at all, and catching all the flow upstream...

Researcher: Did you think about opening the whole Mill Creek channel?

Westsmith: Not viable at all, cost-wise, because again (to) make Mill Creek all open channel...that would be taking...the creek actually goes through the middle of Baylor Hospital, and to route it around that would be going through higher ground and will have to be a much steeper channel, therefore more right-of-way and more property. The area that we did take was the most feasible for daylighting. A second thought (would be) just not making it an engineering solution, but having a stream restoration (would) help the local flooding a little bit.

We are not doing anything with Belleview...we are keeping that...the storm sewer, the main line downstream of I-30, has enough capacity for all the flow that is generated downstream of I-30. So we don't have to do anything with the main pipe...as long as we capture enough flow upstream and either detain it and divert it in the separate pressure sewer. We are talking about 6000cfs, we are not talking about 36 inch pipe. It's a lot of water.

Researcher: What is the present condition of the Belleview pressure sewer?

Westsmith: Actually it's very nice. We have some people walk up there and it is in very good condition, considering how old it is!

Researcher: How old is it?

Westsmith: Probably it is about 1930s. About 70-80 (years). It's in an excellent condition. It doesn't seem to be spalling. There are a couple of cracks. It's very smooth inside there.

Researcher: So another 50 years?

Westsmith: (Laugh) Keeping my fingers crossed. But yeah.

Researcher: Did you compare the cost of the Belleview sewer replacement? Did you see any funding resources?

Westsmith: We did take that into account. There is a possibility of outside funding. We did look at TxDOT participation, Corps of Engineers possible participation. During some of this, they showed interest but so far there is no money coming forth.

Researcher: Was there any public involvement?

Westsmith: Yes, we did some presentations to the public, to the neighborhoods that were affected by the flooding. All the different alternatives. We pointed out each (part)

of it. We can put storm sewer, here we can daylight, here we can put detention. We just explained everything to them and took their comments and went back and reworked the report.

Q.7. What are the key parameters that should be considered before determining which streams to daylight?

Cost... (Long silence) benefits to the area daylighted, (if the) stream (is in the) middle of the commercial area. If it's really industrial or shops and things like this, then yes, you can daylight in a commercial area. But putting it in somebody's parking lot and saying here is a daylighted stream...doesn't bring much benefit to the area. And then as we have talked about before, but again....velocities and possible structures you might have to add to slow down the velocities, and again the cost of the engineering part. In daylighting a stream you look at whether it's going to be a wet stream all the time or if it's going to be mostly dry. Those things which you have to consider, which offset the pros and cons like mosquito problems if you have standing water. And if all the water goes into the stream, then you have to look at all the debris from upstream that is collected in the grass on the slope. Somebody has to go there and clean it up all the time unless you capture the debris somehow before it gets there.

Researcher: Did you look at the property values which can be increased with daylighting?

Westsmith: We have not projected possible increases in properties. We are just looking...we state it as a benefit. Well, you know, whether the property value will go up to 50 % or 5% is sort of "crystal ball gazing eye" for an engineer (laughs).

Researcher: I am trying to say a long term benefit of daylighting.....

Westsmith: Well...it's interesting...some people say I want storm sewer just like they have up in the North Dallas, because they have got storm sewers and their storm sewers are big. They handle the entire flood. So some people will say, "OK, put it all underground so that we can develop this and make this a big tax base," and others say daylight and have more parks where people can play. But it's expensive.

Q.8. Are there criteria for deciding which sections of a stream should be left buried or which should be resurrected?

Again burying a creek...I would say not to bury a creek in the first place. The plan back to the Kessler Plan, a planner for Dallas said in the 30s...we should keep Mill Creek like Turtle Creek. But that didn't happen... they went in and connected the pipes on the roads and buried the creek. If they had kept it open to begin with, then a lot of this would not have been a problem. There would still (have been) a problem with crossing

I-30, because I-30 was built as a depressed freeway. They had to figure out how to get the water across, and the other thing was the outfall for Mill Creek is (where) the Belleview pressure sewer is. Again it can only convey about a 2 year flood, so we have to have a large amount of detention or some way to cut the peakable maintenance in the outfall. It's for 100 years, if all the water was cut off at I-30. So (if) it didn't have any water coming (from the) north part of the Mill Creek, then it's big enough, but it's not big enough for the watershed. It can carry about 2300-3000 cfs. But it's about 6000 cfs when the water gets there. We would need four city blocks for a detention pond in order to capture that much water in the lower portion. Being in the downstream end of the watershed, it doesn't give us much benefit because of its basin capturing it just before it gets to the Trinity River. So all the pipes upstream have to be improved (to be) able to hold water there. There is no reason to daylight if it already has the capacity. The City of Dallas had input on which one to choose for the final plan. We originally decided to do the detention and not having the open channel, but then they decided to do the open channel and pressure sewer.

APPENDIX D

ENHANCED DAYLIGHTING CRITERIA FOR MILL CREEK

REFERENCES

- Adams, Barry J, and Fabian Papa. *Urban Stormwater Management Planning with Analytical Probabilistic Models*. New York: Wiley, 2000.
- Aird, Janet. "Restoration of Streams and Buffer Zones." *STORMWATER, the Journal for Surface Water Quality Professionals* (2008). Feb. 2008
<http://www.stormcon.com/sw_0803_restoration.html>.
- Baeck, M. L. Smith, J. A. "Rainfall Estimation by the WSR-88D for Heavy Rainfall Events." *Weather and Forecasting* 13 (1998): 416-436. Academic Search Complete. UT Arlington Library, Arlington, TX. 5 Nov. 2007 <<http://search.ebscohost.com>>.
- Bennett, M and DW Teague. *The Nature of Cities: Ecocriticism and Urban Environments*. Tucson: University of Arizona P, 1999.
- Blomberg, Jorgen. Telephone interview. 25 Sep. 2008.
- Buchholz, Tracy, and Tamim Younos. *URBAN STREAM DAYLIGHTING Case Study Evaluations*. Virginia Polytechnic Institute and State University. Blacksburg, VA: Virginia Water Resources Research Center, 2007. 01 Sept. 2007
<www.vwrrc.vt.edu/pdfs/specialreports/sr352007.pdf>.
- Buchholz, Tracy, and Tamim Younos. *URBAN STREAM DAYLIGHTING Case Study Evaluations*. Virginia Polytechnic Institute and State University. Blacksburg,

- VA: Virginia Water Resources Research Center, 2007. 01 Sept. 2007
<www.vwrrc.vt.edu/pdfs/specialreports/sr352007.pdf>.
- Butler, David, and John W. Davies. *Urban Drainage*. London: E&FN Spon, 2000.
- Cairns, and Palmer . "Restoration of Urban Waterways and Vacant Areas: the First Steps Toward Sustainability." *Environmental Health Perspectives* 103 (1995): 452-453. JSTOR. UT Arlington Library, Arlington, TX. 26 Oct. 2007
<<http://links.jstor.org/sici?sici=00916765%28199505%29103%3A5%3C452%3AROUWAV%3E2.0.CO%3B2-T>>.
- City of Dallas and the North Texas Tollway Authority. *MS4 NPDES Permit No: TX000701 Closing Report*. Dallas: North Texas Tollway Authority, 2006.
- City of Portland Bureau of Environmental Services. *TABOR to the RIVER: BROOKLYN CREEK BASIN PROGRAM-sewer and green stormwater improvements for clean rivers*. 23 Sep. 2008 <http://www.portlandonline.com/bes/index.cfm?&cal=DisplayEvent&event_id=34910&mode=calendar&a=0&c=47591>.
- Conklin, Bruce, and David Noonan. "Managing Storm Flows in Boston and Brookline's Historic Emerald Necklace." *The Journal for Surface Water Quality Professionals Stormwater* 50.4 (2002): 79-110.
- Conradin, Fritz. "The Zurich Stream Daylighting Program". *Zurich Sewerage & Waste Dept., Switzerland*. 2004. 19 Aug. 2008 <<http://www.gsd.harvard.edu/events/conferences/restoration/pages/program/abstracts/zurichstream.htm>>.
- Dallas Appraisal District*. 2008. 10 Oct. 2008 <<http://www.dallascad.org/>>.

Dallas. Map. Dallas: TX, 1893.

“Design Merit Award: Strawberry Creek Park.” *Landscape Architecture* Nov. 1995: 46-47.

De Villiers, Marq. *Water: the Fate of Our Most Precious Resource*. Boston, MA: Houghton Mifflin, 2001.

De Villiers, Marq. *Water: the Fate of Our Most Precious Resource*. Boston, MA: Houghton Mifflin, 2001.

Ferguson, Bruce K. *Introduction to Stormwater Concept, Purpose, Design*. New York: Wiley, 1998.

Ferguson, Bruce K. "Urban Stream Reclamation. Bruce K. Ferguson Looks At How Cities Have Dealt with Restoring Stream Corridors That are Disrupted by Urban Development." *Journal of Soil and Water Conservation* 46.5 (1991): 324-328.

Ferguson, Bruce, Pinkham Richard, and Timothy Collins. "Restorative Redevelopment: the Nine Mile Run Model." *STORMWATER, the Journal for Surface Water Quality* Aug. 2001. 05 Dec. 2007
<http://www.stormcon.com/sw_0107_restorative.html>.

Figurski, Jim. E-mail to the author. 22 Sep. 2008.

France, R. L. *Handbook of Regenerative Landscape Design. Integrative Studies in Water Management and Land Development*. Boca Raton: CRCP, 2008.

“From Ditch to Delight: Movement Gives ‘Daylight’ to Lost Streams, Improves Water Quality.” *Daily Headlines* 02 Aug. 2005. 30 Aug. 2008
<<http://dailyheadlines.uark.edu/5072.htm>>.

- Green Streets Innovative Solutions for Stormwater and Stream Crossings*. Portland, OR: Metro, 2002.
- “Had a Career of Wide Achievement.” *Dallas Morning News* 20 Mar. 1923, Late Ed.: 1+ ed. *Texas Newspaper Collection*. UT Arlington Library, Arlington, TX. 25 Oct. 2007 <<http://www.newsbank.com>>.
- Halff Associates. City of Dallas. *Mill Creek Master Drainage Plan Study*. Dallas: Department of Public Works and Transportation Dallas, 2005.
- Hall, Landon. “Agency Sued Over Putting Hydropower Ahead of Fish.” *Seattle Post-Intelligencer* 04 May 2001. 10 Feb. 2008 <http://seattlepi.nwsourc.com/local/21559_salmon04.shtml>.
- Heaney, J.P, et al. “*Costs of Urban Stormwater Control*.” *United States Environmental protection agency*. Jan. 2003. 06 Mar. 2008 <<http://www.epa.gov/nrmrl/pubs/600r02021/600R02021.pdf>>.
- Henderson, Karla A. *Dimensions of Choice a Qualitative Approach to Recreation, Parks, and Leisure Research*. State College, PA: Venture Pub, 1991.
- Herzog, Thomas R. “A Cognitive Analysis of Preference for Waterscapes.” *Journal of Environmental Psychology* 3rd ser. 5 (1985): 225-241. *Sciencedirect*. UT Arlington Library, Arlington. 03 Nov. 2007 <<http://www.sciencedirect.com>>.
- House, M. A., et al. “Urban Drainage--Impacts on Receiving Water Quality.” *Water Science and Technology : a Journal of the International Association on Water Pollution Research*. 27.12 (1993): 159.

- Irwin, Elena G. "The Effects of Open Space on Residential Property Values." *Land Economics* 78.4 (2002): 465-480. JSTOR. UT Arlington Library, Arlington, TX. 26 Oct. 2007 <<http://www.jstor.org>>.
- James, William. "A Historical Perspective on the Development of Urban Water Systems." *University of Guelph*. 10 Dec. 2007 <<http://www.soe.uoguelph.ca/webfiles/wjames/homepage/Teaching/437/wj437hi.htm#top>>.
- Kaplan, Rachel , Stephen Kaplan, and Robert L. Ryan. *With People in Mind Design and Management of Everyday Nature*. Washington, D.C.: Island P, 1998.
- Kaplan, Stephen , and Rachel Kaplan. *Humanscape Environments for People*. North Scituate, Mass: Duxbury P, 1978.
- Karr, Jr, and Ew Chu. "Sustaining Living Rivers." *Hydrobiologia* 42.0 (2000): 1-14.
- Kelly, Fred. New Jersey. Department of Environmental Protection. *Restoration of Urban Streams: Practical Evaluation of Options for 319(H) Funded Projects*. Mar. 2001. 15 Feb. 2008 <www.nj.gov/dep/watershedmgt/DOCS/Restoration%20of%20Urban%20Streams.pdf>.
- Kelly, Fred. New Jersey. Department of Environmental Protection. *Restoration of Urban Streams: Practical Evaluation of Options for 319(H) Funded Projects*. Mar. 2001. 15 Feb. 2008 <www.nj.gov/dep/watershedmgt/DOCS/Restoration%20of%20Urban%20Streams.pdf>.
- Kessler, George E. *A City Plan for Dallas*. Dallas: n.p., 1911.

- Kirkby, G. "Streamkeepers: Restoring Urban Streams In The Heart Of Greater Vancouver." *Goldseal*. 1997. Canadian Fishing Company. 06 Mar.2008
<http://goldseal.ca/education/salmon_education.asp?article=6>.
- Kitchell, Anne, and Thomas R. Schueler. *Unified Stream Assessment: A User's Manual*. Urban subwatershed restoration manual, no. 10. Ellicott City, Md: Center for Watershed Protection, 2004.
- Klesius, Mike. "Daylighting: the Untombing of City Rivers." *River (Bozeman, Mont.)* 2.6 (1999): 83-88.
- Leopold, Aldo. *Round River; From the Journals of Aldo Leopold*. New York: Oxford UP, 1953.
- Levine, Adam. "FROM CREEK TO SEWER." *Philly H2O*. 3 July 2003. 05 Jan. 2008
<<http://www.phillyh2o.org/creek.htm>>.
- Lewis, Mark N. *Stream Daylighting As a Best Management Practice Applications for Water Quality Renovation and Habitat Enhancement*. 2003.
- Lynch, Kevin. *The Image of the City*. Cambridge [Mass.]: Technology Press, 1960.
- Mann, Roy B. "Ten Trends in the Continuing Renaissance of Urban Waterfronts." *Landscape and Urban Planning* 16 (1988): 177-199.
- Mason, Gary "WATER REBORN: A Story about Stream 'Daylighting' in the San Francisco Bay Area." Harvard University Graduate School of Design. 1999. 12 Jan. 2008
<<http://www.gsd.harvard.edu/events/conferences/restoration/pages/program/abstracts/waterreborn.htm>>.

- Map of Dallas, Texas showing Proposed park and boulevard system.* Map. Dallas, TX: City of Dallas, 1911.
- Mays, Vernon. "Stream of Consciousness." *Landscape Architecture* May 1999: 44+.
- McDonald, William Lloyd. *Dallas Rediscovered a Photographic Chronicle of Urban Expansion 1870-1925.* Dallas, Tex: Dallas Historical Society, 1978.
- Mcelhaney, Jackie. "Another Time, Another Place: a History of City Park." *Heritage News* Fall 1982: 222-990.
- Meyer, J.I., and J.b. Wallace. *Lost Linkages and Lotic Ecology: Rediscovering Small Streams.* Ecology: Achievement and Challenge, 10 Apr. 2000, The 41st. Symposium of the British Ecological Society and the Ecological Society of America. 03 Mar. 2008
<http://cwt33.ecology.uga.edu/results_inv_pub.php?s=50&var=Meyer>.
- Moses, Todd; Morris, Scott. "Environmental constraints to urban stream restoration. Part 1." *Public Works* 129:12 (1998): 45 - 48.
- Moses, Todd; Morris, Scott. "Environmental constraints to urban stream restoration. Part 1." *Public Works* 129:12 (1998): 25 - 28.
- Moses, Todd. "The Rehabilitation of City Streams: A Pragmatic Viewpoint". *villanova.edu* 17 Oct 2003. Villanova Univeristy. 17 Oct. 2007
<<http://www3.villanova.edu/VUSP/to/pasym03/pdfs/1C1.pdf>>.
- Newbury, R. *Field Manual of Urban Stream Restoration.* Champaign, Ill: Illinois State Water Survey, 1998.

- Noonan-Guerra, Mary Ann. *The Story of the San Antonio River*. [San Antonio, Tex.]: San Antonio River Authority, 1978.
- Owens-Viani, L. "Daylighting a Creek." *Urban Ecologist* 1997: 1.
- Owens-Viani, Lisa. "Clear Creek Comeback." *Estuary* 10.2 (2001).
- Owens-Viani, Lisa. "Clear Creek Comeback." **Estuary** 10.2 (2001).
- Owens-Viani, Lisa. "Forgotten Waterways See the Light of Day." *California Coast & Ocean* 15.1 (1999).
- Patel, Yogesh. Telephone interview. 01 Oct. 2008.
- Paul, M. J, and J. L Meyer. "Streams in the Urban Landscape." *Annual Review of Ecology and Systematics* 32 (2001): 333-365. JSTOR. UT Arlington Library, Arlington, TX. 21 Oct. 2007 <<http://www.jstor.org>>.
- Payne, Darwin. *Dallas, an Illustrated History*. Woodland Hills, Calif: Windson Publications, 1982.
- Poole, Kathy. "Wet Lands: Civic Stormwater + Contingent Spaces." *Landscape Journal* (1998): 28-30.
- Pratt, James. *Dallas Visions for Community: Toward a 21st Century Urban Design*. Dallas: Dallas Institute of Humanities and Culture, 1992.
- Pratt, James. Telephone interview. 08 Oct. 2008.
- Prejean, Robert. Telephone interview. 10 Sep. 2008.
- Prejean, Robert. *Uncovering Hidden Streams : Treatment of Central Dallas' Heritage Creeks : Dallas Institute of Humanities & Culture*. Dallas: R. Prejean, 2004.

- Promise, John. *Stormwater Management Handbook: Stormwater Estimation and Management Techniques for North Central Texas*. Arlington, TX: North Central Texas Council of Governments, 1984.
- Purcell, Alison H, Carla Friedrich, and Vincent H Resh. "An Assessment of a Small Urban Stream Restoration Project in Northern California." *Restoration Ecology* 10 (2002): 685-694.
- Richard, Pinkham. *Stream Restoration and Daylighting*. Arvada, Colorado: Research Associate, STUDIO for Creative Inquiry, Carnegie Mellon, 2002. 03 Feb. 2008 <<http://3r2n.cfa.cmu.edu/policy/lost/index.htm>>.
- Riley, Ann L. E-mail to the author. 29 Sep. 2008.
- Riley, Ann L., and Marty Roberts. *Urban Stream Restoration a Tour of Ecological Restoration Techniques*. [Santa Rosa, Calif.]: Nolte Media, 1998.
- Riley, Ann L. *Restoring Streams in Cities a Guide for Planners, Policy Makers, and Citizens*. Washington, D.C.: Island P, 1998.
- Rosgen, David L. *Applied River Morphology*. Pagosa Springs, Colo: Wildland Hydrology, 1996.
- Saxon, Gerald D. *Reminiscences, a Glimpse of Old East Dallas*. Dallas: Dallas Public Library, 1983.
- Schueler, Thomas R., and Ken Brown. *Urban Stream Repair Practices*. Urban subwatershed restoration manual, no. 4. Ellicott City, MD: Center for Watershed Protection, 2004.

- Schutze, Jim. "Underground Streams May See Daylight." *Dallas Observer* 30 Mar. 2006. 12 Feb. 2008 <<http://www.dallasobserver.com/2006-03-30/news/devil-creek/>>.
- Seoul Metropolitan Government. *Cheonggyecheon Restoration Project*. Seoul: Seoul Metropolitan Government, 2002. 17 Nov. 2007 <<http://www.metro.seoul.kr/kor2000/chungaehome/en/seoul/main.htm>>.
- Simson, Amanda. "Underground Streams May See Daylight." *The Cavalier Daily* 20 Apr. 2000. 20 Oct. 2007 <<http://www.cavalierdaily.com/CVArticle.asp?ID=4191&pid=575>>.
- Smith, Brooke Ray. "Assessing the Feasibility of Creek Daylighting in San Francisco, Part I: A Synthesis of Lessons Learned from Existing Urban Daylighting Projects." *Restoration of Rivers and Streams, University of California Water Resources Center Archives*. 13 Dec. 2007. 14 Sep. 2008 <<http://repositories.cdlib.org/cgi/viewcontent.cgi?article=1096&context=wrca>>.
- Smith, Brooke Ray. "Assessing the Feasibility of Creek Daylighting in San Francisco, Part II: A Preliminary Analysis of Yosemite Creek." *Restoration of Rivers and Streams, University of California Water Resources Center Archives*. 13 Dec 2007. 14 Sep. 2008 <<http://repositories.cdlib.org/wrca/restoration/smithii>>.
- Steinhart, Peter. "The Meaning of Creeks." *Audubon* May 1989: 22-23.
- Taylor, Steven J, and Robert Bogdan. *Introduction to Qualitative Research Methods a Guidebook and Resource*. New York: Wiley, 1998.

- The Associated Press. "East Dallas Drainage." *Dallas Morning News* 10 Sept 1930, late ed.: 15+. *Texas Newspaper Collection*. UT Arlington Library, Arlington, TX. 25 Oct. 2007 <<http://www.newsbank.com>>.
- The Associated Press. "Mill Creek's Storm Sewer Provided For." *Dallas Morning News* 30 Sep. 1930, late ed.: 15+. *Texas Newspaper Collection*. UT Arlington Library, Arlington, TX. 25 Oct. 2007 <<http://www.newsbank.com>>.
- "The Lost Creek." *Terra Nova: Nature and Culture* 1:4 (1996): 112-119.
- The San Francisco - Zurich Initiative*. 12 Sep. 2008 <<http://www.sfzhinitiative.com/>>.
- Thomas R. Herzog. "A cognitive analysis of preference for waterscapes." *Journal of Environmental Psychology* 5.3, (1985): 225 – 241. ScienceDirect. UT Arlington Library, Arlington, TX. 03 Nov. 2007 <<http://www.sciencedirect.com>>.
- Toronto Green Community*. 1994. 5 Feb. 2008 <<http://torontogreen.ca/>>.
- Trancik, Roger. *Finding Lost Space: Theories of Urban Design*. New York: Van Nostrand Reinhold, 1986.
- U.S. Environmental Protection Agency. *The Quality of Our Nation's Water: a Summary of the 1988 National Water Quality Inventory*. Washington, DC: Office of Water, 1998.
- U.S. Environmental Protection Agency. Heaney, J.P, et al. *Costs of Urban Stormwater Control*. Cincinnati, OH: EPA's Office of research and development, Jan. 2002.
- U.S. Environmental Protection Agency. Heaney, J.P, et al. *Costs of Urban Stormwater Control*. Cincinnati, OH: EPA's Office of research and development, Nov. 1995.

- U.S. Environmental Agency.(n.d.) Low Impact Development (LID).
<http://www.epa.gov/owow/nps/lid/> (accessed September 12, 2008)
- U.S. Environmental Agency.(n.d.) Effluent Guidelines for the Construction and
 Development Industry. [http://www.epa.gov/waterscience/guide/
 stormwater/#nsbd](http://www.epa.gov/waterscience/guide/stormwater/#nsbd) (accessed September 12, 2008)
- U.S. Office of Solid Waste and Emergency Response. Environmental Protection
 Agency. *Guidance for Developing Ecological Soil Screening Levels*. Feb. 2005.
 02 Mar. 2008 <<http://www.epa.gov/oswer/riskassessment/ecorisk/ecosl.htm>>.
- U.S. San Francisco Public Utilities Commission. *Low Impact Design Toolkit: What will
 you do with San Francisco's Stormwater?* Sep. 2007. 21 Sep. 2008
 <http://sfwater.org/Files/Reports/UWP_toolkit.pdf>.
- Wenk, William, and Billy Gregg. "Stormwater Gardens (Convey, Capture, and Reuse:
 Stormwater)." *Landscape Journal* (1998): 24-25.
- Westsmith, Richard. Telephone interview. 23 Sep. 2008.
- Wilson, William H. "Adapting to Growth: Dallas, Texas, and the Kessler Plan."
Arizona and the West Autumn 1983: 25.
- data.crgsc.org/
- iswm.nctcog.org/
- libguides.uta.edu/
- www.dfwmaps.com/clearinghouse/
- www.nrcs.usda.gov.
- factfinder.census.gov

BIOGRAPHICAL INFORMATION

Deepa Harkishore Koshaley was born in Madras (now called Chennai), India. Since childhood, she has a deep interest in arts, artifacts and paintings. Because her dad's job was transferable across the country, she has had the opportunity to know people of different cultures and closely interact with them.

She completed her five-year Bachelor Degree in Architecture from N.D.M.V.P.S. College of Architecture, Nasik, Pune University in 2002. Soon after her graduation, she started her career as an architect under reputable architects and landscape architects in Mumbai up to 2005. During her initial working experience, she realized that architecture is a vast creative field requiring specialized knowledge and skills in order to become a successful entrepreneur. She decided to pursue higher studies in landscape architecture from a reputable university.

She came to United States in August 2005 for her higher education studies in landscape architecture. During her studies in the United States, she did an internship with Carter & Burgess (Now Jacobs Carter & Burgess). She received a Master of Landscape Architecture from The University of Texas at Arlington.