STREAM DAYLIGHTING RESTORATION AS GREEN INFRASTRUCTURE:

A VISUAL PREFERENCE SURVEY FOR THE FUTURE

REVITALIZATION OF DALLAS' MILL CREEK

by

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Abstract

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The University of Texas at Arlington, 2015

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The purpose of this research is to study the visual design elements of stream daylighting through a visual preference survey and apply them to a site along the Mill Creek flowline in Dallas, Texas. This research begins with a study on identifying a specific site location within the Mill Creek watershed. From that study, a visual preference survey determined which visual design elements of stream daylighting were found to be the most desirable. The most desirable visual design elements were then used to digitally depict a suggested stream daylighting outcome through the use of before and after images of the selected site.

Before the 1960s, a common practice was to bury the smaller streams of watershed networks that were water sources for larger rivers, or headwaters, underground for industrial, transportation, and urban development reasons (American Rivers 2014). As a result of burying headwaters, there has been a steady increase of flooding hazards, water contamination and pollution, property damage, animal and plant habitat destruction, and loss of human life (American Rivers 2014; Halff Associates 2005; Koshaley 2008). However, an applicable technique to mitigate the aforementioned issues is called stream daylighting. Stream daylighting is the act of unearthing, restoring, and

revitalizing buried waterways (American Rivers 2014; Koshaley 2008). Studies have shown that the success of a stream daylighting project is determined by the benefits the project provides. Human engagement, increased animal and plant life, increased property value, temperature reduction, improved water quality, reduced air and water pollution, and decreased crime are all potential benefits of stream daylighting, (American Rivers 2014; Downtown Kalamazoo, Inc. 2015; Groundwork Hudson Valley 2015; Mecklenburg County, North Carolina 2015).

There are several studies measuring the success of stream daylighting, however, few studies have analyzed the visual design elements that could contribute to the success of a stream daylighting project. These elements include stream alignment, stream bank design, stream bank materials, stream bank slope, stream width, and water features. They also include how far the creek is from a roadway and how close the creek is to a pedestrian pathway. This study identifies a location and applies these elements to depict a possible stream daylighting scenario for the future.

Mill Creek, a major underground perennial creek system that feeds into the Trinity River, is one of a few major creeks found in Dallas, Texas. Since Mill Creek was buried underground in the 1930s, the outdated and deteriorating piping system has created numerous infrastructure, safety, economic, pollution, and ecosystem complications (Halff Associates 2005). Due to these complications, this area is selected as the study area. Landscape architects, engineers, planners, and researchers can use the findings to not only guide similar studies but further guide similar projects in the area as well. The findings concluded that a braided and divided stream with a 10-20 foot width was very desirable for the area. The stream would include rocks and boulders along its banks with rippling and wave effects. An overtly designed planting scheme, immediately adjacent pathway, and distant roadway would help define the spatial edge of the stream.

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Chapter 1

Introduction

1.1 What is Green Infrastructure?

"Green Infrastructure" (GI) is a multifaceted tool utilized in today's urban planning, urban design, engineering, environmental science, architectural, and landscape architectural practices. It encompasses a wide range of valuable principles, ideas, techniques, and functions that have continuously assisted the design and development of human civilizations throughout history (Kostof 1999). Recently, defining GI in its entirety has become increasingly difficult due to how broadly the term is understood and used in all stages of the design process.

GI represents a common avenue of economic, social, and environmental sustainability ideas that can be mimicked and retrofitted for any size project, ranging from small-scale residential to regional and city-scale visions (M'Ikiugu et al. 2012). Green infrastructure and its functions have been critical to the progression, expansion, integration, and evolution of urban ecosystems (Benedict and McMahon 2002). Derived from recent literature and for the purposes of this research, green infrastructure is defined as a multi-scalar and multifunctional approach to conserving, enhancing, and creating natural or built ecosystems, elements, and concepts that encourage a beneficial interconnectivity between nature and people (Benedict and McMahon 2002; Marsh 2010; M'Ikiugu et al. 2012; Young et at. 2014).

GI adapts and alters itself to fit the needs or demands of any particular society. This flexible quality ensures the long term relevancy of green infrastructure as a valuable planning, engineering, scientific, and design practice into the future (Benedict and McMahon 2002). In other words, when society changes its views on suitable sustainable alternatives or innovations, the ideas and applications of green infrastructure change

along with it (Benedict and McMahon 2002; M'Ikiugu et al. 2012; Nazir et al. 2014; Young et at. 2014).

1.2 Green Infrastructure, Stream Daylighting, and Mill Creek, Dallas, TX

GI sits within a spectrum of infrastructure that most people think of as roads, sewers, utility lines, and highways. This type of infrastructure is referred to as gray infrastructure (Benedict and McMahon 2002). Gray infrastructure is the framework for social infrastructure, which consists of, but is not limited to, hospitals, schools, restaurants, government institutions, and prisons. Collectively, they are referred to as built infrastructure (Benedict and McMahon 2002). The Conservation Fund and USDA Forest Service collaborated in 1999 to form a Green Infrastructure Work Group that defined GI, within the other infrastructure types, as:

> "...our nation's natural life support system - an interconnected network of waterways, wetlands, woodlands, wildlife habitats, and other natural areas; greenways, parks, and other conservation lands; working farms, ranches, and forests; and wilderness and other open spaces that support native species, maintain natural ecological processes, sustain air and water resources, and contribute to the health and quality of life for America's communities and people" (Benedict and McMahon 2002, p. 12).

With this in mind, these infrastructure systems can be classified separately as urban overlays and underlays that work in tandem with one another, feeding off of each other to create today's urban societies. In recent years, the relationship between green, gray, and social infrastructure types has begun to merge, blend, and produce innovative opportunities. Stream daylighting and restoration has emerged as a representative example of this blending.

Stream daylighting is "a deliberate act of exposing the full or partial flow of previously buried rivers, creeks, and streams into restored surface waterways" (American Rivers 2014; Koshaley 2008, p. 5). Deliberately daylighting a stream has become a

popular alternative to water channelization. Stream daylighting is a relatively new trend that has been strategically implemented all over the world in locations such as the United States, South Korea, British Columbia, and New Zealand, just to name a few (American Rivers 2014). Stream daylighting projects have offered a view into the hydrological, geomorphological, ecological, and social outcomes they provide for the urban ecosystems they are a part of (American Rivers 2014). As a result, these fields of research have become increasingly more critical to the strategies and stages of redevelopment that include stream daylighting within its proposed features or methods of construction (American Rivers 2014).

In 2005, the City of Dallas authorized Halff Associates, Inc. to inventory and analyze the gray infrastructure network of an underground perennial creek system known as Mill Creek. This Mill Creek Master Drainage Plan and the conclusions found from its analysis revealed not only the extent of the drainage problems, but also indicated how underutilized and deteriorated the piping system had become since its installation in the 1930s (Halff Associates 2005). The results from the analysis contained several proposed alternatives for improving the infrastructure issues, which also included stream daylighting. This thesis incorporates an in-depth interpretation of the Mill Creek Master Drainage Plan study that proves necessary to: (1) properly discuss the future of Mill Creek both at a design level and political level, and (2) that daylighting, to any degree, is a highly probable alternative outcome.

1.3 Research Purpose and Objectives

The purpose of this research is to study the visual design elements of stream daylighting through a visual preference survey and apply them to a site along the Mill Creek flowline in Dallas, Texas. This research has three (3) main objectives: (1) To target

a specific site location within the Mill Creek, Dallas Texas, watershed, (2) to determine the desirability of stream daylighting design elements through the use of a Visual Preference Survey, and (3) to use photography from the site location to represent and visually depict the most desired design elements through a digitally enhanced scene, or visualization. The Visual Preference Survey is used to evaluate the public's perception of alternative visual design opportunities presented by stream daylighting. Responses to the Visual Preference Survey are used to assess the value of applying these elements to Mill Creek and to similar stream daylighting and restoration projects in the Dallas area.

1.4 Primary Research Questions

The questions that this research answers are:

1. What visual design elements are most desirable in stream daylighting?
2. How can these visual design elements of stream daylighting be successfully used in the future revitalization of the selected site at Mill Creek, Dallas, Texas?
3. What could landscape architects learn from the Visual Preference Survey that can help guide and direct similar studies and projects in the Dallas and Fort Worth areas?

1.5 Methodology

First, a specific site location was chosen along the current Mill Creek flowline. Second, design element criteria were determined for the Visual Preference Survey through an interpretation of the Green Infrastructure Gauge (GIG) (M'lkiugu et al. 2012) in order to understand which GI design elements are applicable to stream daylighting. Third, a series of existing daylighted stream, river, and creek projects were gathered and represented through photography in the Visual Preference Survey. Lastly, the Visual

Preference Survey was distributed utilizing snowball sampling, a method of chain-referrals through acquaintances, to a number of key individuals and organizations.

1.6 Definitions of Terms

Aesthetics: The science of beauty which expand upon the philosophical principles and teachings of harmony in nature or art (Ewald 2001; Lu et al. 2015; Nohl 2001).

Biodiversity: A diverse and variety-driven accumulation of life of a specific habitat or ecosystem within a particular location on earth (Greco 2014; M'Ikiugu et al. 2012).

Built Infrastructure: A term used to describe both the gray and social infrastructures as a combined idea (Benedict and McMahon 2002).

Cultural/Historical Identity: Societal values such as heritage, worship, fashion, folklore, music, dance, language, film, landmarks, architecture, historical, and traditional practices (M'Ikiugu et al. 2012).

Design Element: A feature or features portrayed physically through principles of color, shape, texture, space, form, unity, harmony, balance, hierarchy, scale, proportion, emphasis, similarity, or contrast specifically and contextually (Lidwell et al. 2003).

Disaster Prevention and Mitigation: Protecting an area against floods, storm damage, landslides, earthquakes, fires, droughts, and mitigation of disaster impact (M'Ikiugu et al. 2012).

Economic Activity Support: Provides people opportunities for avoided cost, willingness to pay, hedonic pricing, and marketable goods such as fish, raw materials, recreation, and services (M'Ikiugu et al. 2012).

Ecosystem: A woven network of complex interactions between organisms and their environment (Ahern et al. 2014; Greco 2014; Marsh 2010; Steiner 2014).

Energy Saving: Reduces energy use, demand, and cost (Marsh 2010; M'Ikiugu et al. 2012).

Environmental Education: Providing opportunities for cognitive development, awareness, school excursions, and scientific research (M'Ikiugu et al. 2012).

Food/Resource Production: A source of food, natural raw materials, biomass, fodder, fish, game, and minerals (M'Ikiugu et al. 2012).

Geomorphology: The scientific study of how topography evolves and is created by physical or chemical processes that operate within the earth's surface (Gilvear 1999; Marsh 2010; Newbury 1998; Philips 2011 & 2012).

Gray Infrastructure: A layer of hard, engineered infrastructure that is most commonly known to include roads, storm sewers, gutters, tunnels, culverts, detention basins, utility lines, and highways (American Rivers 2014; Benedict and McMahon 2002).

Green House Gas Reduction: Sequestering carbon, reduction in or alternatives to greenhouse gas emitters (M'Ikiugu et al. 2012).

Green Infrastructure: A multi-scalar and multifunctional approach to conserving, enhancing, and creating natural or built ecosystems, elements, and concepts that encourage a beneficial interconnectivity between nature and people (Benedict and McMahon 2002; Marsh 2010; M'Ikiugu et al. 2012; Young et at. 2014).

Headwater: The smallest streams in a watershed network which are a source of water for larger rivers, typically taking on numerous forms – from small, clear, heavily-shaded springs, to those that flow intermittently following snow melt or rain, and even desert streams that arise from a spring and run above ground (American Rivers 2014).

Hydrology/Hydrologic: The study of earth's water in relation to topographic change, soil structure, movement, velocity, capacity, biological incubation, and chemical properties (Gilvear 1999; Marsh 2010; Newbury 1998; Phillips 2012; Yuill et al. 2013).

Local Climate Improvement: Cooling effects to buildings and spaces, urban heat island mitigation, air circulation, humidity regulation, and wind effect (M'Ikiugu et al. 2012).

Mill Creek, Dallas, Texas: Originally a perennial creek, Mill Creek 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; Koshaley 2008; Pratt 1992).

Nature Conservation: Maintenance of flora and fauna such as native species in their natural habitats. Promote natural systems such as hydrological and nutrient cycles (M'Ikiugu et al. 2012).

Noise Reduction: Buffers and attenuates noise from static or mobile sources before reaching possible disturbance areas (M'Ikiugu et al. 2012).

Perennial Creek System: A stream or river body that has a continuous flow of water throughout the entire year (Koshaley 2008; Newbury 1998).

Planning Structure: Part of the planning components used in the area's overall master plan, either as a physical or philosophical element (M'Ikiugu et al. 2012).

Pollutant Filtration: Water filtration, air cleaning, trapping of dust, breakdown and removal of toxic nutrients and compounds (Marsh 2010; M'Ikiugu et al. 2012).

Public Health Promotion: Encourage physical exercises, jogging, walking, cycling, therapy, clean environment, elimination of vermin and parasites among sites (M'Ikiugu et al. 2012).

Public Infrastructure Cost Reduction: Replaces or reduces public works and alternative transport and communication means (M'Ikiugu et al. 2012).

Rain Water Harvesting: Capacity to trap, store, and use rain water especially for irrigation, and cleaning (M'Ikiugu et al. 2012).

Recreation Opportunity: Provides a chance for travel to natural ecosystems, ecotourism, outdoor sports, play, and relaxation (M'Ikiugu et al. 2012).

Social Infrastructure: A layer of infrastructure that is most commonly known to include hospitals, schools, restaurants, government institutions, and prisons (Benedict and McMahon 2002).

Storm Water Management: Reduction of runoff via increased infiltration, temporary holing before release, evapotranspiration and / or re-use (M'Ikiugu et al. 2012).

Stream Daylighting: A deliberate act of exposing the full or partial flow of previously buried rivers, creeks, and streams into restored surface waterways through architectural, cultural, environmental, and economic revitalization (American Rivers 2014; Koshaley 2008; Marsh 2010).

Stormwater: Precipitation that becomes polluted as it flows over driveways, streets, parking lots, construction sites, agricultural fields, lawns, and industrial areas. Pollutants associated with stormwater include oils, grease, sediment, fertilizers, pesticides, herbicides, bacteria, debris, and litter. Stormwater washes these pollutants through the storm sewer system and into local streams. In addition, because impervious surfaces prevent precipitation from soaking into the ground, more precipitation becomes runoff, and the greater volumes and velocities of stormwater can scour stream and river channels, creating erosion and sediment problems (American Rivers 2014; Marsh 2010).

Watershed: All the land that drains to a given stream or low point; a drainage basin defined by topographic divides (Koshaley 2008; Marsh 2010; Newbury 1998).

1.7 Overview of the Study

The research begins with an exploration of green infrastructure and its influences on urban ecosystems at the economic, social, and environmental levels. This exploration also takes into account the relationship between gray and social infrastructures, known together as the built infrastructure (Benedict and McMahon 2002). Stream daylighting and restoration has emerged and recently proven to play a vital role in the current evolution of the GI term (American Rivers 2014).

Chapter Two includes a literature review of related topics and documentation on GI, a brief historical background behind Mill Creek, Dallas, Texas, criteria for stream daylighting, aesthetic quality in the form of preference via perception, and a series of representative examples of current and future stream daylighting projects from around the world. Chapter Three outlines the research methods which include the selection of a specific target site location, a review of GI principles and design elements, and a Visual Preference Survey, which offers alternative versions of possible stream daylighting design approaches for Mill Creek. Chapter Four synthesizes the findings and outcomes from the Visual Preference Survey and visually depicts the most desirable design elements as a digitally enhanced stream daylighting scene along the Mill Creek flowline. Chapter Five concludes the research by summarizing the survey results and presents an overview of the potential for future research on the topic of stream daylighting.

Chapter 2

Literature Review

2.1 Introduction

Bacon (1976) states that spatial awareness ascends beyond cerebral activity. It engages the full spectrum of senses and feelings, requiring involvement of the entire self to make a complete response to it possible (Bacon 1976). This is a poetic interpretation of how human beings experience their immediate surroundings through visually analyzing the variable categories they are comprised of. These categories include texture, sound, form, smell, sightlines, distances, colors, heights, and proportions. These categories are essential to the development and placement of design elements that are encompassed within GI functions, which in turn can inform stream daylighting and restoration efforts.

2.2 The Evolution of Green Infrastructure

2.2.1 The Origins and Influences

Green infrastructure is a relatively modern interpretation of introducing "natural" functions and aesthetics into urban areas. GI is a concept that has emerged as a way to ensure the retrofit of ecosystem services in human-dominated landscapes (Ahern 2014). GI is not a new idea. The modernist incarnation of GI sprung from planning and conservation efforts that began as far back as one-hundred and fifty years ago. It has evolved from (1) the linking of parks and green spaces for the benefit of people, and (2) the joining of natural areas for biodiversity benefits and to counter fragmentation between habitats (Benedict and McMahon 2002).

"In 1903, landscape architect Frederick Law Olmsted stated that, 'no single park, no matter how large and how well designed, would provide the citizens with the beneficial influences of nature.' Instead, parks needed 'to be linked to one another and to

surrounding residential neighborhoods.' The idea of linking parks for the benefit of people sparked the modern greenways movement" (Benedict and McMahon 2002, p. 13).

Olmsted's concepts are seen throughout historical accounts of city, town, and village planning dating as far back as the second and third centuries. Rome's urban scenography and the Attalid dynasty's capital, known as Pergamon, used an integrated series of visual and kinetic experiences during the Classical and Hellenistic periods (Kostof 1999). Themes such as these influenced and led to a more commonly referenced era known as the European Baroque or simply, the Baroque, through the 16th and 18th centuries. The foundational planning frameworks and innovative inventions of emotionally, physically, and experientially linking people to their surroundings manifested from Baroque thinking, which in turn translated into The Grand Manner (Bacon 1976; Jacobs 1995; Kostof 1999). The Grand Manner incorporates elements of design that we still use today through GI to soften our urban communities and enrich the physical and meta-physical experiences. Examples of such elements include (Bacon 1976; Kostof 1999):

- street intersection and corner placemaking opportunities when the straight and diagonal streets of interconnected grids meet, which offer spaces for naturalistic elements to be used
- an articulated awareness and use of tree-lined streets, boulevards, and medians
- standardized street tree species that accent and celebrate publically oriented civic spaces

More recently, GI has evolved from the Grand Manner and Baroque design philosophies to fit society's needs for the twenty-first century, particularly in the field of hydrology. These philosophies differ from modernist open space planning due to the

views and values they have on conservation, land development, growth management, and the built infrastructure (Benedict and McMahon 2002). As a result of this differentiation, these philosophies have been commonly misused or in other cases completely ignored for the sake of efficiency in funding, construction, politics, industry, and design (Benedict and McMahon 2002).

An important and redefining moment for GI coincided with the decline in popularity of the engineering of urban waterway "improvements" which, for a time, produced concrete-lined channels. The sole purpose of these concrete channels was to capture and direct volumes of water out and away from urban development. "A few decades ago, the relationship between fluvial, or river, geomorphology and river engineering was unclear. Engineering involved the use of straight trapezoidal channels, impoundments, embankments, and a range of training structures to control rivers and their flow. Little consideration was given to downstream environmental impacts. When engineering structures failed, it was normally explained by ‘design’ flood exceedance rather than the dynamics of the geomorphic system had not been taken into account. At the same time, geomorphology was generally concerned with landscape evolution over timescales that seemed inappropriate to the realm of the engineer, and fluvial geomorphology was in its infancy" (Gilvear 1999, p.230).

Given the advances and awareness of new technological breakthroughs and innovations relative to structures and the materials they are made of, certain geomorphological conditions can still implicitly justify the use of a channelized system that was engineered for hydrological drainage in urban settings. However, the lessons learned from modern geomorphologic studies prior to engineering a channel are critical in the transition from the 'wrong way to do it' to the 'right way to do it' (Phillips 2012, p. 151). Dams, levees, and spillways have implications that still need to be designed, directed,

and developed around the physical realm of existing natural conditions and what their value towards the urban context means (Brown 2008).

With today's growing urbanity, the situation with Dallas, Texas, and the Mill Creek watershed becomes especially critical to the success of future redevelopment efforts due to its underground concrete channelization network. Engineering a channelized system on the scale of Mill Creek is a strategy that is undergoing scrutiny in light of the advantageous impacts GI has proven to offer urban ecosystems. As stated in Halff Associates' analysis of the underground piping system of Mill Creek in 2005, the general concerns of concrete channels are the failures to: (1) prevent flood hazards, (2) limit/control the input of contamination and pollution, (3) avoid unwanted economic, social, or environmental impacts, and (4) decrease overwhelming volumes of local water runoff. These problems associated with Mill Creek being underground for approximately eighty (80) years not only affect the immediate communities, businesses, and organizations within the Mill Creek Watershed, but also affect the areas downstream as well (Halff Associates 2005).

2.2.2 Environmental, Social, and Economic Applications

2.2.2.1 Environmental Applications

An understanding of both the natural and built ecologies of streams and their fundamental mechanics is critical to illustrate why conventional open channel flood design has been detrimental to ecological conservation and natural preservation (Greco 2014). "Key essential natural community and ecosystem patterns, processes, and concepts, which are not considered in conventional flood control channel design, include: naturalized flow regimes, flood-pulse, geomorphically effective stream power, channel meander, floodplain age, bed load transport, vegetation dynamics, patch dynamics and

minimum dynamic area, minimum dynamic area for channel meander using set-back levees, river continuum, large woody debris recruitment, large river ecology, and riparian landscape ecology" (Greco 2014, p. 15).

Green Infrastructure within urban ecosystems, including stream daylighting, attempts to restore the functions and aesthetics of the natural environment. The emergence of this concept has brought skepticism and criticism from a traditional engineering standpoint, as parts of the ecosystem may be found by society to have no value (Steiner 2014). Rebuilding the natural environment to its pre-development state should not control the design criteria used in the decision-making process for community planning. On the contrary, restoration of natural ecosystem services can assist in the understanding of benefits that the general public can derive from our environments (Steiner 2014). "Ecosystems provide direct services, including air, minerals, food, water, and energy. Our environments supply regulating services, such as the purification of water, carbon sequestration, climate mitigation, waste decomposition and detoxification, crop pollination, and pest and disease control. The environment furnishes support services, including seed dissemination and nutrient dispersal and cycling. The environment also produces cultural benefits, such as intellectual inspiration, recreation, ecotourism, and scientific discovery" (Steiner 2014, p. 305).

2.2.2.2 Social Applications

Since the beginning of the greenway movement in 1867 with Frederick Law Olmsted's Boston Park System (the Emerald Necklace), a strategy of any green infrastructure implementation effort has been to synthesize how nature and humans interact (Fábos 2004; Marcus and Francis 1998). The social impact GI has on the interaction between people spans all types of cultures, incomes, and values. Cities like

Los Angeles, Seattle, New York City, Boston, Portland, and Shanghai offer great examples of this interaction (Baptiste et al. 2015; Marcus and Francis 1998). People of all incomes say clean air, an abundance of trees, natural landscapes, places that make them feel better, family safety, opportunities to walk, and places to sit outside are extremely valuable (Marcus and Francis 1998).

Green Infrastructure initiatives and projects provide people a green framework of parks and linear open spaces that are ultimately meant to thrive within their contexts. Creating a green framework helps sustain a vital public realm (Richards 2005). This green framework acts as a stage for people to interact, engage, and flourish, while offering placemaking opportunities for social growth (Richards 2005). "Preserve the best and most distinctive natural features and extend and link them to create a generous, interconnected network of green space, framing urban growth, and buffering incompatible uses while providing a wide range of landscape experiences. Wildness, passive green space, and urbanity should intermingle, offering visual diversity, a variety of settings, and many choices for recreational pursuits" (Richards 2005, p. 48).

2.2.2.3 Economic Applications

Retrofitting GI into an urban environment, especially stream daylighting and restoration, is costly, ranging into the millions of dollars per mile (Halff Associates 2005). However, the benefits outweigh the costs by increasing property values, ensuring cost prevention for long-term culvert maintenance costs, water treatment costs, reducing the amount of stormwater flowing into combined sewer systems, providing job creation, and offering unique places for people to experience, enjoy, and return to (United States Environmental Protection Agency 2015).

"Implementing projects in public spaces can showcase the aesthetic appeal of green infrastructure practices and provide a visual demonstration of how they can function. This real-life context will also allow residents, businesses, and local governments to experience additional benefits and values of many green infrastructure practices such as more walkable streets, traffic calming, green public spaces, shade, and enhanced foot traffic in retail areas. Municipal managers can then use the experience gained from the design, installation, and maintenance of the green infrastructure projects to help tailor regulations and incentive programs and make green infrastructure easier to implement in the future" (United States Environmental Protection Agency 2015, p. 1).

2.3 The History of Mill Creek, Dallas, Texas and its Perception Today

2.3.1 Introduction

"In Dallas' early days, Mill Creek, a tributary of the Trinity River, flowed from the Park Cities (east of Southern Methodist University 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" (Koshaley 2008, p. 53). Today, after approximately eighty (80) years of being buried underground, Mill Creek and its inadequate piping infrastructure spanning over three (3) miles has caused numerous floods, property damage, financial tolls, and loss of life (City of Dallas, 2013).

2.3.2 The History of Mill Creek

In 1910, City of Dallas master planner, George Kessler, proposed a series of parkways (Figure 2-1 & 2-2) associated with east Dallas' Turtle Creek, Mill Creek, and the

Cedar creeks (Kessler 1911). This was an attempt to create a link of linear green spaces for existing amenities that meandered and emphasized the natural creek systems found throughout the city. As major tributaries for the Trinity River, both Turtle Creek and Mill Creek offered aesthetic opportunities for the developmental character of Dallas at the time.

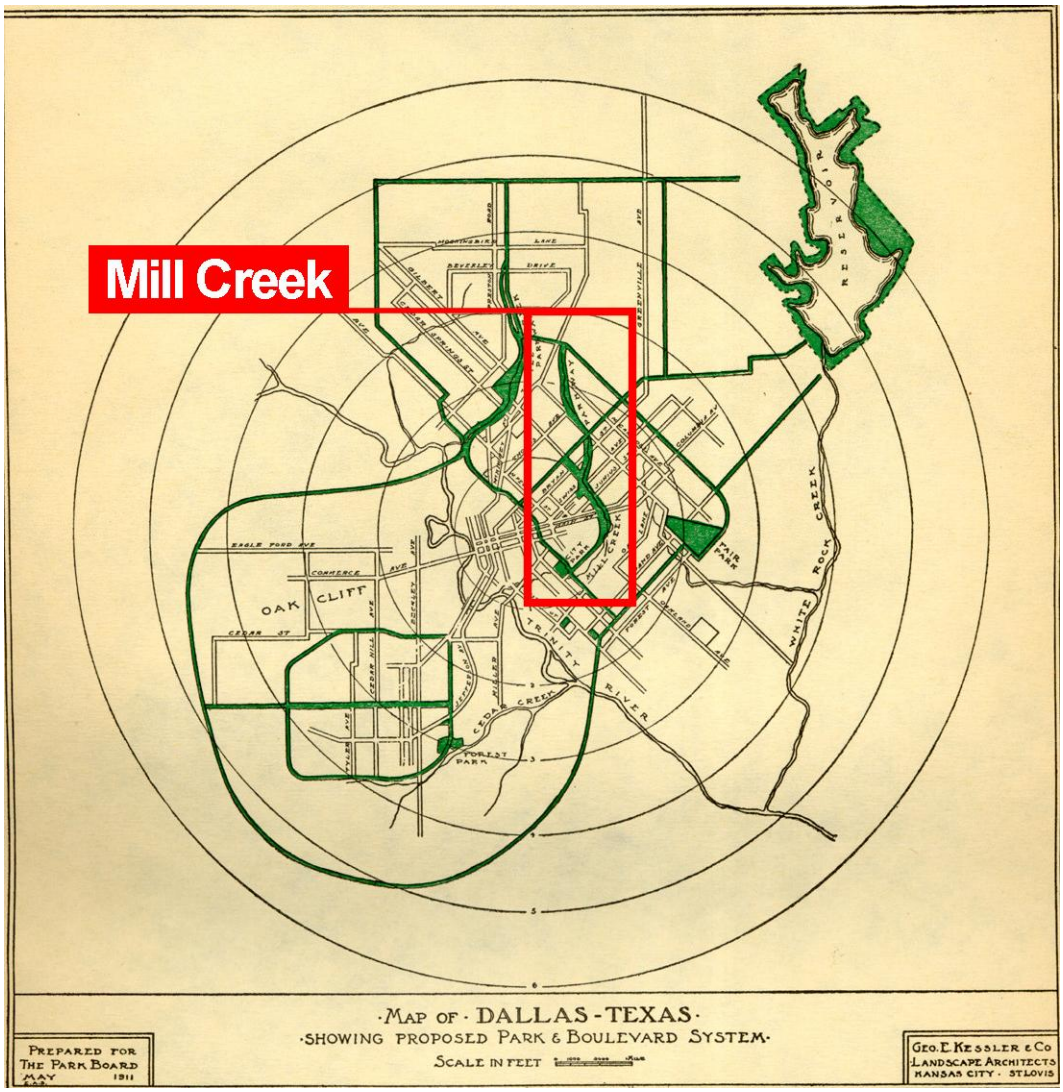

Figure 2-1 Kessler Greenbelt Plan of 1911

(Data Source: Dallas Public Library 2015)

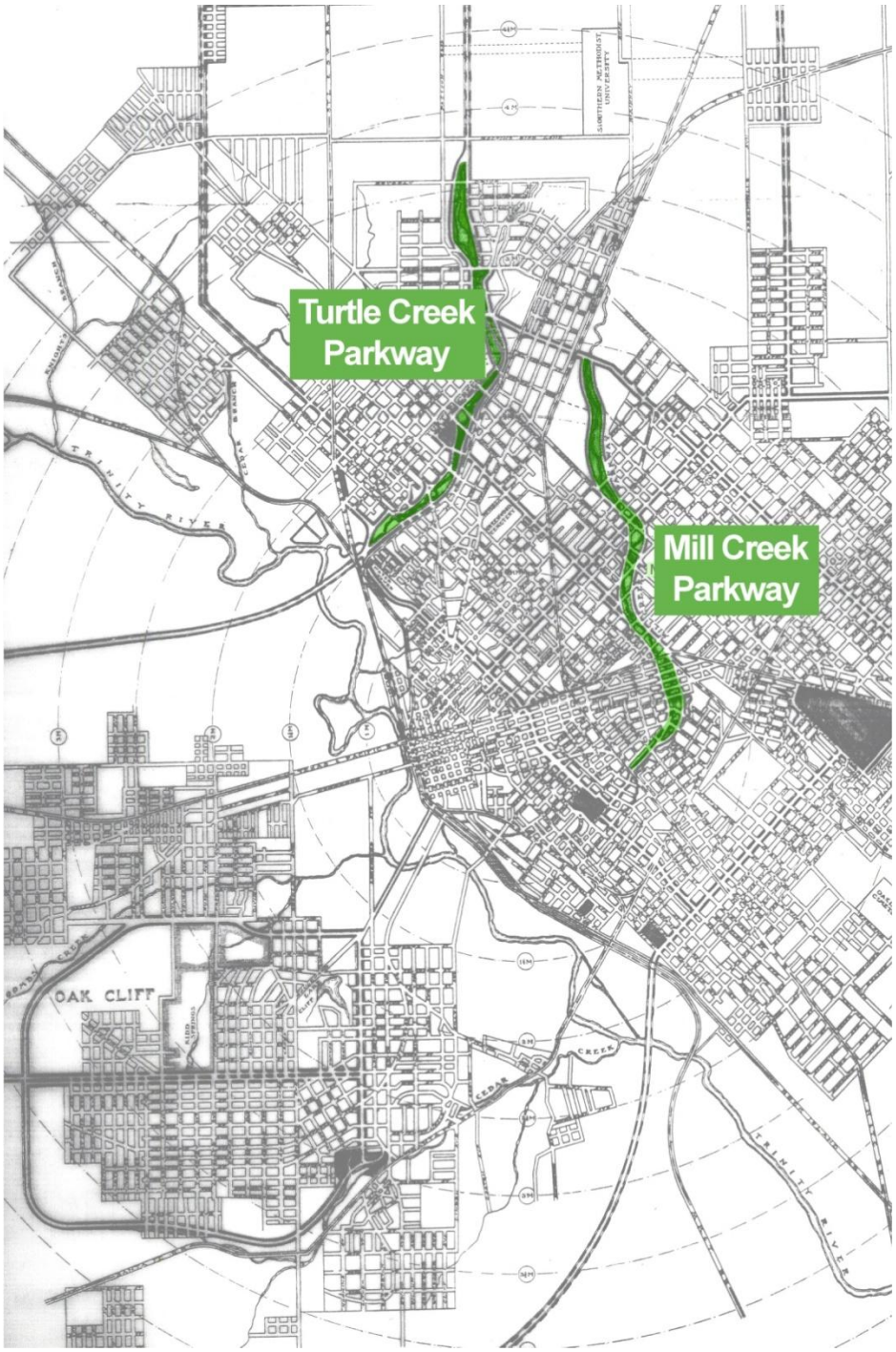

Figure 2-2 Mill Creek Parkway and Turtle Creek Parkway 1911

(Data Source: Dallas Public Library 2015)

Over time, the City of Dallas accepted some of Kessler's advice but limited the parkway concept to only the Turtle Creek area. Today, Turtle Creek is a prized gem that sits in some of the most valuable land throughout the city. It is a destination that links north Dallas to its downtown core. On the other hand, Mill Creek was cast aside. None of Kessler's plan for Mill Creek was implemented and the area became an industrial corridor instead of a parkway. As a result, Mill Creek was buried underground (Figure 2-3 & 2-4) and put into a large piping system in the 1930s. During the stream burial process, urbanization throughout the City of Dallas, as well as the Mill Creek watershed, was still in its infancy and would not become overwhelming until after WWII (Koshaley 2008).

Figure 2-3 Frame house beside a creek - South Preston Road by Old City Park 1930

(Data Source: Dallas Public Library 2015)

Figure 2-4 Mill Creek storm sewer construction 1950

(Data Source: Dallas Public Library 2015)

New development in the area has gradually increased in the amount of surface runoff that gets channeled into the piping system. In 1995 and 2006, Dallas suffered major flooding, bringing attention back to Mill Creek. Due to the underground infrastructure's outdated and undermanaged piping system, there were thirty-nine (39) reports of damage and structures being flooded (Baeck 1998). Unfortunately, the floods reached the Baylor Hospital Emergency Room and caused loss of life (Baeck 1998).

2.3.3 The Importance of Mill Creek Today

When flooded, some streets in the Mill Creek Watershed look and act like rivers (Figure 2-5 through 2-9) with flood depths up to 10 feet high in some areas (City of Dallas 2013). Approximately 3,800 properties are currently impacted by one (1) foot or more of

flooding in the Mill Creek/Peaks Branch area due to inadequate piping systems (City of Dallas 2013).

16 deaths blamed on storm

Paul Griffin on Saturday examines some of the damage inflicted on cars at Fair Park during Friday's storm.

4 missing after floods; 100 hurt

By Randy Lee Loftis and Nora López

The stunning violence of the latest spring storm to slam through the Dallas area became clear Saturday: At least 16 people were dead and an much as $60 million worth of property damaged after Friday night's rain-pegs.

Among the victims of one of the area's deadliest, most destructive storms in history were five members of an Oak Cliff family who drowned when floodwaters washed away their car.

At least seven people drowned in other flooded areas. A lightning-spawned fire killed a Dallas woman, and a lightning strike killed an Irving boy. Late Saturday, at least four people were missing and feared dead.

Late Saturday, searchers continued going through a

Please see 16 DEATHS on Page 20A.

911 response times criticized

By Nora López and Jason Sickles

Staff Writers The Dallas Morning News

During Friday's devastating rains and hail, hundreds of motorists were stranded in city streets submerged under several feet of water. Roofs collapsed under the strain of heavy rain. Families watched in horror as loved ones were swept away in storm drains.

Nearly all turned to 911 for help. Many times, all they got was a busy signal.

City officials said the demand for city services was so great late Friday that the calls simply overloaded the 911 system, resulting in busy signals and delayed response times of up to an hour.

"No practice. We train. We study. And we prepare

Please see CALLS20 on Page 20a.

Lives lost, families torn

Storm victims from all walks of life, neighborhoods

By Bill Miesnaglio and Eric Gazzia

Staff Writers of The Dallas Morning News

The surrounding storm leave no boundaries when it claimed its victims.

There was the elderly woman who quietly cared for the animals in her neighborhood. The teacher who had proudly posed for a recent photo with her young students. The family of five swept away as they headed for a restaurant.

One woman was saved from the flooding — only to be engulfed

Please see VICTIMS on Page 20A.

NORTH TEXAS STORMS

Storm makeup	20A	Closings	22A
World storms	20A	TV coverage	22A
The damage	20A	Effect on voting	22A
How to help	20A	Drainage woes	22A
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Figure 2-5 Fair Park - May 5, 1995

(Data Source: City of Dallas 2015)

Figure 2-6 Hall Street - March 19, 2006

(Data Source: City of Dallas 2015)

Figure 2-7 Skillman Street near Oram Street - March 19, 2006

(Data Source: City of Dallas 2015)

Figure 2-8 Baylor Hospital, Worth Street at Hall Street - March 19, 2006

(Data Source: City of Dallas 2015)

Figure 2-9 Munger Boulevard - March 19, 2006

(Data Source: City of Dallas 2015)

Figure 2-10 Flooding of IH-30 - March 19, 2006

(Data Source: City of Dallas 2015)

Figure 2-11 Police cruiser - Flooding of IH-30 - March 19, 2006

(Data Source: City of Dallas 2015)

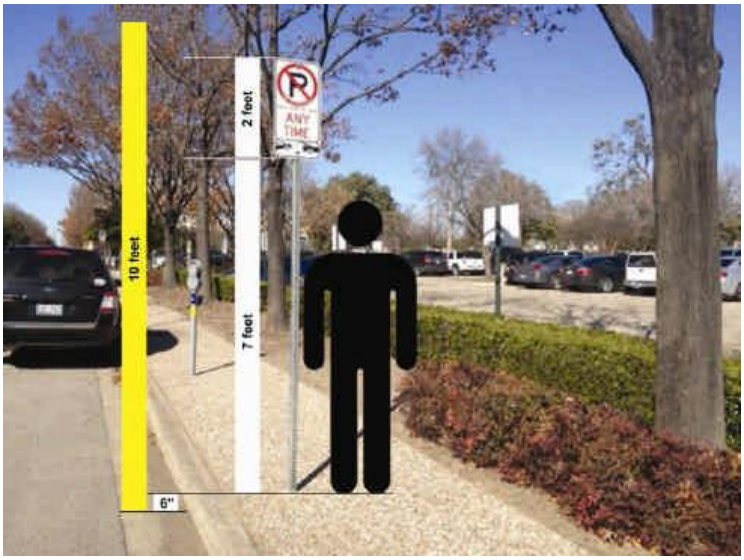


Figure 2-12 10' flood depth analysis 2013

(Data Source: City of Dallas 2015)

The City of Dallas is fully aware of the issues Mill Creek has caused and is still causing today (City of Dallas 2015). In 2006 and 2012, bond programs issued by the City of Dallas provided funding for the design and construction of storm drainage relief improvements for the Mill Creek, Peaks Branch, and State-Thomas watersheds (Jordan 2015). These efforts are focused on a drainage relief tunnel spanning approximately five (5) miles through each watershed, with a thirty (30) foot diameter and a minimum depth of one-hundred (100) feet (City of Dallas 2015). The tunnel will reach to White Rock Creek, south of Scyene Road, and have a stormwater capacity to meet a 100-year storm event (City of Dallas 2015). Construction is anticipated to begin in early 2015 and be completed in 2019 (City of Dallas 2015).

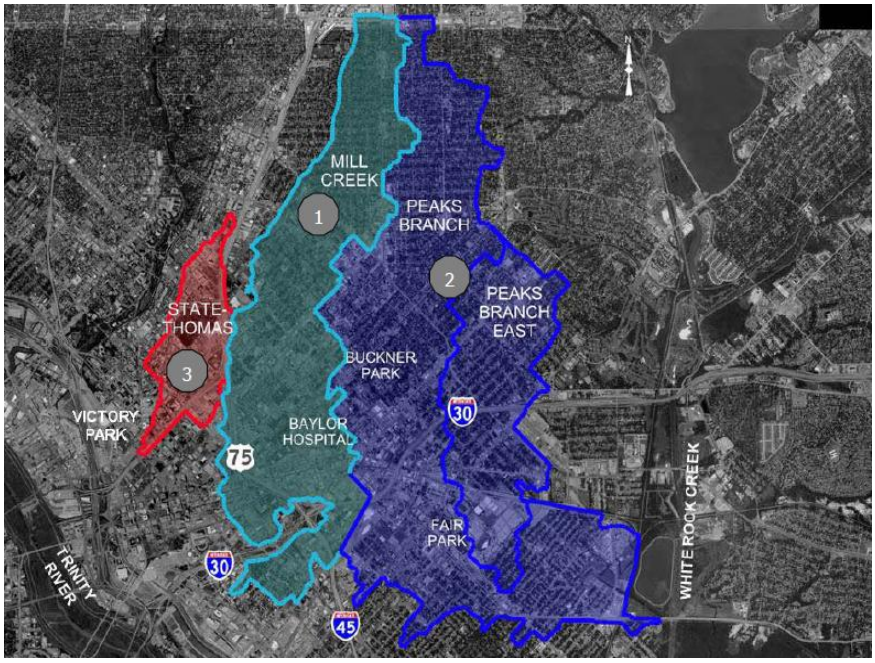


Figure 2-13 Mill Creek/Peaks Branch/State-Thomas watersheds 2015

(Data Source: City of Dallas 2015)

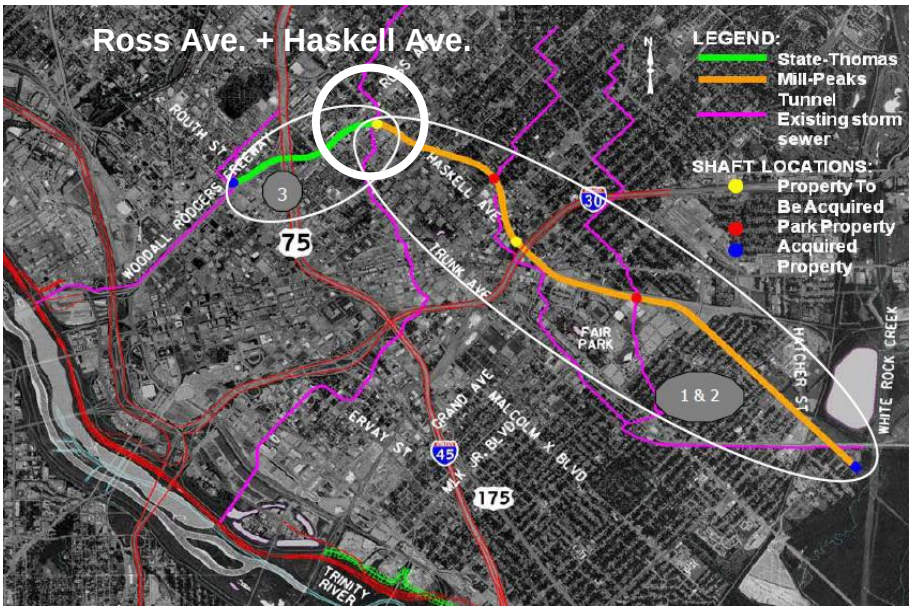


Figure 2-14 Proposed Drainage relief tunnel location 2015

(Data Source: City of Dallas 2015)

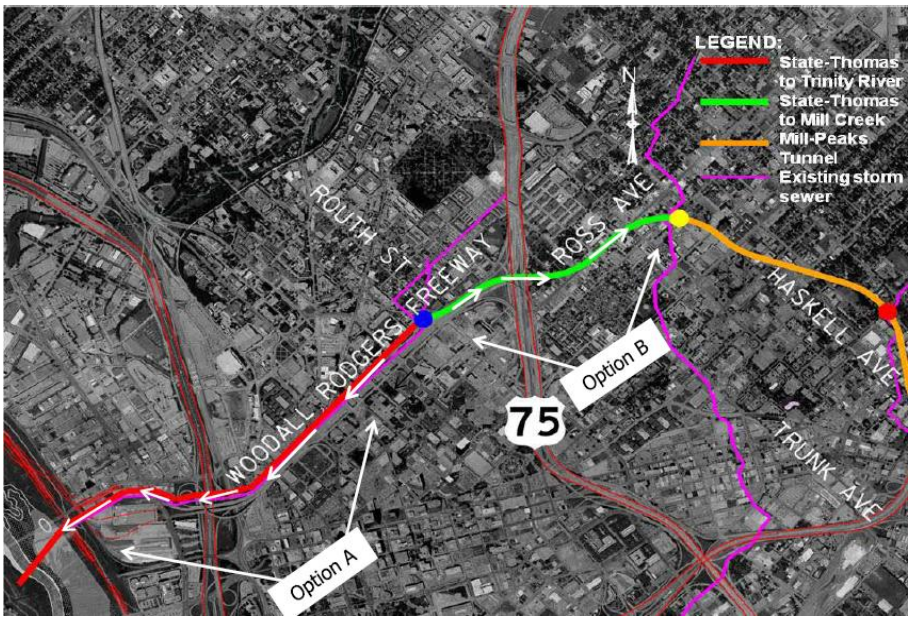


Figure 2-15 Drainage relief tunnel options 2015

(Data Source: City of Dallas 2015)

According to Figure 2-4 and Figure 2-15, the intersection of Ross Avenue and Haskell Avenue is a key location of the Drainage Relief Tunnel within the Mill Creek watershed (the yellow dot in Fig. 2.15). This specific location will help locate a nearby site that is suited for daylighting Mill Creek.

2.4 Koshaley's Criteria for Daylighting Streams

2.4.1 Introduction

Earlier research has indicated that Mill Creek is a viable candidate for stream daylighting. According to Koshaley (2008), developing eligibility criteria for daylighting streams, specifically Mill Creek in Dallas, Texas took two considerable steps. "First, preliminary daylighting criteria were synthesized based on a review and analysis of available literature. Secondly, the proposed Mill Creek project was evaluated against preliminary daylighting criteria using interviews and enhanced eligibility criteria. Then a

spatial inventory and analysis was performed using Geographic Information Systems (GIS) in order to test Mill Creek if it achieved the 'design criteria' eligibility for daylighting or not" (Koshaley 2008, p. 71). The enhanced eligibility criteria developed are discussed in the following sections.

2.4.2 Historic and Cultural Perspectives

The significance behind the historical and cultural perspectives was found to be important at the time of the research. To support this notion, it was found that Mill Creek was critical to establishing Dallas as a transportation and economic center in North Texas. Dallas' geographical location was vital because of its access to the Trinity River and utilitarian functions for industrial expansion through the northern region of Texas (Koshaley 2008).

Mill Creek played an interesting role in the development of Dallas. Since the 1880s, Mill Creek was being pumped to Main Street's standpipe for an accessible water source (Koshaley 2008). This eventually led to the creek being buried through a piping infrastructure that exists today (Koshaley 2008). Old City Park, a park along the creek's historic route, contained an early remnant known as Browder Spring which was a source for natural spring drinking water for the City of Dallas until 1888 (Koshaley 2008). Browder Spring was also used as a reference point for establishing the Texas & Pacific Railroad line in Dallas in 1872 (Koshaley 2008). During Dallas' transition to an industrial city, Mill Creek and Browder Spring were buried underground. The historical attributes are important when developing a revitalization effort for Mill Creek in the future.

2.4.3 Technical Feasibility

In a more technical sense, the feasibility of daylighting Mill Creek calls for an analysis of land use, slope, hydrology and hydraulics, stormwater collection system, and the invert of outfall in relation to the stream (Koshaley 2008). These aspects point towards the need for an interdisciplinary approach to strategizing an appropriate method for the future design and construction of Mill Creek (Koshaley 2008). This analysis is important because each aspect plays a vital role in the research, planning, design, construction, and performance of daylighting Mill Creek.

The success of physically constructing a daylighted stream relies on how prepared and knowledgeable the design, engineering, planning, and scientific teams are during the early stages of concept development. Analysis and research topics for feasibility can include: the location of daylighting, daylighting distance, excavation depth, excavation width, water flow diversion, debris cleanup, water pollution, habitat creation, ground stabilization, flood prevention, and of course visual appeal.

Koshaley (2008) states that in a fully developed feasibility study of daylighting certain portions of Mill Creek, further research was needed to understand the topographic grade changes both before and after construction as well as the surface and subsurface impacts that followed.

2.4.4 Thoroughfare, Transportation, and Circulation

Transportation and circulation, although complex, need to be addressed when daylighting a stream due to the potential for pollution, increased water runoff, safety issues, habitat overlapping, and maintenance issues (Koshaley 2008). 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 (Koshaley 2008).

Impact on thoroughfares can be evaluated based on peak hour traffic volumes for the major thoroughfares in the Mill Creek watershed (Halff Associates 2005; Koshaley 2008). Stream daylighting can also conflict with street patterns and accessibility routes for all vehicles including maintenance, safety, and law enforcement (Koshaley 2008). Additionally, knowing where the thoroughfare utilities are placed and how they intersect to the creek needs to be addressed (Koshaley 2008).

2.4.5 Economic Considerations

Economically speaking, the considerations of daylighting Mill Creek instead of repairing an aging culvert is understood best through a cost comparison. According to Halff Associates, specifically repairing a section of pipe or providing a relief structure to the drainage system is estimated to cost up to ten (10) million dollars per mile, while daylighting an "100 foot wide stream buffer to convey the upstream flows in excess of 2300 cubic feet per second (cfs) in the upper-middle segment (Henderson Avenue to San Jacinto Street)" is estimated to cost thirty-two (32) million dollars per mile (Halff Associates 2005). This comparison includes property acquisition, relocation, demolition and moving expenses, but excludes any amenities or aesthetic improvements and alterations (Koshaley 2008). However, long-term economic impacts could potentially provide incentives such as recognition, water-front property, and prime locations for future developers, home owners, renters, organizations, business owners, and visitors which generate return opportunities for the daylighting investment (section 2.2.2.3).

2.4.6 Ecological Considerations

Ecological aspects and impacts are categorized into wildlife habitat, water quality enhancement, and soil investigation. A soil inventory and a Geographic Information Systems (GIS) spatial analysis can provide insight into how subsurface construction can influence a stream daylighting design and its implementation phases. Habitat diversity begins with the stabilization and health of the soil (Koshaley 2008). Daylighting Mill Creek can be initiated with goals of wildlife habitat and water quality enhancements. These can be achieved through the use of geotechnical and geomorphological studies of the soil characteristics, biodiversity, and restorative/erosive factors found throughout the watershed (Koshaley 2008).

2.4.7 Decision Makers

Experts in stream daylighting should take a leading role in the decision making process and be included in public interest, community involvement, safety awareness, technical advisory groups, and regulatory agencies. At an early stage, the public interest and community involvement should act as a guiding hand for the design feasibility of a stream daylighting project. Regulatory agencies are in place to manage public involvement and that the research, design, and construction are under careful consideration throughout all phases of the project. As part of the decision making process, increasing the awareness of how important and beneficial to people and animals urban waterways are coincides with increasing the efforts of generating stream daylighting projects in North Texas (Koshaley 2008).

2.5 Preference via Perception

2.5.1 Aesthetic Quality as a Valuable Resource

Environmental, social, economic, historical, and cultural resources are valuable aspects of any implemented GI project (Koshaley 2008). However, there is another valuable resource that gets commonly overlooked: Aesthetics. The overall quality of the scenery and visual relationships that make a dynamic and interesting place has become widely taken for granted, misused, and even destroyed (Kaplan 1985). In recent decades, more designers have come to realize the importance of this resource. Aesthetics directly impact all other resources and conditions, such as property value, community character, economic development, recreation, safety, and transportation, making the visual attributes one of the most valuable (Kaplan 1985; Kalivoda et al. 2014).

The value of perception lies within the details. We evaluate the physical properties of a scene, image, portrayal, or photograph through the relationships between form, line, texture, color, variety, harmony, unity, vividness, scale, rhythm, complexity, illumination, transparency, incongruity, ambiguity, surprise, and novelty (Kalivoda et al. 2014; Kaplan 1985; Nasar 1994). These physical properties are difficult to use simultaneously, but when focused on an outward aesthetic for visual character, should be designed, reviewed, and controlled for the public good (Nasar 1994).

Humans respond differently to the visual arrangements and, by extension, the possibility of alternate visual arrangements of these properties depending on their prior experiences, judgmental assumptions, or their current situation (Kaplan 1985). This is what makes aesthetic quality inherently so complex, especially for a landscape amenity or feature such as a daylighted stream. "A systematic approach to the management of the visual resource could hardly be a simple matter. It must be sensitive to a host of considerations and yet be workable and affordable. It must not only take the existing

landscape into account, but anticipate the consequences of changes and, somehow, the visual experience of all the real and potential views must be synthesized into a coherent whole" (Kaplan 1985, p. 162). A landscape can be thought of as a synthesized experience that attempts to find a balance between the built and natural aspects that influence it, essentially showcasing the power of human intervention and modern urbanization (Kaplan 1985).

2.5.2 Urban Environments vs. Naturalistic Environments

2.5.2.1 Urban Environments

An urban environment and its overall design can consist of "Nature" or "Natural" elements and can include a wide variety of GI functions. An urban design emphasizes these functions by incorporating public appearance, visual character, pleasantness, excitement, and calmness through the functionality, building styles, building facades, sidewalks, wayfinding, and furnishings (Cubukcu 2005; Nasar 1994). "Development may occur in a variety of urban and nonurban settings, including central business districts, small town commercial strips, neighborhoods, industrial parks, and mixed-use developments. In each case, urban design attempts to shape the character of the exterior of buildings outward" (Nasar 1994, p. 379). Due to the proximity of urban and suburban areas nearby, understanding what can be accomplished through urban design and GI is vital to Mill Creek and to any stream daylighting efforts.

2.5.2.2 Naturalistic Environments

In contrast to urban environments, naturalistic environments employ a softer influence on the surroundings, focusing on landscape characteristics including vegetation, topography, slope, ground textures, and water. "Nature perceived in the

context of an urban or suburban landscape will likely be different than that derived in a relatively pristine, unmanaged landscape. In reality, many environments that people consider 'natural' exist in highly managed landscapes" (Crow et al. 2006, p. 283). Again, this is important for understanding Mill Creek and its contexts. Unfortunately, the "natural" aspects of Mill Creek are lost and will never be fully restored to its original state. However, using GI practices, a naturalistic character can be achieved depending on the degree to which the intrinsic properties of the landscape can be recreated from human activities (Crow et al. 2006).

2.6 Representative Stream Daylighting Project Case Studies

2.6.1 Introduction

The practice of stream daylighting has only become popular in the last couple of decades. According to available literature, there are only a handful of successful projects that solely focused on daylighting an underground, and otherwise unused or problematic, stream, river, or creek infrastructure system. These projects span across the world and offer very unique design alternatives to achieve the same ultimate goal of stream daylighting. These alternatives were visually analyzed and used as photographic references for Part 2: Visual Preference of the Visual Preference Survey.

The projects and their associated photographs that follow were chosen to represent and contain specific visual design elements of the existing streams, rivers, and creeks that have been daylighted. These visual design elements were highlighted in the Visual Preference Survey. These projects and their images were specifically chosen based on how successful the project was in terms of the visual differences they offer, the design alternatives they used, the overall visual quality, their relationship to an urban setting, and the degree of human interaction offered. In addition, their different

geographical locations were important for providing a variety of relevant projects that are not culturally, socially, economically, and environmentally similar. The main similarity they have to one another is that they had systems of underground streams, rivers, and creeks.

These criteria might appear differently from photograph to photograph, but it is necessary to create a foundation of images that showcase several distinct design alternatives that act as viable options for a preliminary design discussion of daylighting a site such as Mill Creek.

The stream daylighting projects that were chosen as examples for the Visual Preference Survey are represented below (American Rivers 2014) as well as by their associated photographs.

2.6.2 Arcadia Creek, Kalamazoo, Michigan

Figure 2-16 Arcadia Creek 1

(Image: American Rivers 2014; Downtown Kalamazoo, Inc. 2015)

Figure 2-17 Arcadia Creek 2

(Image: American Rivers 2014; Downtown Kalamazoo, Inc. 2015)

For 100 years, Arcadia Creek (Figure 2-16 & 2-17) in Kalamazoo, Michigan, was buried underground within one of the city's most highly urbanized locations (Downtown Kalamazoo, Inc. 2015). As part of a major downtown redevelopment initiative, portions of the creek were daylighted after engineers researched and documented the frequent flooding hazards as well as the how much it would cost to replace culverts (American Rivers 2014; Downtown Kalamazoo, Inc. 2015; Hamilton County Planning and Development 2011).

Prior to being daylighted, the creek wasn't large enough to handle the increased stormwater runoff. Construction of the project began in 1982 and was completed in 1995. The length daylighted was 1,550 ft. which cost $18 million (American Rivers 2014). Post daylighting, businesses in the downtown area no longer have to pay for flood insurance and this amenity now hosts events and festivals and generates $12 million in revenues annually (American Rivers 2014; Downtown Kalamazoo, Inc. 2015; Hamilton County

Planning and Development 2011). It offers pedestrians a picturesque sight of soft, naturalistic scenery and vegetation that is accented by urban architecture, constant flowing water, vertical water features, foot bridges, event spaces, and easy creek access (American Rivers 2014; Downtown Kalamazoo, Inc. 2015; Hamilton County Planning and Development 2011).

2.6.3 Cheong Gye Cheon, Seoul, South Korea

Figure 2-18 Cheong Gye Cheon 1

(Image: American Rivers 2014)

Figure 2-19 Cheong Gye Cheon 2

(Image: American Rivers 2014)

Figure 2-20 Cheong Gye Cheon 3

(Image: American Rivers 2014)

Running through the heart of Seoul, South Korea, the Cheong Gye Cheon (Figure 2-18 through 2-20) has a history of flooding, dredging, and degradation due to increased development in the city (American Rivers 2014). For 600 years through the Choson Dynasty, Seoul continued to dredge and build higher embankments for the Cheong Gye Cheon until it was decided in the 1950s to pave over the stream, turning the stream into Cheong Gye Cheon road. Additionally, a freeway was built above the road, completely burying the stream (American Rivers 2014).

With the support of 79% of Seoul's residents, in 2002 the daylighting project began and ended in 2005 costing $380 million. The freeway was demolished, the road was removed, and four miles of the stream was daylighted. The city used 75% of the removed concrete to build walkways, fountains, and bridges, which add to the art installations and stone steps. The amenity is favored by the residents and has been found to include fish, birds, and insects as well as to decrease the overall temperature by 3.6 degrees Celsius (American Rivers 2014).

2.6.4 Cow Creek Hutchinson, Kansas

Figure 2-21 Cow Creek 1

(Image: American Rivers 2014)

Figure 2-22 Cow Creek 2

(Image: American Rivers 2014)

Running through Avenue A Park in Hutchinson, Kansas, Cow Creek (Figure 2-21 & 2-22) originally ran directly underneath Avenue A, which acted as a bridge over the buried stream (Buchholz and Younos 2007; Hamilton County Planning and Development 2011). After attempts to resolve the issues of the Avenue A bridge since the 1980s, city engineers decided to completely avoid a bridge in order to restore and reroute the old streambed through a daylighting project in 1997 (Hamilton County Planning and Development 2011; Rivers and Trails Program 2015).

The city found that daylighting Cow Creek was cheaper than replacing a damaged bridge. As a result, the amenity serves as an 800 ft. daylighted centerpiece for a very popular and thriving park in Downtown Hutchinson that not only visually stimulates a rich and diverse series of spaces for people but was also designed to absorb the high flooding events during the winter storms (Hamilton County Planning and Development 2011; Rivers and Trails Program 2015).

2.6.5 Hastings Creek, Vancouver, British Columbia

Figure 2-23 Hastings Creek 1

(Image: American Rivers 2014)

As part of the historic Hastings Park in Vancouver, British Columbia since 1935, Hastings Creek (Figure 2-23) once flowed on the east side of the city. The park and its creek was the location for horseracing, professional sports, conventions, trade shows, concerts, and an amusement park. Due to its popularity and increased development, Hastings Creek no longer exists as a natural element to the park (Hamilton County Planning and Development 2011). It instead was diverted in storm sewers and covered with residential housing.

In 1994 and as a result of community lobbying since the 1980s, a renewal program was put in place to restore and daylight Hastings Creek as a contribution to the park itself as well as the surrounding natural areas and cultural history (Hamilton County Planning and Development 2011). Although the project is still in progress, a 4-hectare series of ponds and gardens known as The Sanctuary has been completed, which many native plants and animals already call home. It invites pedestrians to interact and

experience the spaces by including bridges, winding pathways, riparian plantings, and tucked-away seating areas (Hamilton County Planning and Development 2011).

2.6.6 Kids Creek, Traverse City, Michigan

Figure 2-24 Kids Creek 1

(Image: American Rivers 2014)

Through a partnership between Munson Medical District, the Watershed Center Grand Traverse Bay, and the Grand Traverse Conservation District, the Kid's Creek (Figure 2-24) in Traverse City, Michigan was daylighted in order to improve the environmental health of the creek while also making it accessible to the community (American Rivers 2014). The daylighted section was 2 miles long and was designed to restore its natural sinuosity and provide a natural riparian buffer (American Rivers 2014).

Since its completion in 2013, the daylighting project restored 4,500 ft. of stream passageways from culverts, channelized ditches, and underground pipes into a naturalistic waterway amenity that removed the built-up sand and silt that impaired proper

water flow and the aquatic habitat from moving upstream (American Rivers 2014). The cost of project was $2.5 million and helped alleviate flooding hazards from rainstorms (American Rivers 2014).

2.6.7 La Rosa Stream, Auckland, New Zealand

Figure 2-25 La Rosa Stream 1

(Image: American Rivers 2014)

Starting in 2010 as Auckland, New Zealand's first stream daylighting project, La Rosa (Figure 2-25) was brought back to life in order to connect back to Auckland's earliest European history and bring a naturalistic environment to the city's communities (Joseph 2014). La Rosa was buried underground in the 1970s to make the land easier to manage which has recently been the victim of flooding with its insufficient water capacity volumes (Joseph 2014).

Upon its opening in 2011, the project restored 180 meters of the Waitahurangi and Parahiku streams of the La Rosa water body to a more suitable sanctuary for native

birds, plants, and humans through its ecological management (Joseph 2014). A landscape architect led the design which included foot bridges, floating pathways, vegetated embankments, and rock formations that lined the streams (Joseph 2014).

2.6.8 Little Sugar Creek, Charlotte, North Carolina

Figure 2-26 Little Sugar Creek 1

(Image: American Rivers 2014)

Figure 2-27 Little Sugar Creek 2

(Image: American Rivers 2014)

Figure 2-28 Little Sugar Creek 3

(Image: American Rivers 2014)

A smaller daylighting project in the midst of a larger greenway initiative for Charlotte, North Carolina, Little Sugar Creek (Figure 2-26 through 2-28) was covered by a parking lot spanning 1,880 ft. (Mecklenburg County, North Carolina 2015). Through the efforts of the Mecklenburg County and its communities, the parking lot was removed from the floodplain to make way for a public open space (Mecklenburg County, North Carolina 2015).

Throughout the entire greenway initiative, 5,940 ft. of the stream bed have been restored alongside 6,336 ft. of greenway trails have been added alongside the water body (Mecklenburg County, North Carolina 2015). The project is ongoing and plans to provide cleaner water, better habitat for plants, animals, and people to enjoy, educational opportunities, a biking and hiking trail linkage through South Carolina, a gathering place for people, and a signature Charlotte destination for community pride (Mecklenburg County, North Carolina 2015).

2.6.9 Nine Mile Run, Pittsburgh, Pennsylvania

Figure 2-29 Nine Mile Run 1

(Image: American Rivers 2014)

Nine Mile Run (Figure 2-29) is a stream that drains from the Wilkinsburg and Squirrel Hill areas to the Monongahela River and is a typical water body found through the city of Pittsburgh, Pennsylvania (Ferguson et al. 1999). Out of the 6.5 square miles of the stream's watershed, two (2) miles of that has been buried underground using culverts (Ferguson et al. 1999). In 1998, a team of landscape architects, architects, civil engineers, environmental scientists, artists, geologists, public works, and planners sought a design solution that would restore the land once lost to the immediate urbanization (Ferguson et al. 1999). This plan that was only a small part of a $3 billion rehabilitation initiative that included collector systems and pollution control alternatives throughout the region (Ferguson et al. 1999).

While the regional initiative is still ongoing, the Nine Mile Run design effectively restored the natural functions of the creek including stormwater management, soil stability, water filtration, pollution prevention, and habitat engagement (Ferguson et al. 1999).

2.6.10 San Luis Obispo Creek, San Luis Obispo, California

Figure 2-30 San Luis Obispo Creek 1

(Image: American Rivers 2014)

Figure 2-31 San Luis Obispo Creek 2

(Image: American Rivers 2014)

Figure 2-32 San Luis Obispo Creek 3

(Image: American Rivers 2014)

Originating from a 1963 feasibility study from a community college class project in San Luis Obispo, California, the daylighting of the San Luis Obispo Creek (Figure 2-30 through 2-32) became a centerpiece for the adjacent plaza, named Mission Plaza (San Francisco Public Utilities Commission 2015). The project began to receive support in 1969 and in 1973 the project's research indicated that the underground creek had been the victim of dumping, sedimentation, and neglect for eighty (80) years, which reduced the flow capacity of the other local creeks (San Francisco Public Utilities Commission 2015).

The daylighting design emphasized the creek as an amenity and asset that transformed the city's downtown with shops, restaurants, plazas, generous pathways, local vegetation, and event spaces that host concerts, festivals, and farmer's markets (San Francisco Public Utilities Commission 2015). The walkability of the creek,

pedestrian access, and art pieces all contribute to the vibrancy of the restored creek as well (San Francisco Public Utilities Commission 2015).

2.6.11 Saw Mill River, Yonkers, New York

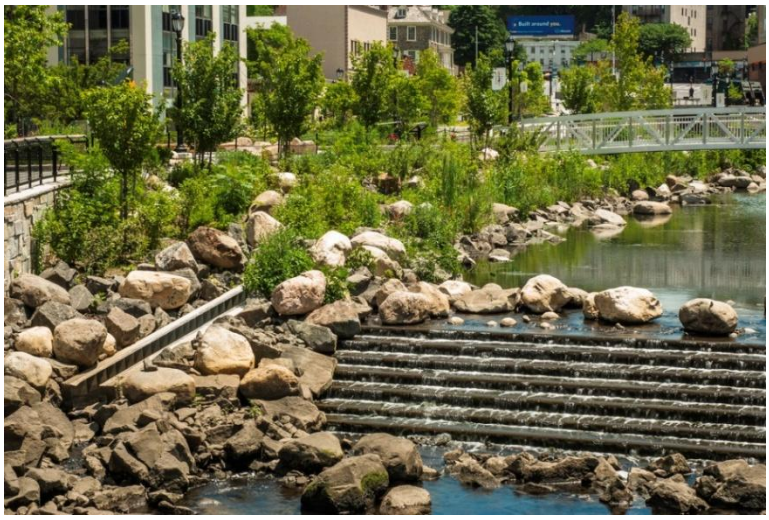


Figure 2-33 Saw Mill River 1

(Image: American Rivers 2014; Groundwork Hudson Valley 2015)

Figure 2-34 Saw Mill River 2

(Image: American Rivers 2014; Groundwork Hudson Valley 2015)

The Saw Mill River (Figure 2-33 & 2-34) in Yonkers, New York was buried in the 1920s in response to the city's development and expanding population. Through the 1990s however, pollution levels rose dramatically due to its industrial past, rampant illegal dumping, and sewage overflows during flooding events (Groundwork Hudson Valley 2015).

In December 2010, the Saw Mill River daylighting project was initiated and after its completion in December 2011, the project created 13,775 square feet of aquatic habitat for flora and fauna, put in place flood prevention infrastructure, included water filtration and aeration features, and cost $19 million to construct (American Rivers 2014). This project acted as the centerpiece for revitalizing the space for ecological workshops, musical performances, and relaxation areas for reading and internet use, all of which were used to incentivize residents to come downtown. The project also helped spark other neighboring revitalization projects which play on the newly developed visual character and unique feel of the river amenity (American Rivers 2014; Groundwork Hudson Valley 2015).

2.6.12 Additional Stream Daylighting Projects

In addition to the previously highlighted daylighting projects, there are several others that have either been designed, constructed, or in the process of being completed. These projects are listed as extended references below (American Rivers 2014):

- Bloody Run Creek, Detroit, Michigan
- Dunnes Creek, Indiana Dunes State Park, Indiana
- Madrona Creek, Seattle, Washington
- Strawberry Creek, Berkeley, California

- Codornices Creek, Berkeley, California
- Darbee Brook, Roscoe, New York
- Embarrass Creek, Urbana, Illinois
- Jenkins Creek, Maple Valley, Washington
- Jolly Giant Creek, Arcata, California
- Petty's Run, Trenton, New Jersey
- Phalen Creek, St. Paul, Minnesota
- Rocky Branch, Raleigh, North Carolina
- Shoal Creek Tributary, Dekalb, Georgia
- Upper Baxter Creek, El Cerrito, New York
- Valley Creek, Port Angeles, Washington
- Village Creek, Albany, New York
- West Ox Pasture Brook, Rowley, Massachusetts

Chapter 3

Research Methods and Data Acquisition

3.1 Introduction

The research methods begin with a study to identify a specific site location within the Mill Creek watershed of Dallas, Texas. An additional study was completed to determine which visual design elements of GI are most impactful for a stream daylighting project. From those two studies, a Visual Preference Survey determined which visual design elements of stream daylighting were found to be the most desirable. The most desirable visual design elements were then used to digitally depict a suggested stream daylighting outcome through the use of before and after images of the selected site.

3.2 Research Design

3.2.1 Mill Creek Site Selection

An important factor for this research is the selection of a site-specific location along the Mill Creek flowline that offers an opportunity for representing a stream daylighting project. According to Koshaley (2008) on the matter of eligibility criteria (section 2.4) for daylighting streams, the most suitable sites on Mill Creek are the upper-middle and lower-middle segments of the watershed. These segments were part of the analysis that Halff Associates (2005) created in order to categorize and breakdown the watershed area (Figure 3-1).

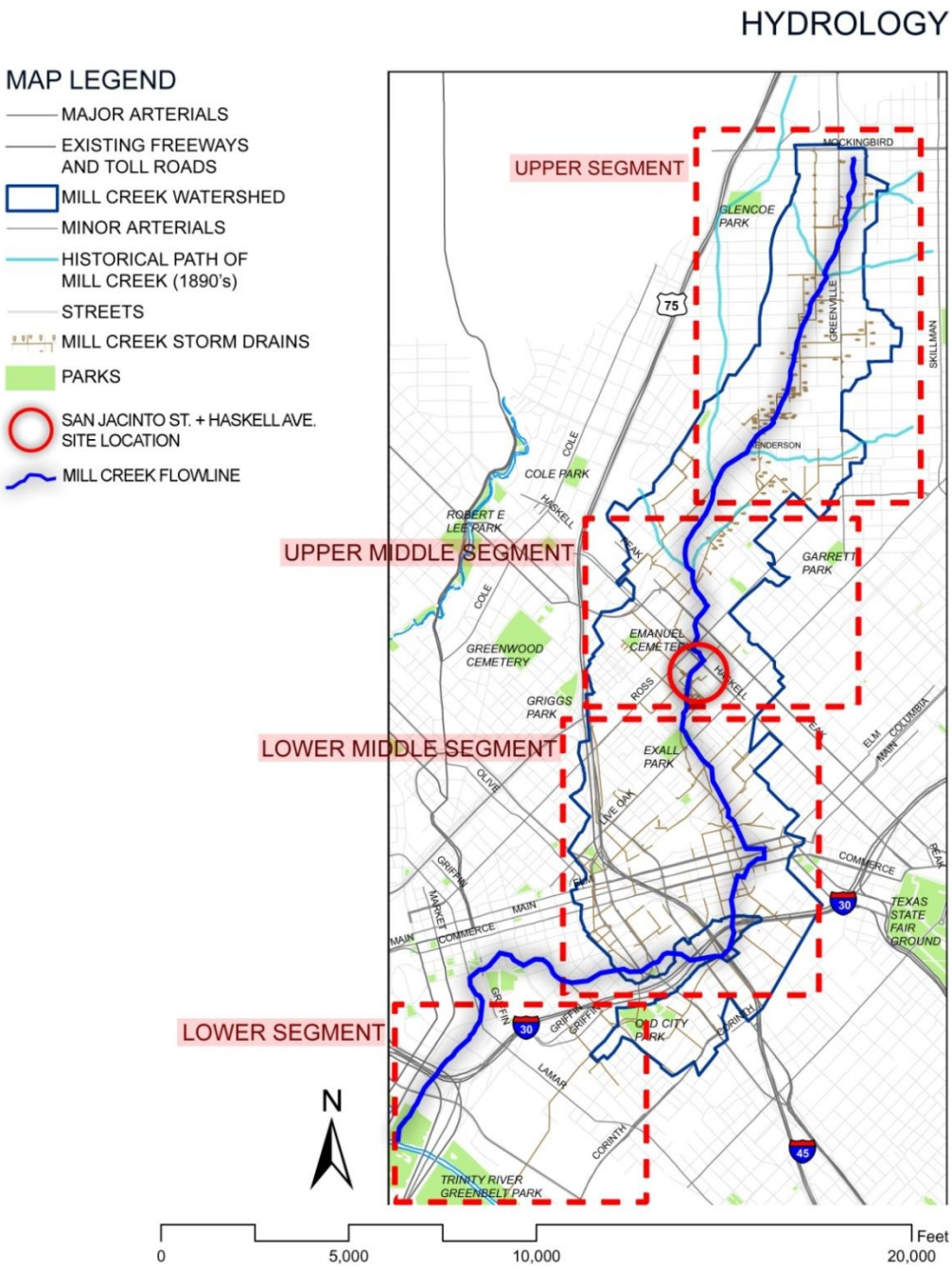


Figure 3-1 Hydrology (four segments) of Mill Creek

(Data Source: Halff Associates 2005)

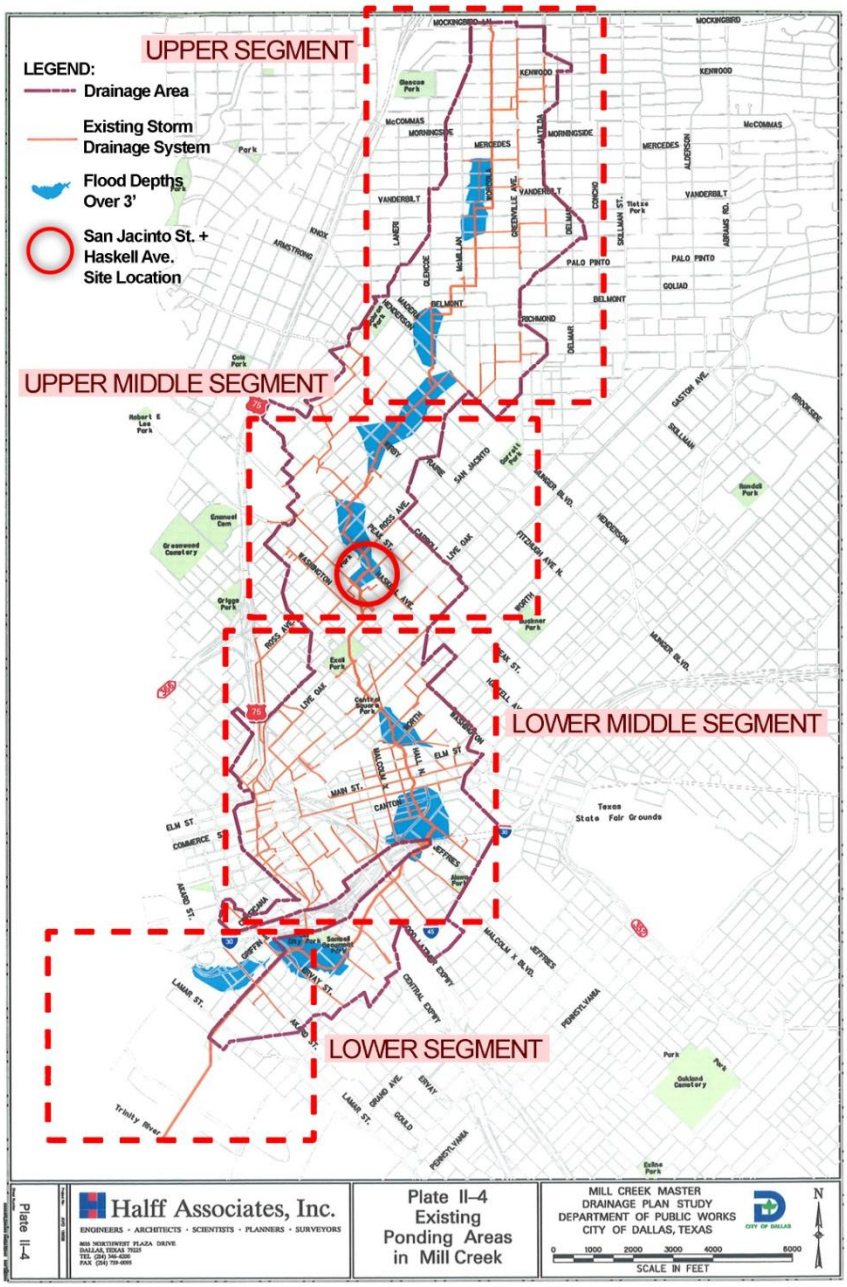


Figure 3-2 Existing Ponding Areas in Mill Creek

(Data Source: Halff Associates 2005)

From this, the criteria for selecting a specific site for this research study was: (1) the site must be along or immediately adjacent to the existing Mill Creek flowline according to Halff Associates' (2005) hydrology segmentation diagram (Figure 3-4), (2) the site must be located within the upper-middle or lower-middle segment of the hydrology segmentation diagram (Figure 3-4), (3) the site must be a common area for flooding according to Halff Associates' (2005) existing ponding diagram (Figure 3-5), (4) the site must be along the City of Dallas Drainage Relief Tunnel's expected trajectory (2006-2015), and (5) the site must be contextually appropriate based on the Koshaley (2008) criteria (section 2.3) and openly available for visually depicting a stream daylighting project.

These criteria were derived from an interpretation of information from Koshaley (2008), Halff Associates, Inc. (2005), and the City of Dallas Drainage Relief Tunnel Program (2006-2015). As a result, two intersections within a one-block radius along the Mill Creek flowline were chosen and are shown below:

Figure 3-3 Possible street intersections along Mill Creek Flowline

(Data Source: Google Earth Pro 2015)

In order to locate a potential site for visually depicting a stream daylighting project, street intersections were strategically chosen in accordance with the criteria

specified above to indicate points of reference throughout the Mill Creek watershed that are easy-to-find and easy-to-understand. Each intersection was then divided into four (4) quadrants (Figure 3-2) in order to pinpoint a specific lot that was capable of meeting all of the site location criteria.

Figure 3-4 Street intersection quadrants

(Data Source: Google Earth Pro 2015)

The intersection of Haskell Avenue and Ross Avenue is the location where the Mill Creek flowline and the City of Dallas Drainage Relief Tunnel (2006-2015) meet. However, the lots at each quadrant do not meet all the criteria because they are not visually available for depicting a stream daylighting project, as seen below in Figure 3-3 - Figure 3-6. This intersection is also heavily trafficked with a one-way thoroughfare with three lanes spanning approximately forty (40) feet. The intersection also has few elements in place for pedestrian crossing and safety. There are businesses on every corner, which has created a hindrance for the City of Dallas Drainage Relief Tunnel (2006-2015) in obtaining the land necessary for redevelopment.

Below: the intersection of Haskell Avenue and Ross Avenue.

Figure 3-5 Haskell Avenue + Ross Avenue - Quadrant 1 Looking North

(Data Source: Google Earth Pro 2015)

Figure 3-6 Haskell Avenue + Ross Avenue - Quadrant 2 Looking West

(Data Source: Google Earth Pro 2015)

Figure 3-7 Haskell Avenue + Ross Avenue - Quadrant 3 Looking South

(Data Source: Google Earth Pro 2015)

Figure 3-8 Haskell Avenue + Ross Avenue - Quadrant 4 Looking East

(Data Source: Google Earth Pro 2015)

Located approximately one block south, the intersection of San Jacinto Street and Haskell Avenue has an open lot that fits all the criteria in quadrant 3 (Figure 3-9), while the other quadrants do not fit all the criteria. In contrast to the previous intersection, this location has less vehicular traffic, is easily accessible, has usable sidewalks, is adjacent to existing housing and business developments, has limited hardscape and utility infrastructure, and is large enough to visually depict a possible stream daylighting project.

Overall, the lot within quadrant 3 of the San Jacinto Street and Haskell Avenue intersection is the most well rounded and feasible site location for representing the possibility of unearthing and restoring Mill Creek, based on the site location criteria, the knowledge gained from Koshaley (2008), Halff Associates' (2005) watershed analysis (Figure 3-11 and Figure 3-12), and the City of Dallas Drainage Relief Tunnel (2006-2015).

Below: the intersection of San Jacinto Street and Haskell Avenue.

Figure 3-9 San Jacinto Street + Haskell Avenue - Quadrant 1 Looking North

(Data Source: Google Earth Pro 2015)

Figure 3-10 San Jacinto Street + Haskell Avenue - Quadrant 2 Looking West

(Data Source: Google Earth Pro 2015)

Figure 3-11 San Jacinto Street + Haskell Avenue - Quadrant 3 Looking South

(Data Source: Google Earth Pro 2015)

Figure 3-12 San Jacinto Street + Haskell Avenue - Quadrant 4 Looking East

(Data Source: Google Earth Pro 2015)

3.2.2 Visual Design Elements for Stream Daylighting

In 2012, a tool for evaluating how green infrastructure was included in existing and future urban areas was created as part of a study, known as the Green Infrastructure Gauge (M'Ikiugu et al. 2012). This Green Infrastructure Gauge (GIG), compiled an extensive list of GI functions and design elements that are commonly used and understood, which by extension includes the practice of stream daylighting. Although all GI functions are relevant, not all of the associated design elements are able to be used for a stream daylighting visual analysis in an urban context such as Mill Creek.

The functions and design elements of the GIG help establish a broad understanding of what GI is capable of providing urban communities through stream daylighting. How these functions and design elements play into a design that visually illustrates a cohesive representation of stream daylighting is critical to the Visual Preference Survey. Below are the functions and design elements that the GIG systematically provides (M'Ikiugu et al. 2012):

1. Biodiversity Promotion
2. Cultural/Historical Identity

3. Disaster Prevention and Mitigation

4. Energy Saving

5. Economic Activity Support

6. Environmental Education

7. Food/Resource Production

8. Good Aesthetics

9. Local Climate Improvement

10. Nature Conservation

11. Noise Reduction

12. Part of a Larger Green Network

13. Planning Structure

14. Pollutant Filtration

15. Communal Activity Promotion

16. Public Health Promotion

17. Rain Water Harvesting

18. Recreation Opportunity

19. Green House Gas Reduction

20. Public Infrastructure Cost Reduction

21. Storm Water Management

According to the GIG, these GI functions are products and categorizations that have maintained universality when the following design elements are utilized accordingly (M'Ikiugu et al. 2012). As stated above, it is important for the Visual Preference Survey categorization to understand which Green Infrastructure design elements, as proposed

by the GIG (M'Ikiugu et al. 2012), are the most relevant to the discussion, practice, and evolution of stream daylighting. The GIG design elements are listed below:

1. Cycling Route / Walking Route / Trail / Promenade.
2. Green Buffer / Green Belt.
3. Green Network / Greenway.
4. Green Roofs / Green Walls / Green Curtains.
5. Landscaping Plants (Trees, Shrubs, Groundcovers, Lawn).
6. Renewable Energy Harvesting and Use / Energy Saving Facilities.
7. Nature Reserve / Woods / Forest / Grasslands.
8. Parks / Gardens / Squares / Beach / River Front.
9. Rain Water Harvesting, Storage, Use, and Infiltration Facilities.
10. Disaster Prevention / Mitigation Elements.
11. Waterways / Water Features.
12. Wetlands / Bogs / Peat Land.
13. Working Lands (Farming, Natural Resource Extraction, etc).

For the design and structure of the Visual Preference Survey, the GI design elements and functions for a stream daylighting examination like Mill Creek were categorized into seven distinct areas of visual interest. These categories were selected from an interpretation of Rosgen's stream classification system and the GIG design elements and functions that were most feasible for Mill Creek's stream daylighting and restoration process (M'Ikiugu et al. 2012; Rosgen 1994). Not all of the GI design elements that were proposed from the GIG are necessary for the discussion of Mill Creek, such as farming, woodland habitat, bogs, beaches, or river fronts. Each of the

seven categories contained three accepted design alternatives or variations, which are indicated below:

1. Stream Alignment Characteristics

Variations:

***1.1 Straight*:** A straight, linear channel for water direction and viewing sightlines.

***1.2 Braided/Divided*:** Landforms, rocks, and vegetation that divide and dissect the middle of the stream, creating a more organic feel.

1.3 Meandering/Curvilinear: A curvilinear, or arching, stream that mimics the surrounding landforms.

2. Stream Bank Materials

Variations:

2.1 Rocks/Boulders: Rocks and boulders are used to line the banks of the water body.

2.2 Vegetation: Low-lying vegetation is used as a soft edge for the stream bank.

2.3 Vertical Wall: The use of vertical walls take the place of the bank, offering vantage points and directed access to the water body.

3. Stream Width

Variations:

3.1 Narrow: A less than 10 ft. wide stream, offering easy crossing opportunities and access.

3.2 Moderate: A 10-20 ft. wide stream, proportional to the human scale.

3.3 Wide: A 20 ft. or wider stream, offering more recreational possibilities but hindering the ease of crossing.

4. Stream Water Features

Variations:

4.1 Ripples and Waves: Small waves on the water's surface that create a calm, yet simple way of adding noise, interest, interaction, and oxygen to the water body.

4.2 Fountain: A more mainstream solution through the use of a vertical jet fountain that has either a single jet or multiple jets. Provide aeration and can act as a lively sculpture and be placed in different locations within the water body.

4.3 Cascade: Water flowing down over a waterfall-like structure that offers intrigue, noise, relaxation, air cooling, water oxygenation, and level changes.

5. Vegetation Types

Variations:

5.1 Minimal: Very limited plant palette, or simple plant palette.

5.2 Natural/Native: The stream vegetation resembles a more naturally oriented aesthetic utilizing native plants ecologically suited to the stream edge condition.

5.3 Overtly Designed: Stream edge plantings that exhibit an obvious visual order and design in their selection and arrangement.

6. Proximity of a Path

Variations:

6.1 Immediately Adjacent: A pathway immediately up against the water body located at the same level as the stream edge.

6.2 Nearby: A pathway that has a 15-30 ft. buffer between the stream for vegetation, stream bank slope changes, and flood prevention.

6.3 Raised: A pathway that is immediately adjacent to the water body but is simply raised above the stream edge.

7. Proximity of a Roadway

Variations:

7.1 Immediately Adjacent: A roadway that is literally up against the stream.

7.2 Nearby: A roadway that has a 30-75 ft. buffer between the water body so vehicular traffic is less likely to compete with the naturalistic quality of the stream.

7.3 Distant: The roadway is still within proximity, yet can still be seen and heard from the stream edge. Given that daylighted streams are primarily located in urban settings and rely on accessible routes for maintenance, the roadway has a minimum distance of 75 ft. and a maximum distance of 150 ft. from the water body.

These design elements were represented visually through photography in order to create a foundation for a common visual frame of reference within the Visual Preference Survey. This is so the design explorations of stream aesthetics that follow have a common reference point regarding how design alternatives might look, and what

level of detail is desired when discussing the stream daylighting and restoration possibilities for Mill Creek.

3.2.3 Visual Preference Survey

After considering two site locations along the Mill Creek flowline (section 3.1.1), quadrant 3 of the San Jacinto Street and Haskell Avenue intersection was chosen as the best location for a base image for a digital rendering depicting the daylighting of Mill Creek. This was necessary in order to reduce the study area and scope of analysis to an area representative of this portion of the Mill Creek watershed. Several stream daylighting projects from around the world were gathered and analyzed in order to find photographs of each project that could be used for the Visual Preference Survey, and which ultimately would serve as visual aids when analyzing the results from the survey. The survey itself was influenced by and interpreted from previously designed Visual Preference Survey's (Calgary Regional Partnership 2015; Institute for Public Administration 2015; Peachtree City 2007; The Lakota Group 2011).

Part 1 of the survey was a multiple choice section that focused on groups of people based on their specific relationships to Mill Creek, such as local residents, employees working nearby, visitors, tourists, local/commuting students, professional designers who have envisioned alternatives for Mill Creek, engineers who have studied the area, existing businesses, and future businesses. The purpose of this was to incorporate different categories of people which offer insights into their knowledge and experiences of Mill Creek.

Part 2 includes a series of photographs of existing streams, rivers, and creeks that have been daylighted. These photographs represent stream daylighting projects that have been completed around the world (section 2.6). There were seven categories: (1)

Stream Alignment Characteristics, (2) Stream Bank Materials, (3) Stream Width, (4) Stream Water Features, (5) Vegetation Types, (6) Proximity of Path, and (7) Proximity of Roadway, each having three photographs representing different variations of that specific design element (section 3.1.2). At the end of each category, the respondents were asked to describe why they chose that image, or images, to be the most or least desirable. Understanding which photographs were most desirable and least desirable were helped establish what design elements were used as suggestions and to what level of detail they were depicted for the final Visualization (section 4.2). Below is the Visual Preference Survey that was distributed from March 31 - April 14, 2015, marking the conclusion of the data collection (Appendices A, B, & C):

PART 1 - Participant Information

1) What age group do you belong to?

- o 21-30
- o 31-40
- o 41-50
- o 51-60
- o 61+

2) How long have you lived in the Dallas/Fort Worth area?

- o 0-5 Years
- o 5-10 Years
- o 10-15 Years
- o 15-20 Years
- o 20+ Years

3) Are you a business owner, landowner, employee, resident, visitor, or student of Dallas, Texas? Select all that apply.

- o Business Owner
- o Landowner
- o Local or nearby employee
- o Resident of Dallas County
- o Visitor
- o Student (resident or commuter)
- o Other_____
- o None of the above

4) Do you currently work as a professional designer, engineer, transportation expert, or planner? If yes, please indicate the number of years you have contributed to your field.

- o Yes, for how many years? _____
- o No

5) How familiar are you with the Mill Creek Watershed in Dallas, Texas?

- o Very familiar
- o Familiar
- o Somewhat familiar
- o Not very familiar
- o Never heard of it

6) Are you aware that Mill Creek has been buried underground since the 1930s?

- o Yes
- o Maybe
- o No

7) How familiar are you with the term, "Stream Daylighting"?

- o Very familiar
- o Familiar
- o Somewhat familiar
- o Not very familiar
- o Never heard of it

PART 2 - Visual Preference

The following photographs are of existing rivers, creeks, and streams that have been **daylighted**, or a "deliberate act of exposing the full or partial flow of previously buried rivers, creeks, and streams into restored surface waterways" (Koshaley 2008).

On a scale of -3 to +3, please rate the desirability of each of the following photographs (+3 being the most desirable, 0 being neutral, and -3 being the least desirable).

CATEGORY 1: Stream Alignment Characteristics

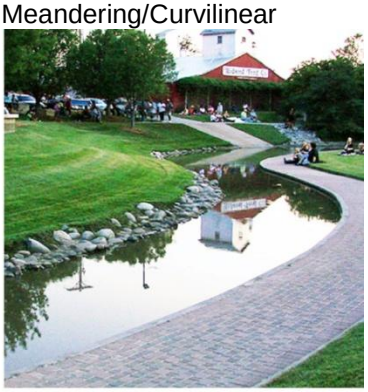
Straight

○ ○ ○ ○ ○ ○ ○
-3 -2 -1 0 1 2 3

Braided/Divided

○ ○ ○ ○ ○ ○ ○
-3 -2 -1 0 1 2 3

Meandering/Curvilinear



○ ○ ○ ○ ○ ○ ○
-3 -2 -1 0 1 2 3

8) Why did you choose that image, or images, as the most desirable? Please explain your answer.

_____

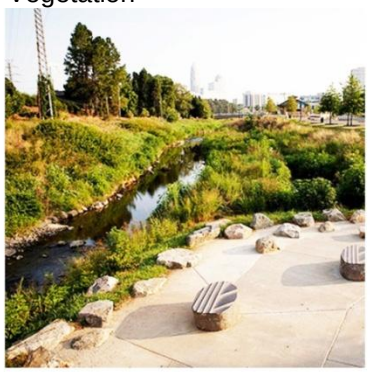
_____

CATEGORY 2: Stream Bank Materials

Rocks

○ ○ ○ ○ ○ ○ ○
-3 -2 -1 0 1 2 3

Vegetation



○ ○ ○ ○ ○ ○ ○
-3 -2 -1 0 1 2 3

Vertical Wall

○ ○ ○ ○ ○ ○ ○
-3 -2 -1 0 1 2 3

9) Why did you choose that image, or images, as the most desirable? Please explain your answer.

_____

_____

CATEGORY 3: Stream Width

Narrow

○ ○ ○ ○ ○ ○ ○
-3 -2 -1 0 1 2 3

Moderate

○ ○ ○ ○ ○ ○ ○
-3 -2 -1 0 1 2 3

Wide

○ ○ ○ ○ ○ ○ ○
-3 -2 -1 0 1 2 3

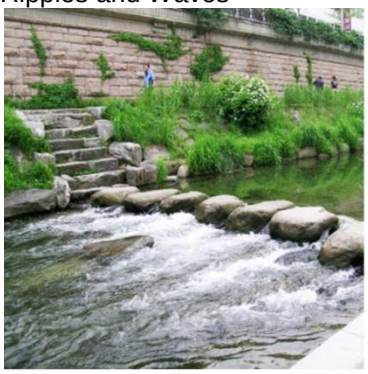
10) Why did you choose that image, or images, as the most desirable? Please explain your answer.

_____

_____

CATEGORY 4: Stream Water Features

Ripples and Waves



○ ○ ○ ○ ○ ○ ○
-3 -2 -1 0 1 2 3

Fountain

○ ○ ○ ○ ○ ○ ○
-3 -2 -1 0 1 2 3

Cascade

○ ○ ○ ○ ○ ○ ○
-3 -2 -1 0 1 2 3

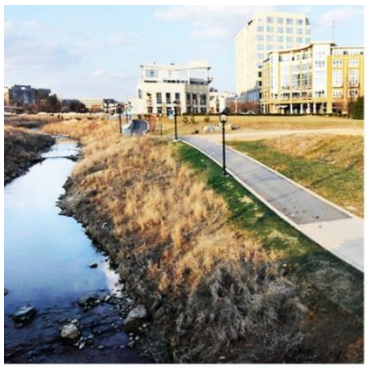
11) Why did you choose that image, or images, as the most desirable? Please explain your answer.

_____

_____

CATEGORY 5: Vegetation Types

Minimal



○ ○ ○ ○ ○ ○ ○
-3 -2 -1 0 1 2 3

Natural/Native

○ ○ ○ ○ ○ ○ ○
-3 -2 -1 0 1 2 3

Overtly Designed

○ ○ ○ ○ ○ ○ ○
-3 -2 -1 0 1 2 3

12) Why did you choose that image, or images, as the most desirable? Please explain your answer.

_____

_____

CATEGORY 6: The Proximity of a Walkway to the Stream

Immediately Adjacent

○ ○ ○ ○ ○ ○ ○
-3 -2 -1 0 1 2 3

Nearby

○ ○ ○ ○ ○ ○ ○
-3 -2 -1 0 1 2 3

Raised

○ ○ ○ ○ ○ ○ ○
-3 -2 -1 0 1 2 3

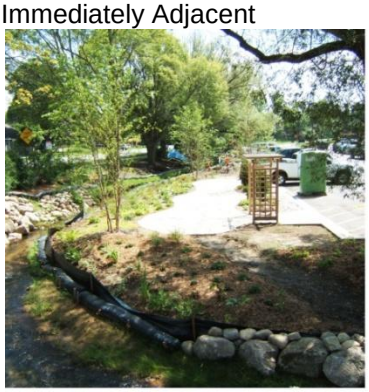
13) Why did you choose that image, or images, as the most desirable? Please explain your answer.

_____

_____

CATEGORY 7: The Proximity of a Roadway to the Stream

Immediately Adjacent



○ ○ ○ ○ ○ ○ ○
-3 -2 -1 0 1 2 3

Nearby

○ ○ ○ ○ ○ ○ ○
-3 -2 -1 0 1 2 3

Distant

○ ○ ○ ○ ○ ○ ○
-3 -2 -1 0 1 2 3

14) Why did you choose that image, or images, as the most desirable? Please explain your answer.

_____

_____

3.2.4 Study Participants

Through snowball sampling, a method of chain-referrals through acquaintances, the Visual Preference Survey was distributed to a number of key individuals and organizations that then assisted in additional distribution of the survey material. Correspondences to key individuals and organizations were made digitally through the use of the internet via electronic mail, or email.

The Visual Preference Survey was created through Qualtrics.com and made active March 31, 2015. The survey remained open for participation for two weeks (14 days). The survey closed at midnight on April 14, 2015. By the end, fifty-one (51) people, including Dallas residents and employees from numerous organizations were confirmed to have completed the survey. The seventeen (17) organizations who had confirmed participation with a Dallas location, within or near the Mill Creek watershed, have

knowledge of, or have researched, include governmental agencies, multi-disciplinary design firms, landscape architecture design firms, a transportation firm, engineering firms, a construction company, a local bank, research and advocacy groups, and a hospital.

3.3 Limitations

Limitations to the reliability of this research can be attributed to:

- A limited number of daylighted stream restoration projects that have been completed to a degree that allows a visual study and analysis of their design elements.
- The lack of completed projects extends to a limited number of usable photographs and imagery that portray the design elements clearly.
- Given that stream daylighting is a recent practice coming to a more mainstream awareness in the past couple of decades, the amount of available research performance data and study information is limited.
- Bias towards specific photographs could potentially hinder the overall results. There are several photographs that can be used for any particular design element trying to be showcased.
- The wording of the actual survey questions as well as the context the photographs have in relation to the questions.
- The opinions, perceptions, and experiences of the survey participants may create discrepancies in the results and short answer portions.
- The politics behind a stream daylighting effort and acquiring the support from the communities, stake holders, and city staff could limit how effective this study could be for daylighting Mill Creek.

3.4 Summary

A specific site found along the Mill Creek flowline was selected for visually representing a stream daylighting project. The site was chosen because it is geographically situated in the upper-middle segment of the Halff Associates' drainage report (Halff Associates 2005). In addition, the site was also chosen due to its proximity to the expected line of construction for the City of Dallas Drainage Relief Tunnel Program (City of Dallas 2015).

For this research, a Visual Preference Survey is suggested prior to any construction. Creating a stable foundation of visual design preferences for any potential redevelopment provides important information for the early stages of the preliminary design process, particularly the inclusion of the public's perception, needs, and priorities relative to such a significant environmental and visual change.

A study was then conducted in order to understand which GI design elements are applicable to stream daylighting through an interpretation of Rosgen's stream classification system and the GIG (M'Ikiugu et al. 2012; Rosgen 1994). On that basis, design element criteria were determined which helped create the Visual Preference Survey. The design elements included:

1) Stream Alignment Characteristics
2) Stream Bank Materials
3) Stream Width
4) Stream Water Features
5) Vegetation Types
6) Proximity of Path
7) Proximity of Roadway

To visually represent the design elements, a series of projects were organized to illustrate existing examples of streams, rivers, and creeks from around the world that have been daylighted. Each project was represented through photography in the Visual Preference Survey. The survey recorded fifty-one (51) participants which included Dallas residents, organizations, and groups that were selected because they have conducted research, have knowledge of, have visited or live, work, or operate a business within or near the Mill Creek watershed.

Chapter 4

Findings

4.1 Demographics - PART 1: Participant Information

The data from Part 1: Participant Information from the Visual Preference Survey is described, graphically illustrated, and analyzed below:

1) What age group do you belong to?

- 18-30
- 31-40
- 41-50
- 51-60
- 61+

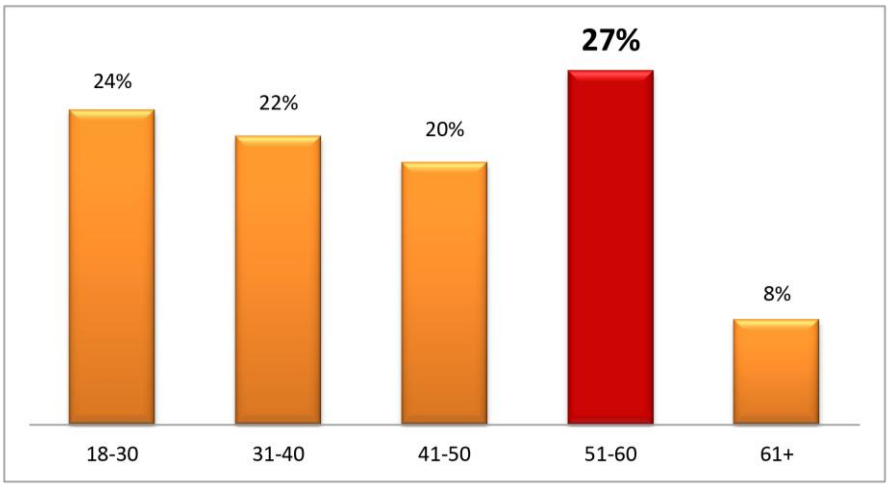


Figure 4-1 Age groups

Of the 51 respondents, 27% are 51-60 years of age (Figure 4-1). The 18-30, 31-40, and 41-50 categories were all relatively close to one another, indicating a high participation from several age groups except those over 61.

2) How long have you lived in the Dallas/Fort Worth area?

- 0-5 Years
- 5-10 Years
- 10-15 Years
- 15-20 Years
- 20+ Years

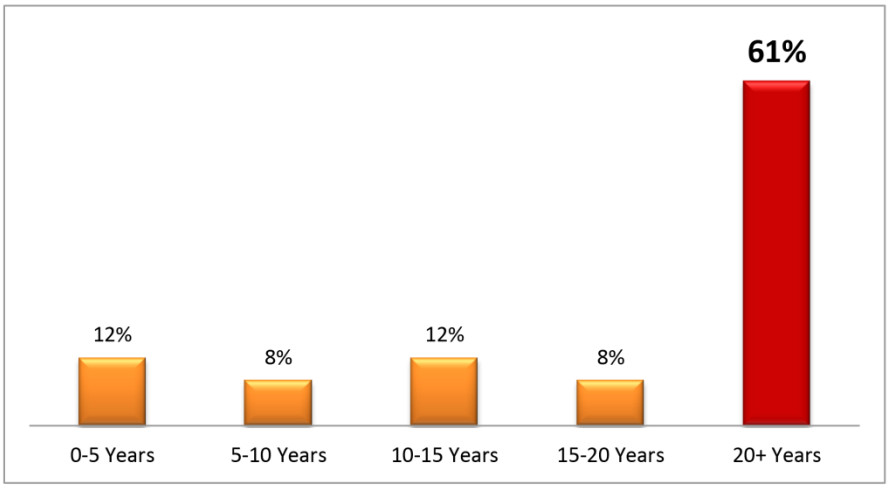


Figure 4-2 Years Living in Dallas/Fort Worth area

Of the 51 survey respondents, 61% indicated that they have lived in the Dallas/Fort Worth area for twenty (20) or more years (Figure 4-2). The other categories remained under 15%. This specifically illustrates the wealth of knowledge and contextual awareness brought by the participants and can be extremely valuable for including the public in the process of any future redevelopment within or around the Mill Creek, State-Thomas, and Peaks Branch watersheds.

3) Are you a business owner, landowner, employee, resident, visitor, or student of Dallas, Texas? Select all that apply.

- Business owner
- Landowner
- Local or nearby employee
- Resident of Dallas County
- Visitor
- Student (resident or commuter)
- Other_____
- None of the above

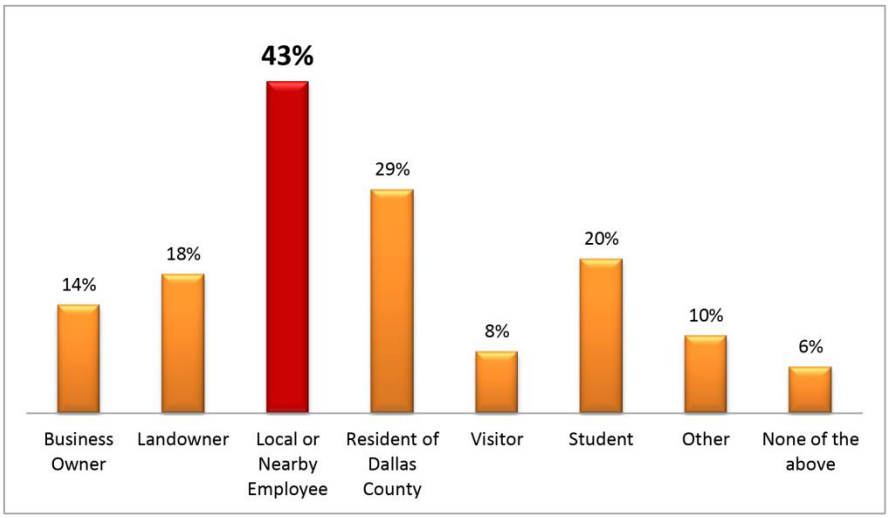


Figure 4-3 Business Owner, Landowner, Employee, Resident, Visitor, or Student of Dallas, Texas

Of the 51 survey respondents, 43% said they were local or nearby employees in Dallas, Texas (Figure 4-3). Additionally, 29% of the respondents said they were residents of Dallas County. Responses for the "Other" category were stated that individuals had prior knowledge of Dallas having grown up there or are residents of Rockwall or Tarrant Counties.

4) Do you currently work as a professional designer, engineer, transportation expert, or planner? If yes, please indicate the number of years you have contributed to your field.

- Yes, for _____ years.
- No

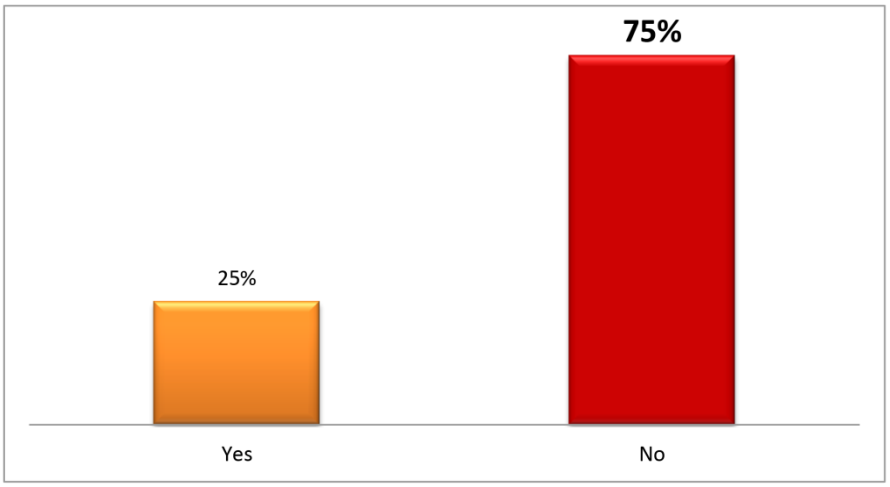


Figure 4-4 Professional Designer, Engineer, Transportation Expert, or Planner

In order to maintain a balance, a differentiation between (1) people who are or have been professionals in the design, engineering, transportation, or planning fields and (2) people who are not in the design, engineering, transportation, or planning fields, was important to this research in order to maintain a healthy variation of data sources. Of the 51 survey respondents, 75% said that they do not currently work as a professional designer, engineer, transportation expert, or planner (Figure 4-4). Since the design, engineering, transportation, and planning professions potentially have a distinct knowledge of stream daylighting, they should certainly be included in the survey but not overused.

The remaining 25% of the survey respondents indicated that they currently work as a professional designer, engineer, transportation expert, or planner.

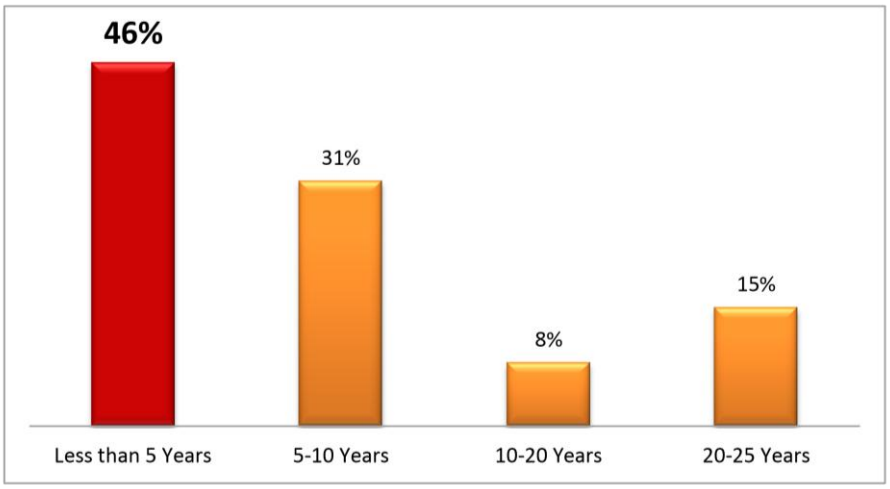


Figure 4-5 Years as a Professional Designer, Engineer, Transportation Expert, or Planner

Of that 25%, 46% of the survey respondents said they have less than five years of professional experience, 31% said they have 5-10 years of professional experience, and 15% said that they have 20-25 years of professional experience (Figure 4-5). This suggests that there were individuals from all levels of knowledge, insights, and expertise who participated in this survey.

This also indicates that there wasn't a overuse of one particular field. Instead, the fields of design, engineering, transportation, and planning were thought of as one unit of information being combined rather than keeping the fields separated.

5) How familiar are you with the Mill Creek Watershed in Dallas, Texas?

- Very familiar
- Familiar
- Somewhat familiar
- Not very familiar
- Never heard of it

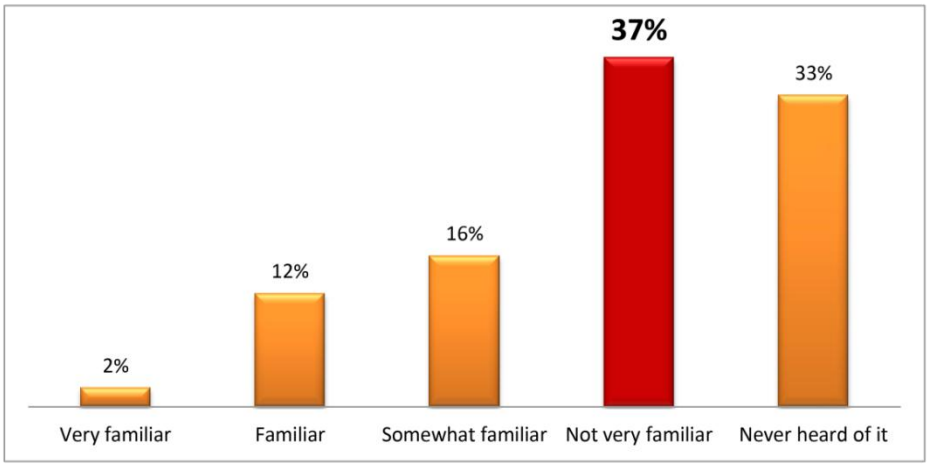


Figure 4-6 Familiarity with the Mill Creek watershed in Dallas, Texas

Of the 51 survey respondents, 37% said that they have little to no familiarity with the Mill Creek watershed (Figure 4-6). Additionally, 33% said that they have never heard of the Mill Creek watershed. This is interesting because the majority of the respondents said that they have lived within or near Dallas, Texas for more than twenty years. Within those twenty years, there have been two major cases of flooding caused by the deterioration of the Mill Creek watershed storm water infrastructure. This suggests that despite the recent awareness of Mill Creek by Dallas residents and city staff, the awareness of the issues has been only made public through tragedy or out of necessity.

6) Are you aware that Mill Creek has been buried underground since the 1930s?

- Yes
- Maybe
- No

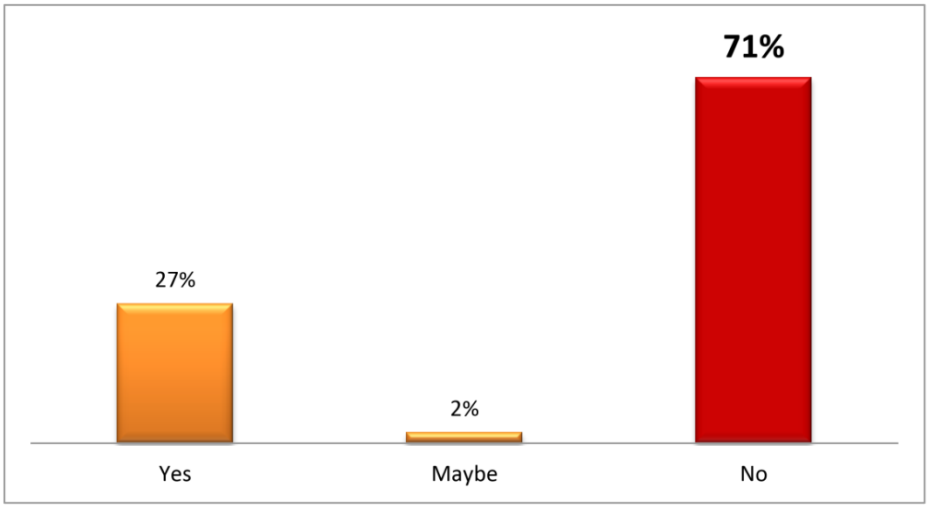


Figure 4-7 Awareness that Mill Creek has been buried underground since the 1930s

Of the 51 survey respondents, 71% said that they are unaware that Mill Creek has been buried underground since the 1930s (Figure 4-7). This suggests that the awareness of Mill Creek's existence is likely to be low for most of the survey respondents. Simply stated, if an individual knows that Mill Creek is underground, then they have knowledge of Mill Creek itself. If an individual does not know Mill Creek is underground, it is likely that they are unaware that Mill Creek even exists.

7) How familiar are you with the term, "Stream Daylighting"?

- Very familiar
- Familiar
- Somewhat familiar
- Not very familiar
- Never heard of it

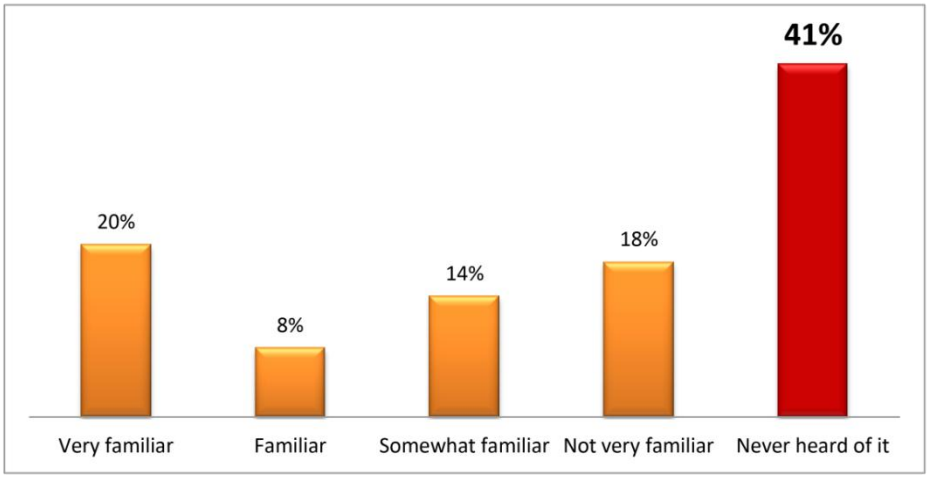


Figure 4-8 Familiarity with the term, "Stream Daylighting"

Of the 51 respondents, 41% said they have never heard of the term "stream daylighting" while 20% said that they are very familiar with the term (Figure 4-8). This indicates that 59% of the survey respondents have knowledge of the "stream daylighting" practice.

4.2 Desirability - PART 2: Visual Preference

Please note that this part of the Visual Preference Survey utilizes a rating scale of -3 to +3. -3 indicates the least desirable option, 0 indicates the neutral option, +3 indicates the most desirable option, and +1 and +2 indicate a "semi-desirable" option. The data from Part 2: Visual Preference from the Visual Preference Survey is described, graphically illustrated, and analyzed below:

CATEGORY 1: Stream Alignment Characteristics

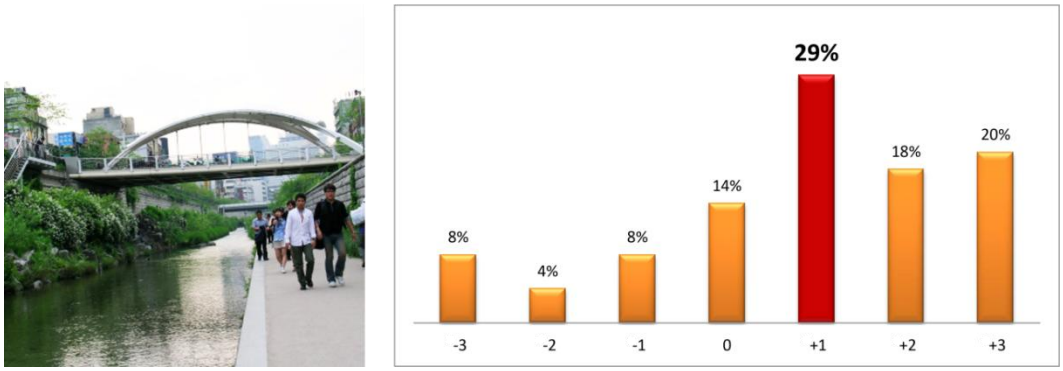


Figure 4-9 Stream Alignment Characteristics - Straight

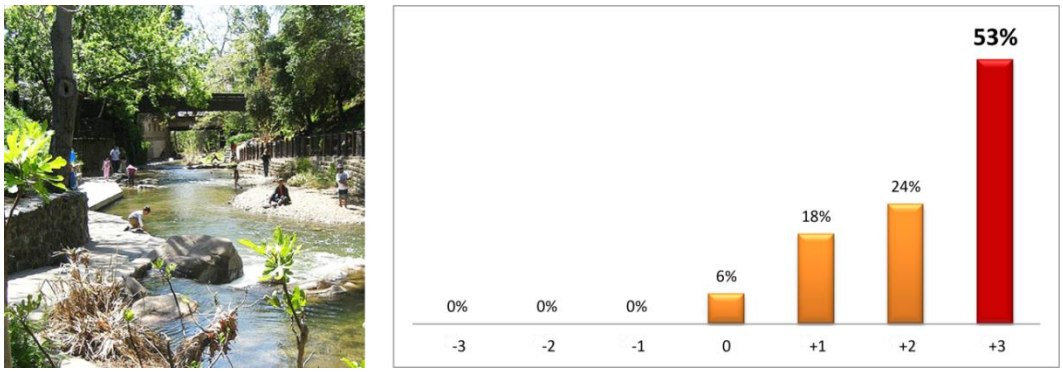


Figure 4-10 Stream Alignment Characteristics - Braided and Divided

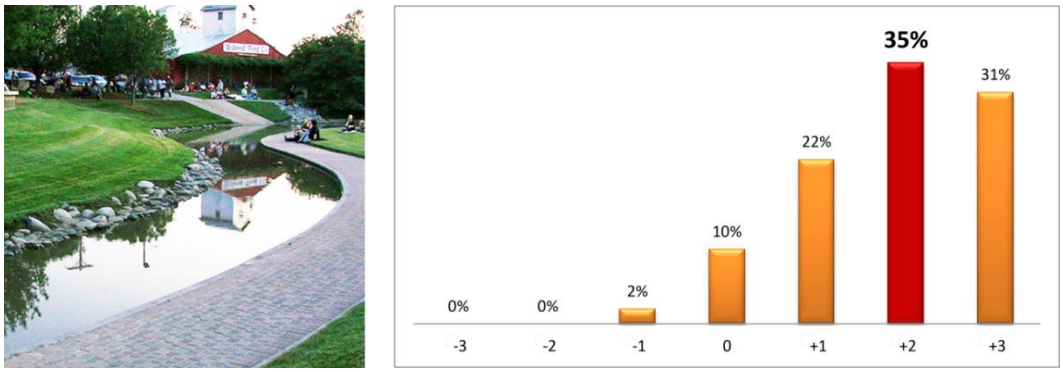


Figure 4-11 Stream Alignment Characteristics - Meandering/Curvilinear

For Category 1: Stream Alignment Characteristics (Figure 4-9 through 4-11), of the 51 survey respondents, 29% thought a straight stream was semi-desirable while 35% of the respondents thought a meandering/curvilinear stream was semi-desirable. Additionally, 53% of the respondents thought a braided/divided stream was the most desirable.

The braided/divided stream was the most desirable characteristic for the overall stream alignment. When asked why they chose that particular image, the responses could be grouped into desirable and undesirable themes, such as:

Desirable Themes:

- Connects to nature/naturalistic quality/organic form/more trees/earthliness
- Fun to explore/walk/talk/bring family and kids/be active
- Visually pleasing/appealing/beauty/peaceful/calm/relaxing/soothing/attractive
- Freedom of choice/diversity of textures
- Inviting to people as well as friendly animals
- Water reflection
- Minimal hardscape/less controlled/more rocks
- Easy access to the water

Undesirable Themes:

- Could be mixed with a more meandering quality
- Harder to maintain
- Needs more clean or elaborate lines
- Lacks a true formal design/almost too natural

CATEGORY 2: Stream Bank Materials

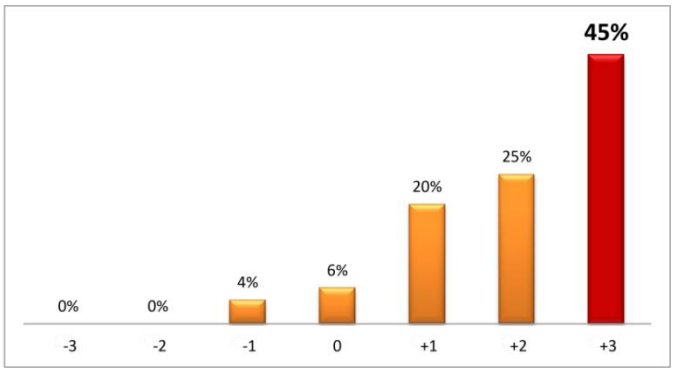


Figure 4-12 Stream Bank Materials - Rocks and Boulders

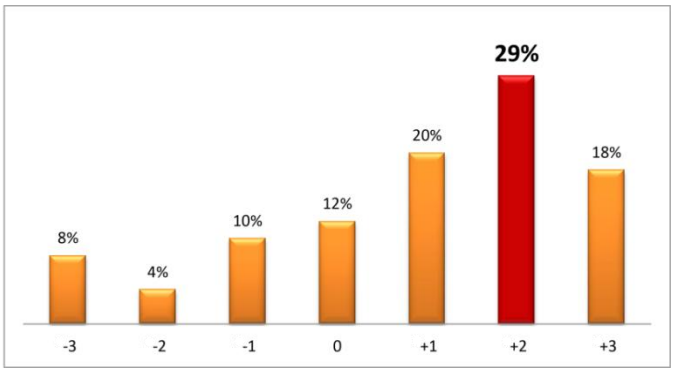
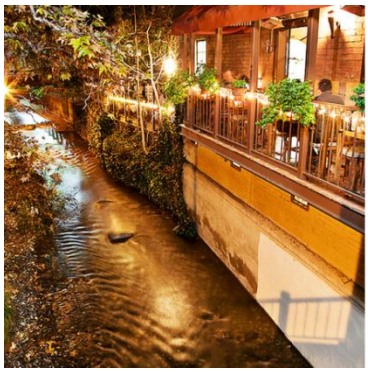


Figure 4-13 Stream Bank Materials - Vegetation



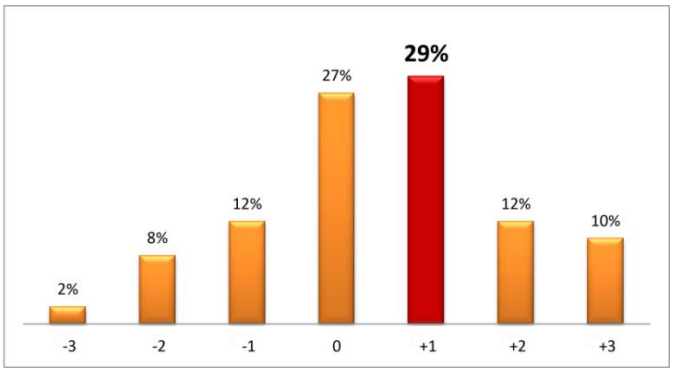


Figure 4-14 Stream Bank Materials - Vertical Wall

For Category 2: Stream Bank Materials (Figure 4-12 through 4-14), of the 51 survey respondents, 45% preferred rocks and boulders for a stream bank. For both the vegetation and vertical wall categories, 29% of the respondents found them semi-desirable for a stream bank.

Rocks and boulders were chosen as the most desirable set of materials for the stream bank by the majority of respondents. When asked why they chose that particular image, the responses could be grouped into desirable and undesirable themes, such as:

Desirable Themes:

- Creates a bold edge condition/remains transparent/helps establish character
- Fun to explore/walk/talk/bring family and kids/be active/inviting
- Act as stepping stones/sitting stones/crossing opportunities/access/more rocks
- Visually pleasing/appealing/beauty/peaceful/calm/relaxing/soothing/attractive
- Visually removes you from the city
- Efficient use of the water
- Easy to maintain/control/manageable/doesn't make it look over grown
- Creative expression of mixing commercialized and natural design

Undesirable Themes:

- Lacks people interaction/pedestrian ambiance
- Needs more vegetation/naturalistic features/variety
- Contextually unaware/careful where and how to place this type of design

CATEGORY 3: Stream Width

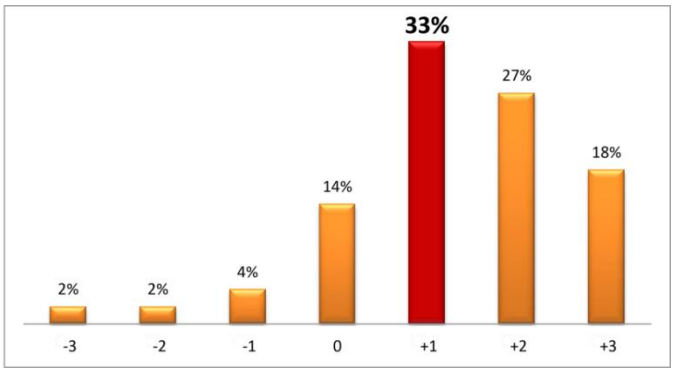
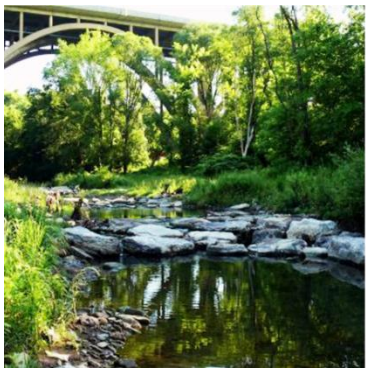


Figure 4-15 Stream Width - Narrow



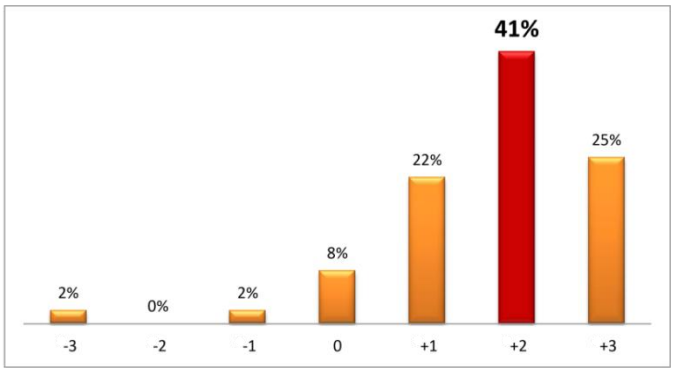


Figure 4-16 Stream Width - Moderate

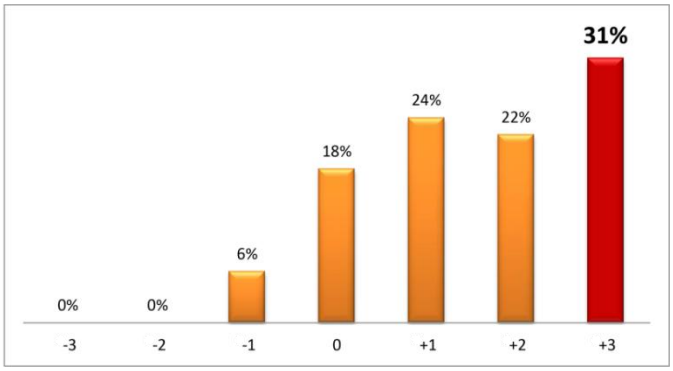


Figure 4-17 Stream Width - Wide

For Category 3: Stream Width (Figure 4-15 through 4-17), of the 51 survey respondents, 33% found a narrow stream to be semi-desirable while 41% found a moderately wide stream to be semi-desirable. Additionally, 31% found a wide stream was the most desirable of all the options.

A moderate width stream, when compared to a wide stream, was the most desirable stream width overall. When asked why they chose that particular image, the responses could be grouped into desirable and undesirable themes, such as:

Desirable Themes:

- Ratio of water to land to trees to people is balanced/size is just right
- Connects to nature/naturalistic quality/organic form/more trees/earthliness/real
- Water reflection/interaction/shaded/user-friendly/approachable
- Attractive to wildlife
- Fun to explore/walk/talk/bring family and kids/be active/inviting
- Act as stepping stones/sitting stones/crossing opportunities/access/more rocks
- Visually pleasing/appealing/beauty/peaceful/calm/relaxing/soothing/attractive
- Looks more like a stream instead of a river
- Water movement discourages mosquitoes
- Able to fit in several settings

Undesirable Themes:

- Needs more open space for people
- Lacks a backdrop for scenery/intimate settings
- Looks prone to flooding/needs simple levees

CATEGORY 4: Stream Water Features

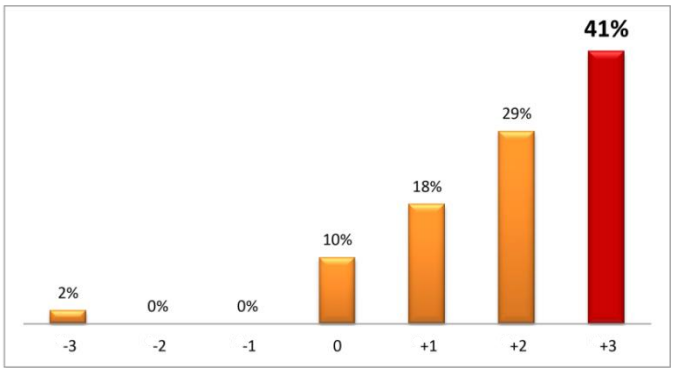


Figure 4-18 Stream Water Features - Ripples and Waves

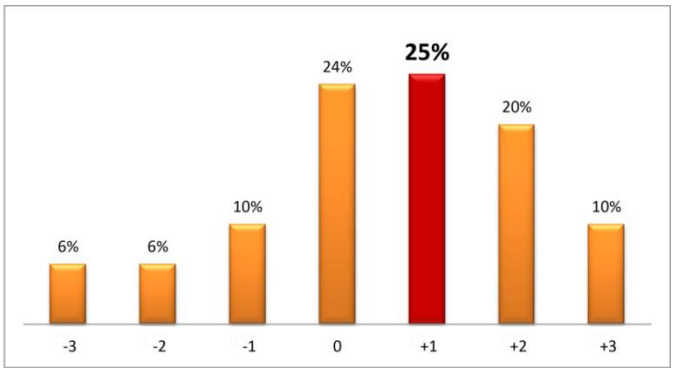


Figure 4-19 Stream Water Features - Fountain

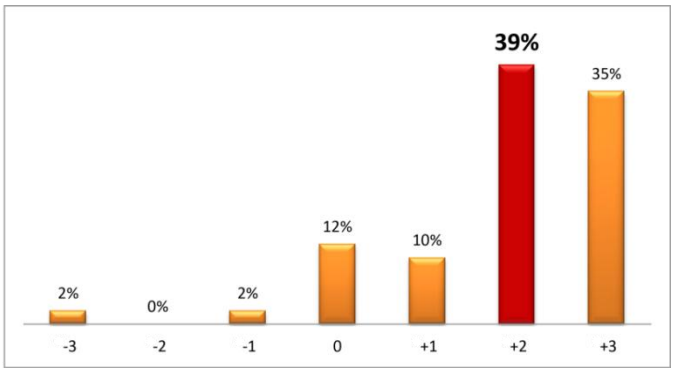


Figure 4-20 Stream Water Features - Cascade

For Category 4: Stream Water Features (Figure 4-18 through 4-20), of the 51 survey respondents, 41% found a ripple and wave water feature to be the most desirable. Additionally, 25% found a fountain water feature to be semi-desirable while 39% found a cascade water feature to be semi-desirable.

A ripple and wave water feature was the most desirable despite the 2% desirability margin over a cascading water feature. This implies that either water feature can be used to meet the same appeal. When asked why they chose that particular image, the responses could be grouped into desirable and undesirable themes, such as:

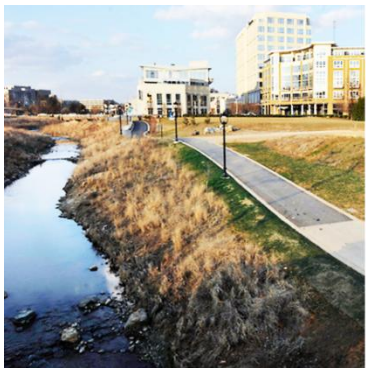
Desirable Themes:

- Dynamic/energetic/creates hot spots of interaction/interesting pathways/movement
- Creates noise/sound/water music/natural audio/water aeration
- Brings a picturesque scene of waves to the city
- Connects to nature/naturalistic quality/organic form /earthliness/real
- User-friendly/approachable
- Easy to maintain/water and energy efficient
- Fun to explore/walk/talk/bring family and kids/be active/inviting
- Act as stepping stones/sitting stones/crossing opportunities/access/more rocks
- Visually pleasing/appealing/beauty/peaceful/calm/relaxing/soothing/attractive
- Looks more like a stream found in natural areas around the world, like Colorado
- Flowing water movement discourages mosquitoes

Undesirable Themes:

- Needs to be used accordingly based on context
- Could be mixed with a more vertical water feature/or topographic change

CATEGORY 5: Vegetation Types



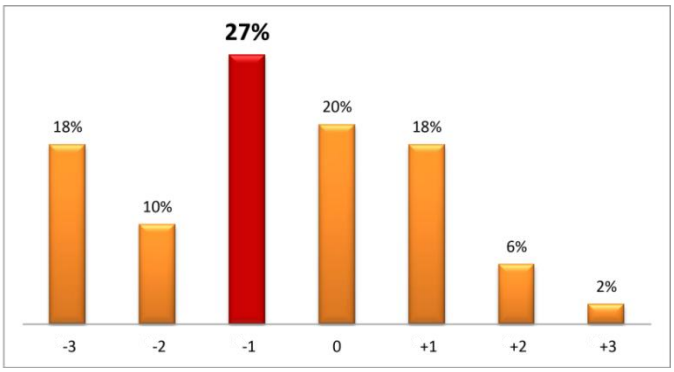


Figure 4-21 Vegetation Types - Minimal

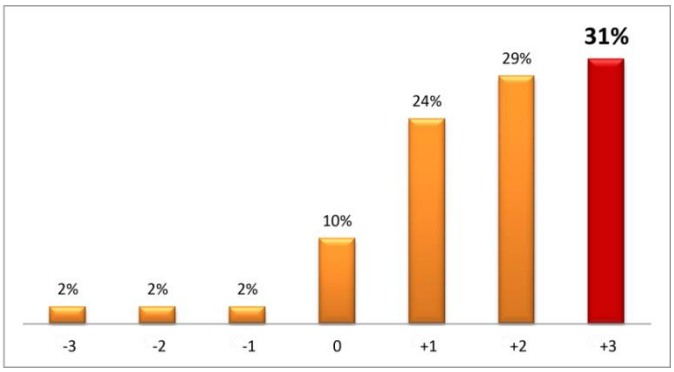


Figure 4-22 Vegetation Types - Natural and Native

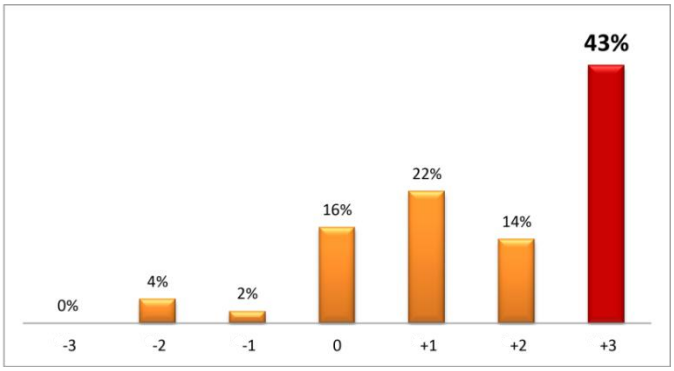


Figure 4-23 Vegetation Types - Overtly Designed

For Category 5: Vegetation Types (Figure 4-21 through 4-23), of the 51 survey respondents, 27% thought minimal vegetation was undesirable. In addition, 31% thought natural and native vegetation was most desirable. However, 43% thought overtly designed vegetation was most desirable overall.

An overtly designed planting scheme was the most desirable stream vegetation type. When asked why they chose that particular image, the responses could be grouped into desirable and undesirable themes, such as:

Desirable Themes:

- Clean, crisp, and sharp appearance/safe/designed/neater
- Has order/hierarchy/structure/easy to understand/purposeful
- Easy access to water
- Enhances low impact development (LID) opportunities
- User-friendly/approachable
- Easy to be maintained/not over grown
- Fun to explore/walk/talk/bring family and kids/be active/inviting
- Visually pleasing/appealing/beauty/peaceful/calm/relaxing/soothing/attractive
- Fits better within urban settings

Undesirable Themes:

- Needs to at least include some naturalistic elements/chances for discovery
- Be careful not to make it look too constructed
- Add denser or stronger vegetation for erosion control/biological functions

CATEGORY 6: Proximity of Path

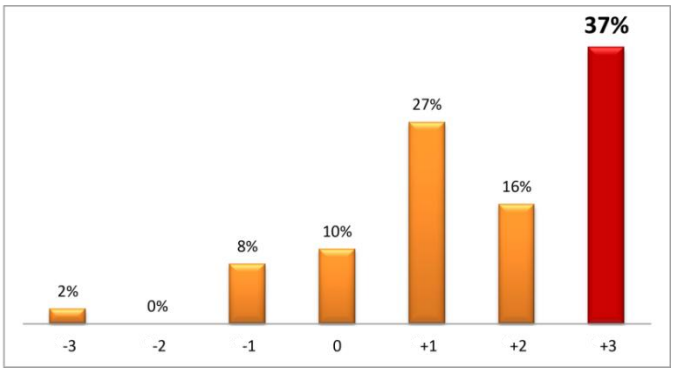


Figure 4-24 Proximity of Path - Immediately Adjacent

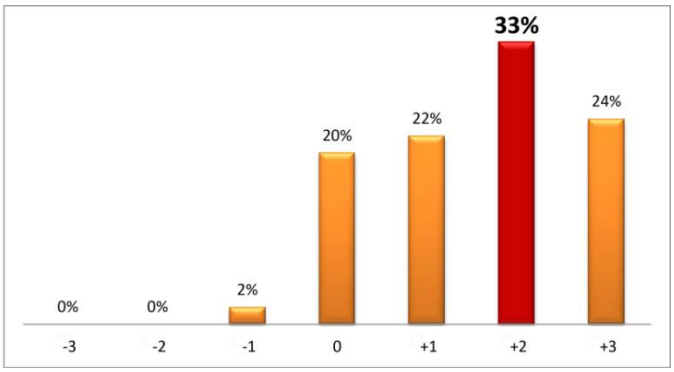


Figure 4-25 Proximity of Path - Nearby

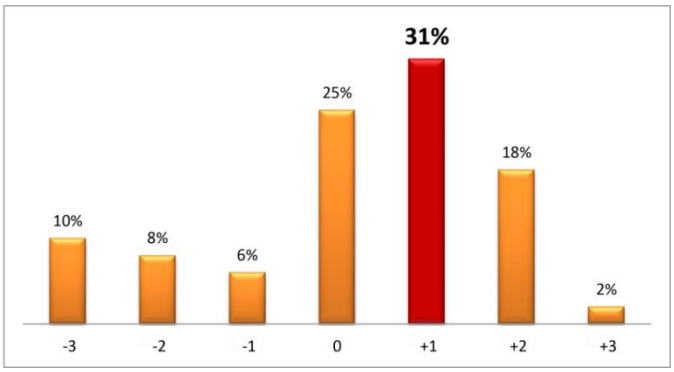


Figure 4-26 Proximity of Path - Raised

For Category 6: Proximity of Path (Figure 4-24 through 4-26), of the 51 survey respondents, 37% found that a path immediately adjacent to the stream was most desirable. Additionally, 33% found that a path nearby to the stream was semi-desirable while 31% found that a path raised above the stream to be semi-desirable.

An immediately adjacent pathway was the most desirable distance away from a stream. When asked why they chose that particular image, the responses could be grouped into desirable and undesirable themes, such as:

Desirable Themes:

- Easy access to water/as close as possible to water/interaction
- Visually pleasing/appealing/beauty/peaceful/calm/relaxing/soothing/attractive
- Fun to explore/walk/talk/bring family and kids/be active/inviting/jog/ride
- Easy to be maintained
- Fits better within urban settings/vital to the life of the urban dweller/city park feel
- Emphasizes the creek more
- Looks like a path found in a natural setting
- User-friendly/approachable

Undesirable Themes:

- Be careful about the surrounding context
- Understand the depth of water since people are literally up against the stream
- Safety may be a concern for children/may need a small buffer

CATEGORY 7: Proximity of Roadway

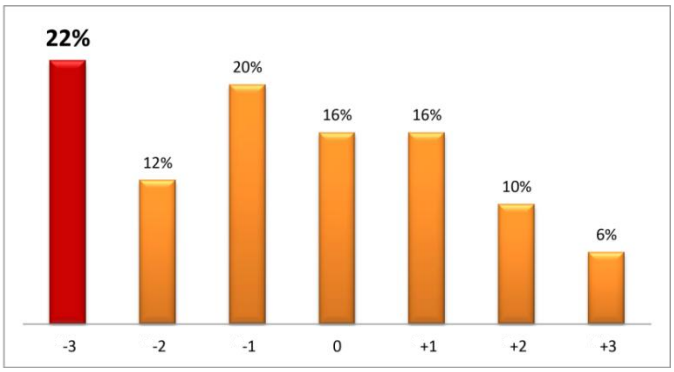


Figure 4-27 Proximity of Roadway - Immediately Adjacent

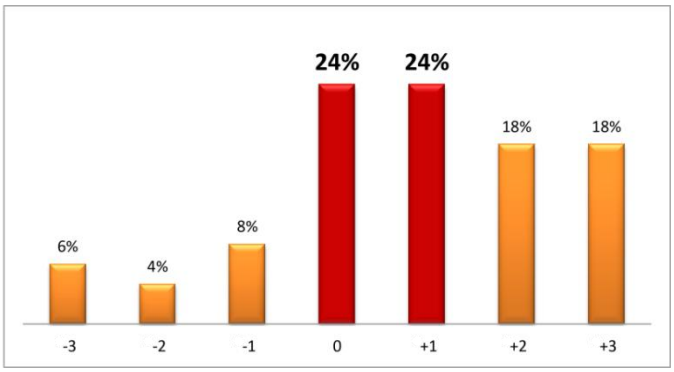


Figure 4-28 Proximity of Roadway - Nearby

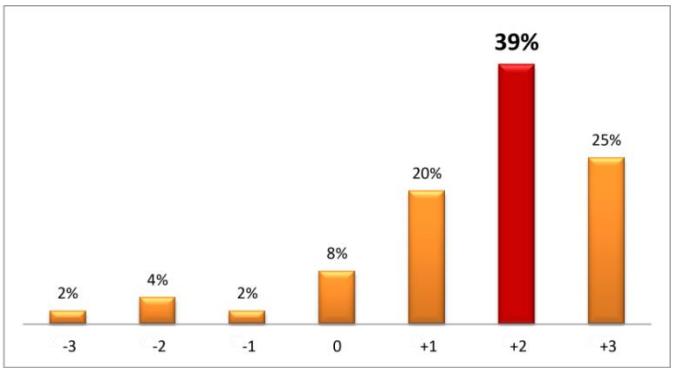


Figure 4-29 Proximity of Roadway - Distant

For Category 7: Proximity of Roadway (Figure 4-27 through 4-29), of the 51 survey respondents, 22% found that a roadway immediately adjacent to the stream was least desirable. Two sets of 24% for 0 and +1 found that a roadway nearby to the stream was neutral and undesirable. Additionally, 39% found that a roadway set back at a distance from the stream was semi-desirable.

A distant roadway was the most desirable distance away from a stream. When asked why they chose that particular image, the responses could be grouped into desirable and undesirable themes, such as:

Desirable Themes:

- Emphasize pedestrian experience more than vehicular traffic
- Utilizes a much-needed barrier/ larger buffer equals the high water filtration
- Open space/viewing corridors/ scenery/backdrop/picturesque
- Resembles something more natural/humanity and nature working together
- Easy to be maintained/reduces trash and debris/less likely to flood/clean
- Less traffic/ambient and vehicle noise/reduces exhaust
- Physically and visually removes you from the city/ user-friendly/approachable
- Visually pleasing/appealing/beauty/peaceful/calm/relaxing/soothing/attractive
- Fits better within urban settings/vital to the life of the urban dweller/city park feel

Undesirable Themes:

- Do not include elements such as port-a-potty's/use architecture instead
- Vehicular access for maintenance and service/bridges are needed
- Include specific views so that people driving don't miss it
- Understand what it looks and feels like to drive by a daylighted stream
- Offer a natural element to the overall design

4.3 Summary

For two weeks (14 days) starting March 31, 2015 and ending April 14, 2015, the Visual Preference Survey recorded fifty-one (51) survey participants. For Part 1: Participant Information, 27% of those respondents were 51-60 years old, 61% have lived in the Dallas/Fort Worth area for more than twenty years, and 43% were local or nearby employees in Dallas, Texas. Additionally, 75% were not professional designers, engineers, transportation experts, or planners while the remaining 25% were. Of that 25% that were in the related topic fields, 46% of those participants had only been in their profession for 5 years or less. Of the overall participants, 31% were not very familiar with the Mill Creek watershed in Dallas, Texas while 71% were unaware that Mill Creek had been buried underground since the 1930s. Finally, 41% of the participants had never heard of the term "stream daylighting".

For Part 2: Visual Preference, 53% of the participants chose a braided and divided stream alignment characteristic to be the most desirable, 45% chose rocks and boulders as the most desirable material selection for the stream bank, and 41% slightly preferred a moderately wide stream. For the stream water features, 41% of the participants found ripples and waves to be the most desirable while 43% chose an overtly designed vegetation scheme to be the most desirable. To conclude, 37% found an immediately adjacent pedestrian path next to the stream to be the most desirable while 39% found a distant roadway in proximity to the stream to be the most desirable.

Chapter 5

Conclusions

5.1 Introduction

From the findings, a series of design suggestions for the stream daylighting scenario of Mill Creek was accumulated in order to elaborate and help specify how and to what extent each design element could potentially be utilized for future revitalization. These suggestions assisted in developing the digital depiction, or Visualization. The before image of the Visualization sequence visually showcases the existing conditions of the chosen site (section 3.1.1). The after image of the Visualization sequence however, illustrates how an underground water channel can be aesthetically depicted as an open water channel using the design element suggestions as an implementation guide.

Understanding how Landscape Architects and by extension, other design and engineering professions, can benefit from stream daylighting knowledge is important to how urban hydrological methods will continue to advance into the future. Gaining such knowledge can be achieved through additional research into stream daylighting as a whole.

5.2 Suggestions and Visualization

At quadrant 3 of the San Jacinto Street and Haskell Avenue intersection, there is an open lot that has potential to become a project site for daylighting Mill Creek (section 3.1.1). The site is surrounded by single and multi-family housing and small, deteriorating business structures. The streets and roadways offer little to no pedestrian sidewalks, pathways, or crosswalks and lack proper elements of traffic control, such as paint and reflectors.

Despite the physical and visual issues, desirable elements for a viable restoration site are in place. These desirable elements include limited easement complications, plenty of space for interesting public interaction and traversing zones, clear sightlines and view corridors, contextual relation to downtown Dallas as well as the surrounding historic and hospital districts, is in walking distance to restaurants, parks, housing, and open space, and is along the flowline of Mill Creek.

Before and after images of the site at the intersection of San Jacinto Street and Haskell Avenue are used as guides to help understand the results from the Visual Preference Survey. The before image (Figure 4-30) represents the existing conditions found at the site, while the after image (Figure 4-31) is a digital depiction, or Visualization, of the site when the most desirable design elements chosen by the fifty-one (51) survey respondents are added. The after image is a design that utilizes what design elements were found to be the most desirable.

This site (Figure 4-30) in particular, along the Mill Creek flowline and less than a block away from the Drainage Relief Tunnel (section 2.3.3) location of the Ross Avenue and Haskell Avenue intersection, is characterized by roadway deterioration, run-down buildings, and unsafe pedestrian conditions. As an alternative to the Drainage Relief Tunnel (section 2.3.3), the after image, or Visualization, below (Figure 5-1) depicts a stream daylighting solution that can not only mitigate the Mill Creek infrastructural issues that have surfaced since the 1930s, but can also assist in preventing future issues of increased stormwater runoff, pollution filtration, microclimate enhancement, and human, animal, and plant habitat rehabilitation. The Visualization makes use of the suggestions taken from the survey to visually illustrate how an immediate pathway can work alongside rocks and boulders as a combined stream bank that is linked together by gently sloping landforms leading to rock crossways and mid-stream formations. This adds interest and

dynamism to the hierarchical planting scheme and to the stream itself by including a channel width that is easy to traverse. The roadway being at a distance does not interfere with all the other elements that help tie the created space together as an urban daylighting scene.

The results from the Visual Preference Survey as well as the desirable and undesirable themes that derived from the results can be used as suggestions for understanding a generalized design direction, as shown through the Visualization depiction (Figure 5-1) below. This depiction is a single design solution, out of a potentially endless number of design outcomes. However, given that the depiction visually demonstrates how each of the most desirable design variations from each design element category in the Visual Preference Survey can be used together holistically, the overall choreography of the elements help dictate where, how, and to what extent they might be applied.

The following are suggestions from the survey results that provide insights on future reinterpretations of the same site or other similar sites along the Mill Creek flowline:

CATEGORY 1: Stream Alignment Characteristics - Braided and Divided

Once Mill Creek has been physically daylighted, the topographic changes will vary depending on how deep the bottom of the creek is. This creates opportunities to include landforms, boulders, vegetation, or a combination of all as intermingling and interconnecting features that break up, divide, and braid the water body. However, further geomorphological and engineering studies are necessary to determine the most appropriate width, depth, slope, and water volume for the stream to take on a braided and divided character (Gilvear 1999; Phillips 2007, 2011 and 2012; Yuill et al. 2013).

CATEGORY 2: Stream Bank Materials - Rocks and Boulders

For the creek bank, the option perceived as most desirable would be the use of rocks and boulders. They are visually pleasing and also purposeful. They help create water friction, enhance filtration and biological growth, offer structural support for soil, provide visual interest and even encourage pedestrian interaction zones through water crossings and resting stops. The use of well-placed vegetation in conjunction with the rocks and boulders can help emphasize areas of interest, accent land patterns and formations, and to minimize the overuse of any particular style or type of rock or boulder. However, boulders are very unpredictable due to the unique characteristics each stone has. Boulders at the design level only represent a suggested placement, scale, and arrangement. These features could change drastically in the field based on how the boulders are received, situated, and installed.

CATEGORY 3: Stream Width - Moderate

The width and size of the creek can be varied at different locations, but can be kept within a reasonably moderate span of 10-20 ft. in order to maintain a potential crossing option for pedestrians. This design choice may help mitigate the need for some foot and bicycle bridges but may also hinder the connectivity of both sides of the creek. The need for water crossings is important and should be strategically addressed for safety and engineering purposes when designing either foot, bicycle, or multifunctional bridges.

CATEGORY 4: Stream Water Features - Ripples and Waves

When created with rocks and boulders, these features can also be used as stepping stones across the creek. This single design feature offers numerous opportunities for water interaction, water aeration, water ripple and wave effects, picturesque scenery,

natural sound effects, creek character, and an aesthetic quality that can be replicated over and over as check dams for flood control. However, this water feature could potentially pose safety issues concerning the stream slope, the stream width, and type of material used for the stepping stones. Further studies into flood capacities, water depth, and water flow are needed to help mitigate these safety issues.

CATEGORY 5: Vegetation Types - Overtly Designed

Using a vegetation scheme that emphasizes a visual upkeep, cleanliness, and a hierarchy can be a very beneficial addition to the design, which can also include native riparian species. This simply points to a planting arrangement that reflects design principles and elements such as form, line, texture, movement, harmony, scale, color, and variety. An arrangement such as this is dependent on horticultural and environmental factors during the design process. A further understanding of the water quality and soil health is necessary for a heavily designed and articulated planting scheme. Once installed, it is also important for the plants' longevity to be carefully maintained.

CATEGORY 6: Proximity of Path - Immediately Adjacent

Where to place the pedestrian path and creek access is critical to the experience the design offers its audience. Placing the pathway immediately next to the creek wherever possible offers a very distinct invitation to explore, play and connect with nature. This quality attracts families, recreational enthusiasts, and children and can offer visual interest by mimicking the stream alignment. This also allows opportunities for low-lying vegetation and groundcover to flow along gently sloping banks that link up to the pathway. In addition, trails immediately adjacent to the creek may pose safety issues that need to be addressed during the design process.

CATEGORY 7: Proximity of Roadway - Distant

With this site, the immediately adjacent two-way road was removed in order to include even more open green space, vegetation, pedestrian circulation, a wider creek, naturalistic features, and to ultimately balance the use of the design against the urban context. This removal should be considered only in the broader context of how vehicular circulation works within and around the site. This street removal also created a small park-like area spanning more than eight-hundred (800) ft. between the existing northern (San Jacinto Street) and southern (Bryan Street) roadways which act as edges for the space. A downside to this is the overall reduction of accessible routes for vehicular traffic which include emergency and maintenance vehicles.

The before image and after image, or Visualization, are shown as a visual comparison below:

BEFORE) San Jacinto Street and Haskell Avenue

Figure 5-1 Existing site conditions - Quadrant 3 of the San Jacinto Street and Haskell Avenue intersection

AFTER) San Jacinto Street and Haskell Avenue

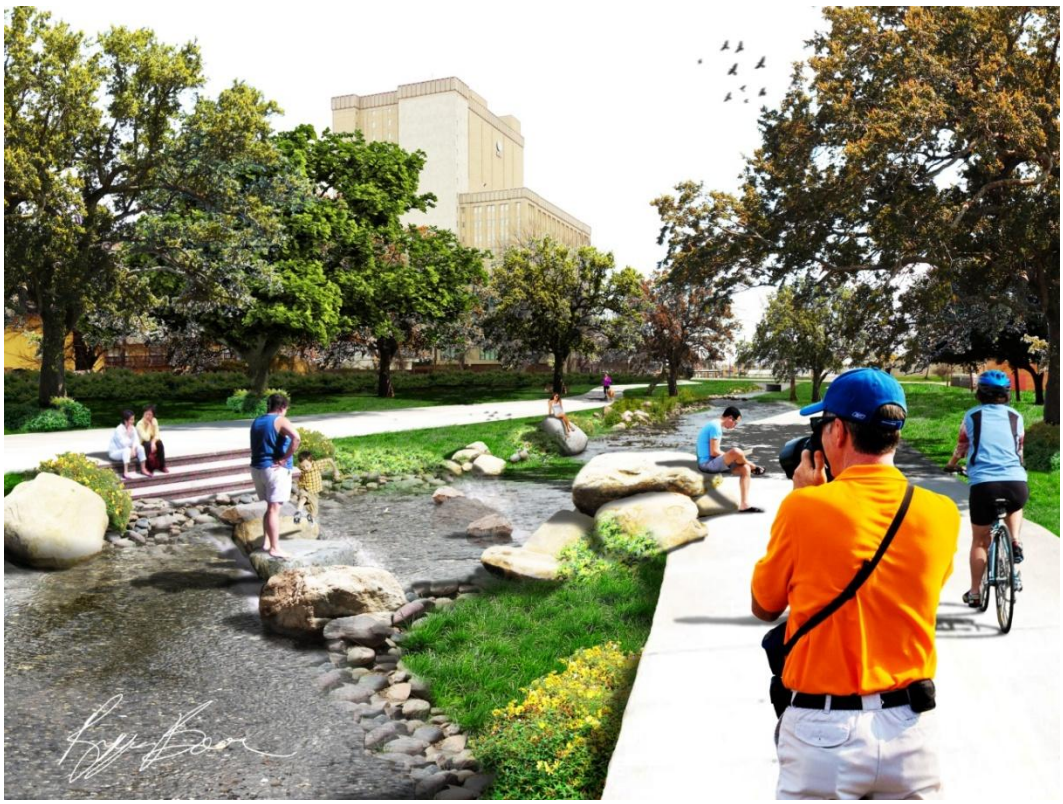


Figure 5-2 Design Element Suggestions for Stream Daylighting - San Jacinto Street and Haskell Avenue

5.3 Relevance of Study

As this study is an extension of Koshaley's (2008) research, the relevance of the this research is to provide important design input as to how urban waterway daylighting projects are designed, planned, engineered, implemented, and maintained in the future (Koshaley 2008). It is important to understand the potential for unearthing the streams, rivers, and creeks that have been buried underground (Koshaley 2008) in light of how recent stream daylighting projects have proven to provide economic, social, environmental, cultural, and historical benefits to their communities (section 3.1.1).

This study presents design suggestions as a visual foundation for the revitalization of Mill Creek, in the form of responses from a Visual Preference Survey including a digital depiction representing a stream daylighting and restoration project. This foundation can be used as a visual reference and can inform any design considerations prior to finalizing design concept exploration and subsequent design refinement. This research can also assist in the early decision making process when attempting to single out a site or multiple sites along the Mill Creek flowline, or any other similar underground streams in or near the target area. The findings are not meant to present a formula applicable to any situation, but to offer results of public perception as one consideration in the search for appropriate and creative design solutions.

5.4 Landscape Architects and Their Role

Landscape architects are not the only professionals who need to be involved in stream daylighting projects. These projects are complex, interdisciplinary, and call for a variety of professions that can provide active participation, contribution, and support such as, but not limited to engineers, hydrologists, urban designers, planners, transportation experts, geomorphology experts, biologists, economists, environmental scientists, and of

course landscape architects. In addition, there is a call for government involvement as well as active and dedicated citizens that are residents or community members.

Among these disciplines, landscape architects in particular are uniquely trained in visual design, a talent that is especially relevant to the integration of interventions with natural and naturalistic systems, which include stream daylighting. In essence, this visual design training allows landscape architects to holistically integrate the technical contributions of all the disciplines into a design expression on the land.

Landscape architects have the opportunity and professional obligation to raise awareness and to mobilize support by operating in a leading role through facilitation, administration, organization, and design (Koshaley 2008). “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," (Koshaley 2008, p. 110).

5.5 Potential for Future Research

This research offers insights into what the design, engineering, and planning professions are doing to create and manage stream daylighting projects. Future research topics might include performance-based analysis of stream daylighting, such as measurement of water quality, social value and economic value. Additionally, geomorphological performance studies using Rosgen's stream classification system (Rosgen 1994) can be studied in further detail as well as the actual design of a particular site using the visual preference data and suggestions provided.

There are also additional opportunities for further research by investigating how flora and fauna habitats flourish and how maintenance protocols differ from other landscape architectural projects. This research narrowed the scope of the Mill Creek

watershed to one specific location based on the current and active plans to mitigate the issues presented by deteriorating infrastructure of Mill Creek. Further analysis of other possible locations for daylighting Mill Creek and other urban watercourses could be useful in providing alternatives to sizes, shapes, and relationships of the design elements themselves. Research into additional visual design elements are critically important to the evolution of stream daylighting and should differentiate as stream daylighting becomes more recognizable as a mainstream practice.

Economic studies such as cost/benefit are also topics for future research, given that the extent and character of a stream daylighting project is largely dictated by the allowed budget. Further research into budgeting and economic impacts of a stream daylighting project is needed as well as research into the political aspect of potential businesses and homes being displaced as a result. How an area can boost economic investment and active public engagement within nearby communities could prove to be helpful through social applications and studies relating to stream daylighting. Research into new technologies that could assist in the stream daylighting process and end result is needed. Further research on the early history of Mill Creek and its original physical properties are opportunities to understand ecology, flow lines, habitats, and water capacity prior to heavy urbanization in order to help dictate how the decisions made about Mill Creek respond to how the city of Dallas grows into the future.

Appendix A

Institutional Review Board (IRB) Research Approval and Acknowledgement

Institutional Review Board (IRB) approval and acknowledgement of this research:

The University of Texas at Arlington
Office of Research Administration
Regulatory Services

Institutional Review Board
Notification of Exemption

March 31, 2015

Ryan Brown
Dr. James Richards
School of Architecture

Protocol Number: 2015-0669

Protocol Title: *Stream Daylighting Restoration as Green Infrastructure: A Visual Preference Analysis for the Future Redevelopment of Dallas' Mill Creek*

EXEMPTION DETERMINATION

The UT Arlington Institutional Review Board (IRB) Chair, or designee, has reviewed the above referenced study and found that it qualified for exemption under the federal guidelines for the protection of human subjects as referenced at Title 45CFR Part 46.101(b)(2).

> • (2)Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures or observation of public behavior, unless:(i) information obtained is recorded in such a manner that human subjects can be identified, either directly or through identifiers linked to the subject; and (ii) any disclosure of the human subjects' responses outside the research could reasonably place the subjects at risk of criminal or civil liability or be damaging to the subjects' financial standing, employability, or reputation.

You are therefore authorized to begin the research as of **March 31, 2015**.

Pursuant to Title 45 CFR 46.103(b)(4)(iii), investigators are required to, "promptly report to the IRB ***any*** proposed changes in the research activity, and to ensure that such changes in approved research, during the period for which IRB approval has already been given, are **not initiated without prior IRB review and approval** except when necessary to eliminate apparent immediate hazards to the subject." Please be advised that as the principal investigator, you are required to report local adverse (unanticipated) events to the Office of Research Administration; Regulatory Services within 24 hours of the occurrence or upon acknowledgement of the occurrence. All investigators and key personnel identified in the protocol must have documented Human Subject Protection (HSP) Training on file with this office. Completion certificates are valid for 2 years from completion date.
The UT Arlington Office of Research Administration; Regulatory Services appreciates your continuing commitment to the protection of human subjects in research. Should you have questions, or need to report completion of study procedures, please contact Alyson Stearns at

817-272-9329 or astearns@uta.edu. You may also contact Regulatory Services at 817-272-3723 or regulatoryservices@uta.edu.

Regulatory Services:
The University of Texas at Arlington, Center for Innovation
202 E. Border Street, Ste 201, Arlington, Texas 76010, Box#19188
(T) 817-272-3723 (F) 817-272-5808 (E) regulatoryservices@uta.edu (W) www.uta.edu/rs

Appendix B

Visual Preference Survey with Informed Consent Document

Distributed Visual Preference Survey with Informed Consent Document:

INFORMED CONSENT DOCUMENT

PRINCIPAL INVESTIGATOR
Ryan Brown
Program in Landscape Architecture
School of Architecture
The University of Texas at Arlington
Email: ryan.brown@mavs.uta.edu
Phone: 972.352.8631

FACULTY ADVISOR
Professor James Richards
Program in Landscape Architecture
School of Architecture
The University of Texas at Arlington
Email: jrichard@uta.edu

TITLE OF PROJECT
Stream Daylighting Restoration as Green Infrastructure: A Visual Preference Analysis for the Future Redevelopment of Dallas' Mill Creek

INTRODUCTION
You are being asked to participate in a research study about the visual attributes and design elements associated with stream daylighting as a potential foundation for redeveloping Mill Creek, Dallas, Texas. You are being selected because you have conducted research, have knowledge of, have visited, live, work, or operate a business within or near the Mill Creek Watershed in Dallas County. Participation is in the form of a short survey questionnaire. Your participation is completely voluntary. Refusal to participate or discontinuing your participation at any time will involve no penalty or loss of benefits to which you are otherwise entitled. Please ask questions if there is anything you do not understand. This research will be compiled into a thesis format and is the final step towards earning my degrees at the University of Texas at Arlington. Thank you so much for your time and consideration.

PURPOSE
The specific purpose(s) of this research study are to understand which visual attributes and design elements are most desirable when associated with stream daylighting and how these elements can be suggested for the future redevelopment of Mill Creek, Dallas, Texas.

DURATION
Participation in this survey will last approximately 15 minutes.

NUMBER OF PARTICIPANTS
The number of anticipated participants in this research study is 500 adults.

PROCEDURES
The procedures which will involve you as a research participant include: Filling out to the best of your ability and truthfully, the (online) survey which includes pictures of existing examples of stream daylighting projects. Submission of your answers will be online.

POSSIBLE BENEFITS
Participants would not be directly benefited from this research. This research does have the possibility of benefiting fields such as landscape architecture, city planning, civil and structural engineering, environmental science, fluvial geomorphology, sociology, retail developers, and professions regarding city design. Indirectly, this would benefit the consumer.

POSSIBLE RISKS/DISCOMFORTS
There are no perceived risks or discomforts for participating in this research study. Should you experience any discomfort please inform the researcher, you have the right to quit any study procedures at any time at no consequence.

COMPENSATION
There will be no compensation for participation in this survey.

ALTERNATIVE PROCEDURES
There are no alternative procedures offered for this study. However, you can elect not to participate in the study or quit at any time at no consequence.

VOLUNTARY PARTICIPATION
Participation in this research study is completely voluntary. You have the right to decline participation or quit at any time at no consequence.

CONFIDENTIALITY
Every attempt will be made to see that your study results are kept confidential. All data collected will be stored at The University of Texas at Arlington in the office of Professor James Richards (room 322) in the School of Architecture building for at least three (3) years after the end of this research. The results of this study may be published and/or presented at meetings without naming you as a participant. Additional research studies could evolve from the information you have provided, but your information will not be linked to you in anyway; it will be anonymous. Although your rights and privacy will be maintained, the Secretary of the Department of Health and Human Services, the UTA Institutional Review Board (IRB), and personnel particular to this research have access to the study records. Your records will be kept completely confidential according to current legal requirements. They will not be revealed unless required by law, or as noted above. The IRB at UTA has reviewed and approved this study and the information within this consent form. If in the unlikely event it becomes necessary for the Institutional Review Board to review your research records, The University of Texas at Arlington will protect the confidentiality of those records to the extent permitted by law.

CONTACT FOR QUESTIONS
Specific questions about this research study may be directed to me, Ryan Brown or my faculty advisor, James Richards. Phone numbers and email listed for both are listed below. Any questions you may have about your rights as a research participant or a research-related injury may be directed to the Office of Research Administration; Regulatory Services at 817-272-2105 or regulatoryservices@uta.edu.

Ryan Brown
Phone: 972.352.8631
Email: ryan.brown@mavs.uta.edu

Professor James Richards
Phone: 817.999.1522
Email: jrichard@uta.edu

CONSENT
By clicking the "Accept" button below, you confirm that you are 18 years of age or older and have read or had this document read to you. You have been informed about this study's purpose, procedures, possible benefits and risks, and have been given the opportunity to ask questions and contact the researcher before you choose to participate.

You voluntarily agree to participate in this study. By choosing to participate, you are not waiving any of your legal rights. Refusal to participate will involve no penalty or loss of benefits to which you are otherwise entitled. You may discontinue participation at any time without penalty or loss of benefits to which you are otherwise entitled.

- Accept

PART 1 - Participant Information

1) What age group do you belong to?

- 21-30
- 31-40
- 41-50
- 51-60
- 61+

2) How long have you lived in the Dallas/Fort Worth area?

- 0-5 Years
- 5-10 Years
- 10-15 Years
- 15-20 Years
- 20+ Years

3) Are you a business owner, landowner, employee, resident, visitor, or student of Dallas, Texas? Select all that apply.

- o Business Owner
- o Landowner
- o Local or nearby employee
- o Resident of Dallas County
- o Visitor
- o Student (resident or commuter)
- o Other_____
- o None of the above

4) Do you currently work as a professional designer, engineer, transportation expert, or planner? If yes, please indicate the number of years you have contributed to your field.

- o Yes, for how many years? _____
- o No

5) How familiar are you with the Mill Creek Watershed in Dallas, Texas?

- o Very familiar
- o Familiar
- o Somewhat familiar
- o Not very familiar
- o Never heard of it

6) Are you aware that Mill Creek has been buried underground since the 1930s?

- o Yes
- o Maybe
- o No

7) How familiar are you with the term, "Stream Daylighting"?

- o Very familiar
- o Familiar
- o Somewhat familiar
- o Not very familiar
- o Never heard of it

PART 2 - Visual Preference

The following photographs are of existing rivers, creeks, and streams that have been **daylighted**, or a "deliberate act of exposing the full or partial flow of previously buried rivers, creeks, and streams into restored surface waterways" (Koshaley 2008).

On a scale of -3 to +3, please rate the desirability of each of the following photographs (+3 being the most desirable, 0 being neutral, and -3 being the least desirable).

CATEGORY 1: Stream Alignment Characteristics

Straight

○ ○ ○ ○ ○ ○ ○
-3 -2 -1 0 1 2 3

Braided/Divided

○ ○ ○ ○ ○ ○ ○
-3 -2 -1 0 1 2 3

Meandering/Curvilinear

○ ○ ○ ○ ○ ○ ○
-3 -2 -1 0 1 2 3

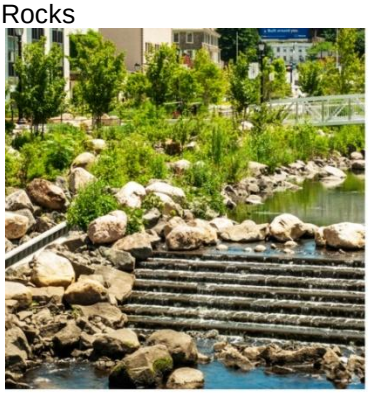
8) Why did you choose that image, or images, as the most desirable? Please explain your answer.

_____

_____

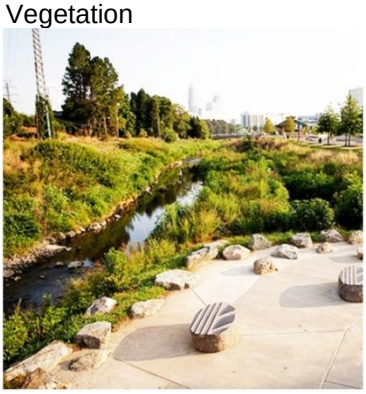
CATEGORY 2: Stream Bank Materials

Rocks



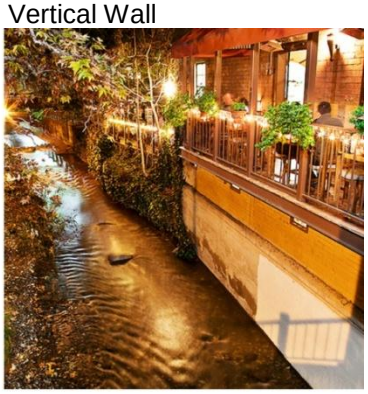
○ ○ ○ ○ ○ ○ ○
-3 -2 -1 0 1 2 3

Vegetation



○ ○ ○ ○ ○ ○ ○
-3 -2 -1 0 1 2 3

Vertical Wall



○ ○ ○ ○ ○ ○ ○
-3 -2 -1 0 1 2 3

9) Why did you choose that image, or images, as the most desirable? Please explain your answer.

_____

_____

CATEGORY 3: Stream Width

Narrow

○ ○ ○ ○ ○ ○ ○
-3 -2 -1 0 1 2 3

Moderate

○ ○ ○ ○ ○ ○ ○
-3 -2 -1 0 1 2 3

Wide

○ ○ ○ ○ ○ ○ ○
-3 -2 -1 0 1 2 3

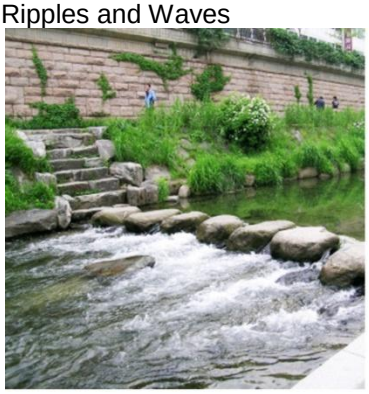
10) Why did you choose that image, or images, as the most desirable? Please explain your answer.

_____

_____

CATEGORY 4: Stream Water Features

Ripples and Waves

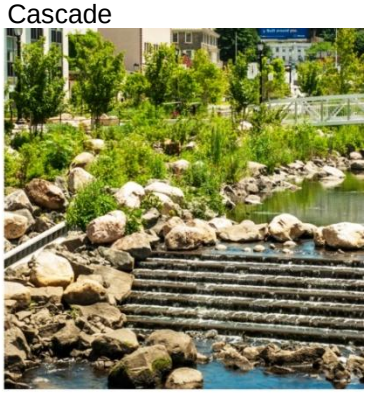


○ ○ ○ ○ ○ ○ ○
-3 -2 -1 0 1 2 3

Fountain

○ ○ ○ ○ ○ ○ ○
-3 -2 -1 0 1 2 3

Cascade



○ ○ ○ ○ ○ ○ ○
-3 -2 -1 0 1 2 3

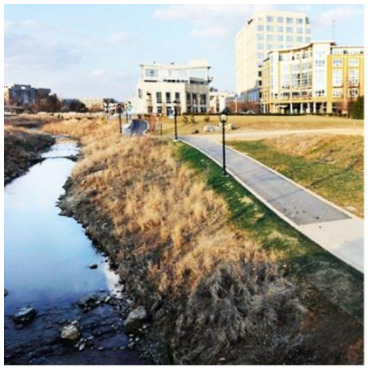
11) Why did you choose that image, or images, as the most desirable? Please explain your answer.

_____

_____

CATEGORY 5: Vegetation Types

Minimal



○ ○ ○ ○ ○ ○ ○
-3 -2 -1 0 1 2 3

Natural/Native

○ ○ ○ ○ ○ ○ ○
-3 -2 -1 0 1 2 3

Overtly Designed

○ ○ ○ ○ ○ ○ ○
-3 -2 -1 0 1 2 3

12) Why did you choose that image, or images, as the most desirable? Please explain your answer.

_____

_____

CATEGORY 6: The Proximity of a Walkway to the Stream

Immediately Adjacent

○ ○ ○ ○ ○ ○ ○
-3 -2 -1 0 1 2 3

Nearby

○ ○ ○ ○ ○ ○ ○
-3 -2 -1 0 1 2 3

Raised

○ ○ ○ ○ ○ ○ ○
-3 -2 -1 0 1 2 3

13) Why did you choose that image, or images, as the most desirable? Please explain your answer.

_____

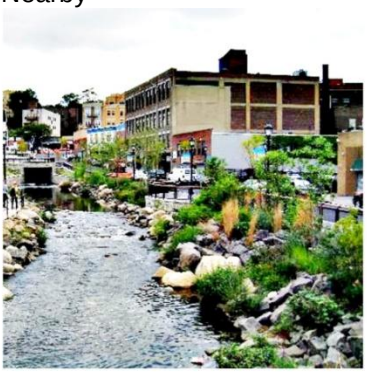
_____

CATEGORY 7: The Proximity of a Street to the Stream

Immediately Adjacent

○ ○ ○ ○ ○ ○ ○
-3 -2 -1 0 1 2 3

Nearby



○ ○ ○ ○ ○ ○ ○
-3 -2 -1 0 1 2 3

Distant

○ ○ ○ ○ ○ ○ ○
-3 -2 -1 0 1 2 3

14) Why did you choose that image, or images, as the most desirable? Please explain your answer.

_____

_____

Appendix C

Email Correspondence and Recruitment Texts

Email Correspondence and Recruitment Texts:

Subject: Ryan Brown - Online Visual Preference Survey Participation Request

Dear Mr. / Ms.

My name is Ryan Brown and I am a graduate student attempting to complete my Masters degree in the Landscape Architecture Program at The University of Texas at Arlington. I am conducting research for my masters' thesis titled: Stream Daylighting Restoration as Green Infrastructure: A Visual Preference Analysis for the Future Redevelopment of Dallas' Mill Creek.

I would like to request you and your organization's participation in my thesis research via an online survey. You are being selected because you have either conducted research, have knowledge of, have visited, live, work, or operate a business within or near the Mill Creek Watershed in Dallas, Texas. The primary goals of this research are to understand which visual attributes and design elements are most desirable when associated with stream daylighting and how these elements can be suggested for the future redevelopment of Mill Creek, Dallas, Texas. The survey will take approximately 15 minutes of your time.

The online survey link is available below for your convenience. Before agreeing to participate in this online survey, I have provided an Informed Consent Form for you to read and acknowledge. This form will explain the study in further detail. Participation in the study is completely voluntary. Additionally, if you know of anyone who is interested in completing this survey, please indicate to me how to best contact them and I will do so accordingly.

Online survey link: https://qtrial2015az1.az1.qualtrics.com/SE/?SID=SV_9BMQIKqmMWgBSwB

Thank you very much for your time and consideration. Your effort, support, and participation will be an invaluable part of this research and is greatly appreciated.
Respectfully,

Respectfully,

RYAN M. BROWN
MLA Candidate | UTA Student ASLA President 2014-2015
Graduate Teaching Assistant | James Richards, FASLA + David Hopman, ASLA, PLA

Program in Landscape Architecture | School of Architecture
The University of Texas at Arlington
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Biographical Information

Ryan Matthew Brown is an award winning landscape architecture student both in design and academic achievement. He graduated from The University of Texas at Arlington in 2012 with a Bachelor of Arts in Interdisciplinary Studies Degree and a Minor in Urban Planning and the Environment.

He then remained at UT Arlington pursuing a Masters Degree in Landscape Architecture. In 2014 he became the President for the UT Arlington Student Chapter in the American Society of Landscape Architects (SASLA) and was chosen to be awarded the *National Who's Who Among Students In American Universities and Colleges Award* for outstanding leadership. He is the recipient of both the Tau Sigma Delta National Architectural Honor Society as well as the Sigma Lambda Delta Landscape Architecture Honor Society.

He grew up seeking to express his creative side through drawing, building, and designing from an early age. Through his high school, undergraduate, and graduate college careers, this interest led him to become an Urban Design Intern for the City of Arlington, Texas within the Arlington Urban Design Center and a Graduate Teaching Assistant for three different professors in the UT Arlington Landscape Architecture Program.

Within the final stages of his educational career, he graduated with honors and was hired through an extending interest in developing and building a prospering career as a landscape architect with Halff Associates, Inc. As he gains the necessary experience, knowledge, and expertise, he would like to become a successful entrepreneur focusing on the public realm and spanning to an international level.