FOURMILE CREEK WATERSHED STUDY

FINAL REPORT

December 2013

Fourmile Creek Watershed

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POLK COUNTY, IOWA
Project #: 111.0076

December 2013

LICENSED PROFESSIONAL ENGINEER MARK A. LAND 14045 IOWA	I hereby certify that this Engineering Document was prepared by me or under my direct personal supervision and that I am a duly Licensed Professional Engineer under the Laws of the State of Iowa. Mark A. Land, P.E. 12/24/13 Date License Number 14045 My License Renewal Date is December 31, 2014 all pages

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Executive Summary

Introduction

Floods are a natural part of Fourmile Creek's history and have been occurring for thousands of years. Floods have periodically occurred on Fourmile Creek throughout recent times and tend to occur in the months of June through August. In recent years, flooding on Fourmile Creek has affected numerous property owners throughout the watershed, such as during the floods of 2008 and 2010. Residents of communities within the watershed have expressed particular concern about flooding, streambank erosion, and the adverse effects of urban development. In response to these challenges, Snyder & Associates, Inc. was commissioned to study the Fourmile Creek Watershed (see Watershed Map) with the intent of improving the understanding of the watershed and preparing a stormwater management plan that addresses resident's concerns. In fulfillment of the study, Snyder & Associates has: produced new and updated hydrologic and hydraulic models of Fourmile Creek for existing (2010) and future (2030) land use conditions; assessed opportunities for stormwater management; prepared recommendations for flood reduction, water quality improvements, and watershed management; and engaged the public through informational meetings and other communications throughout the project. Additionally, this study developed a comprehensive watershed management plan that sets the framework to foster sustainable watershed management, building on both existing and new programs and interinstitutional cooperation.

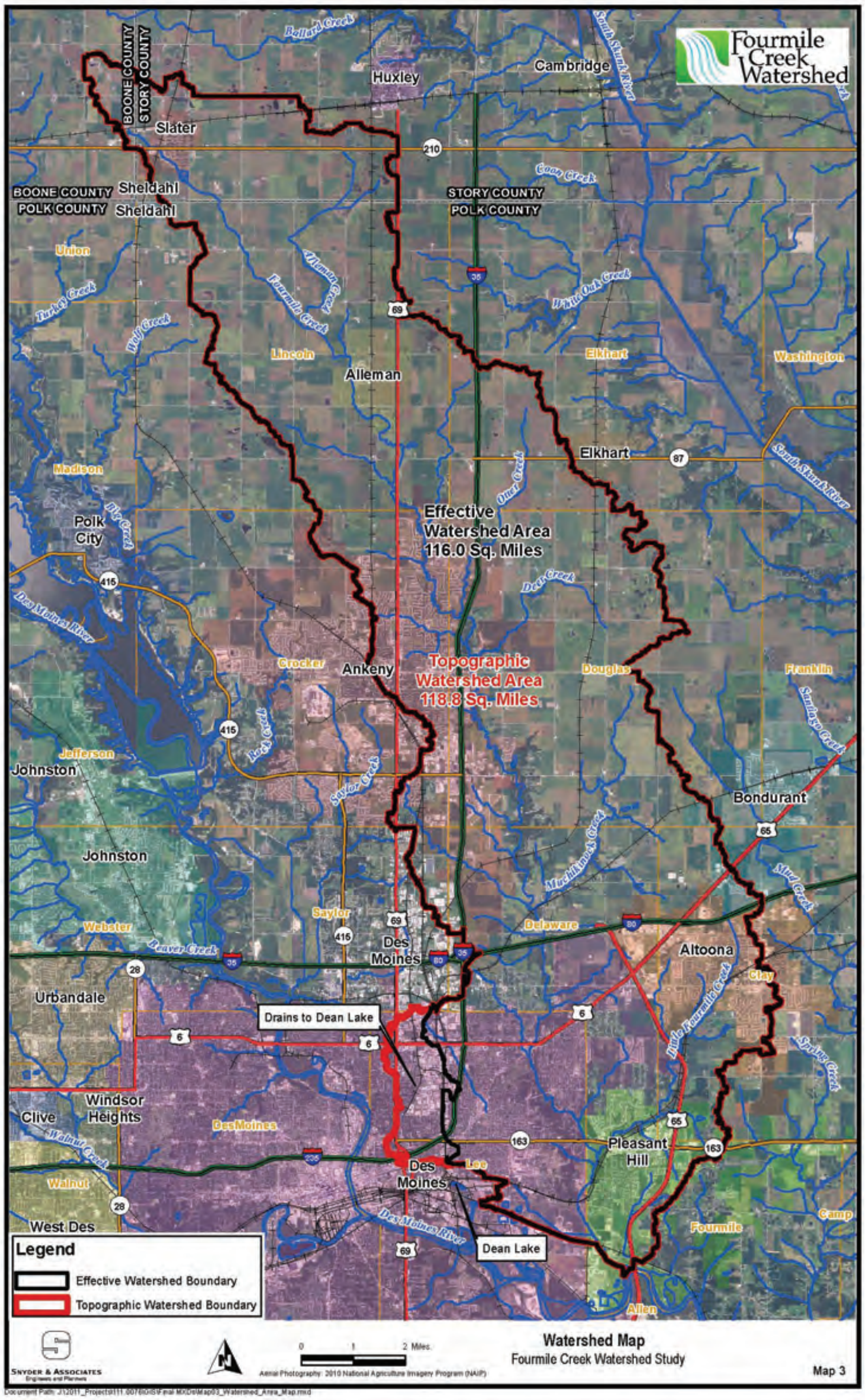
This Fourmile Creek Watershed Study report includes a summary of the findings, covering the watershed characteristics, the hydrologic and hydraulic assessment; the watershed concerns; the stormwater management assessment; and the stormwater master plan. The results of this study reflect the cooperation of many individuals and institutions, including:

- The Steering Committee, with members of Polk County and the cities of Ankeny, Des Moines, and Pleasant Hill.
- The Technical Advisory Committee, with members from federal, state, and local agencies and universities.
- The watershed residents that participated in public meetings and through individual communications.

Hydrologic Assessment

Previous to the study conducted by Snyder & Associates, the hydrology of Fourmile Creek has been investigated in 1988, 1999, 2000 and 2009 flood insurance studies as well as a 2005 US Army Corps of Engineers (USACE) flood reduction study. Hydrologic methods used in these previous studies only took into account current period land use and typically grouped the entire watershed into one basin for modeling purposes or used simplified regression equations.

A more detailed look at the watershed's hydrology was undertaken by Snyder & Associates in this study. For planning purposes, existing (year 2010) and future (year 2030) land use plans were used to develop existing and future conditions hydrologic models. Each model broke the 116 square mile watershed into 115 sub basins with hydrologic parameters for maximum modeling accuracy. Using US Geological Survey (USGS) stream gage data, the model was calibrated to the 2010 and 2008 flood events.



Model results indicate increases in peak flow rate from previous studies for all locations along Fourmile Creek. The 1% annual exceedance probability flow rate (a.k.a. 100-yr flood), which is often used for planning and design purposes, increased from 8,290 cfs in the 2005 USACE study to 11,300 cfs in this study.

Hydraulic Assessment

The hydraulic model developed for this study utilizes the 2005 USACE model from the mouth to E. Douglas Avenue. Snyder & Associates extended the model north to the Polk-Story County line. The USACE portion of the model was updated in the Easton Boulevard area to account for a 2010 bridge replacement project.

Peak flow rates from the hydrologic model were used in the hydraulic model to predict the creek's response to flood events of varying magnitude and recurrence. A profile was established that predicts water surface elevations along Fourmile Creek. Using this profile, LiDAR data, and ArcGIS software, inundation maps were created. Inundation maps for current and future land use conditions are provided in this report and provide a good estimate of flood risk along Fourmile Creek.

Public Involvement

A fundamental goal of the project has been to engage the public in the study and watershed management process. This goal was achieved through a series of public meetings, as well as other communications to receive feedback and recommendations. The initial public meetings helped to gather information, concerns, and opportunities. Following public meetings concentrated in sharing study findings and providing draft stormwater management elements to welcome feedback to strengthen the master plan developed as part of this study.

Stormwater Master Plan

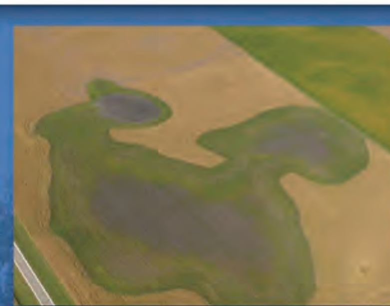
The overall goal for the future direction and management of the Fourmile Creek Watershed is summarized by the study's vision statement:

> ***To foster land stewardship and sustainable watershed management that reduces flood risk, improves water quality, and supports socioeconomic and environmental functions.***

In order to achieve this vision and goals, a stormwater management plan was developed and organized into five components:

SUMMARY OF RECOMMENDATIONS

Sustainable Rural Land Management



- Create Fourmile Creek Watershed Management Authority technical and stakeholder committees on sustainable rural land management.
- Annually measure the amount of conservation practices within the watershed.
- Complete an assessment of prairie potholes and wetland areas and target highest priority areas for acquisition.
- Provide staff to coordinate rural efforts.

Sustainable Urban Land Management

- Investigate locations for stormwater retrofits.
- Work with property owners to implement matching grants.
- Work with Iowa Stormwater Education Program and local jurisdictions on educational opportunities.

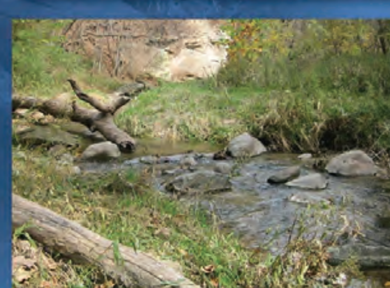
Sustainable Land Development

- Create a Fourmile Creek Watershed Managament Autority committee to establish consistent development standards for all jurisdictions.
- Analyze subwatersheds in developing areas to determine concepts of regional stormwater improvements.
- Acquire property so that regional improvements can be constructed on public lands.
- Develop a maintenance program for regional improvements.

Stormwater Detention

- Provide at least 1,200 Ac-Ft of stormwater detention in the upper watershed.

Stream Corridors



- Continue voluntary buyout program to remove vulnerable structures and establish stream corridor in Des Moines and Pleasant Hill.
- Protect existing stream corridors as development occurs.
- Plan and implement sustainable stream restoration projects.

ACKNOWLEDGEMENTS

Funding Partners

Funding for the Fourmile Creek Watershed Study was provided by:

- Polk County
- The City of Ankeny
- The City of Des Moines
- The City of Pleasant Hill

Steering Committee

A steering committee was established to provide feedback and to assist in the decision making process throughout the project. The steering committee was made up of representatives from the jurisdictions and key staff from Snyder & Associates who led the technical work in coordination with those jurisdictions participating in the study. The table below includes a list of steering committee members.

Steering committee members

Name	Affiliation
Jolee Belzung	City of Ankeny
Bob Rice	Polk County
Bret VandeLune	Polk County
Jeb Brewer	City of Des Moines
Dan Pritchard	City of Des Moines
David Miller	City of Des Moines
Russ Paul	City of Pleasant Hill
Ben Champ	City of Pleasant Hill
Madeline Emmerson	City of Pleasant Hill
Adam Bullerman	Snyder & Associates, Inc.
Ivo Lopez	Snyder & Associates, Inc.
Mark Land	Snyder & Associates, Inc.
Mark Wandro	Snyder & Associates, Inc.
Tyler Rosburg	Snyder & Associates, Inc.

Technical Advisory Committee

A technical advisory committee was established to review study findings and provide technical feedback and support. A list of members is included below.

Technical advisory committee members

Name	Affiliation
Jolee Belzung	City of Ankeny
Dan Pritchard	City of Des Moines
David Miller	City of Des Moines
Jeb Brewer	City of Des Moines
Ben Champ	City of Pleasant Hill
Russ Paul	City of Pleasant Hill
James Martin	Iowa Department of Agriculture and Land Stewardship (IDALS)
Wayne Petersen	Iowa Department of Agriculture and Land Stewardship (IDALS)
Rachel Glaza	Iowa Department of Natural Resources
Nathan Young	Iowa Flood Center - IIHR - Hydroscience & Engineering
Paul Miller	Iowa Natural Resources Conservation Service (NRCS)
Matthew J. Helmers	ISU - Department of Agricultural and Biosystems Engineering
Bob Rice	Polk County
Bret VandeLune	Polk County
Dennis Parker	Polk County Conservation
Loren Lown	Polk County Conservation
Jennifer Welch	Polk Soil & Water Conservation
Zach DeYoung	Polk Soil & Water Conservation
Adam Bullerman	Snyder & Associates, Inc.
Ivo Lopez	Snyder & Associates, Inc.
Mark Land	Snyder & Associates, Inc.
Mark Wandro	Snyder & Associates, Inc.
Tyler Rosburg	Snyder & Associates, Inc.
Dana Kolpin	US Geological Survey (USGS)
David Eash	US Geological Survey (USGS)
Jon Nania	US Geological Survey (USGS)
Toby Hunemueller	US Army Corps of Engineers, Rock Island District
Mark Anderson	US Army Corps of Engineers, Rock Island District
Shirley Johnson	US Army Corps of Engineers, Rock Island District

Herrera Environmental Consultants, Inc. and LT Leon Associates, Inc. were also partners in this study, contributing in many elements. Staff included Mark Ewbank, Mary Larkin, and Niklas Christensen (Herrera); and Luis Leon.

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ACRONYMS

AEP:	Annual Exceedance Probability
CFS or cfs:	Cubic Feet per Second
CN:	Curve Number
DFIRM:	Digital Flood Insurance Rate Map
EPA:	Environmental Protection Agency
FEMA:	Federal Emergency Management Agency
FCWMA:	Fourmile Creek Watershed Management Authority
FIS:	Flood Insurance Study
GIS:	Geographic Information System
HEC-HMS:	Hydrologic Engineering Center – Hydrologic Modeling System
HEC-RAS:	Hydrologic Engineering Center – River Analysis System
HUC:	Hydrologic Unit Code
IDALS:	Iowa Department of Agriculture and Land Stewardship
IDNR:	Iowa Department of Natural Resources
LID:	Low Impact Development
LiDAR:	Light Detection and Ranging
NAVD88:	North American Vertical Datum of 1988
NFIP:	National Flood Insurance Program
NGVD29:	National Geodetic Vertical Datum of 1929
NPDES:	National Pollutant Discharge Elimination System
NRCS:	Natural Resources Conservation Service (formerly known as SCS)
SCS:	Soil Conservation Service
SUDAS:	Statewide Urban Design and Specifications
SWCD:	Soil and Water Conservation District
USACE:	Unites States Army Corps of Engineers
USGS:	United States Geological Survey
WMA:	Watershed Management Authority

1 INTRODUCTION

1.1 Background and Need for the Study

Floods are a natural part of Fourmile Creek's history and have been occurring for thousands of years. Floods have periodically occurred on Fourmile Creek throughout recent times and tend to occur in the months of June through August. In recent years, flooding on Fourmile Creek has affected numerous property owners throughout the watershed. Residents of communities within the watershed have expressed concern about flooding and the adverse effects that future urban development may cause. Snyder & Associates, Inc. was commissioned to study the Fourmile Creek Watershed. In fulfillment of the study Snyder & Associates has: produced new and updated hydrologic and hydraulic models of Fourmile Creek for existing and future land use conditions; prepared recommendations for flood reduction, water quality improvements and watershed management; and engaged the public through informational meetings throughout the project. A map of the Fourmile Creek Watershed study area is provided in Figure 1.1.

Fourmile Creek Watershed

Origin of the creek name and version adopted

The most commonly used versions of the creek name have been **Fourmile Creek** and **Four Mile Creek**, although others include: Four-Mile Creek and 4-Mile Creek.

The creek was named "Four Mile" by common consent because Dragoons (Cavalry Regiment), government officers and traders learned that when they arrived at this stream crossing they were four miles from Fort Des Moines (Union Historical Company, 1880, The History of Polk County, Iowa, pg. 261; http://books.google.com).

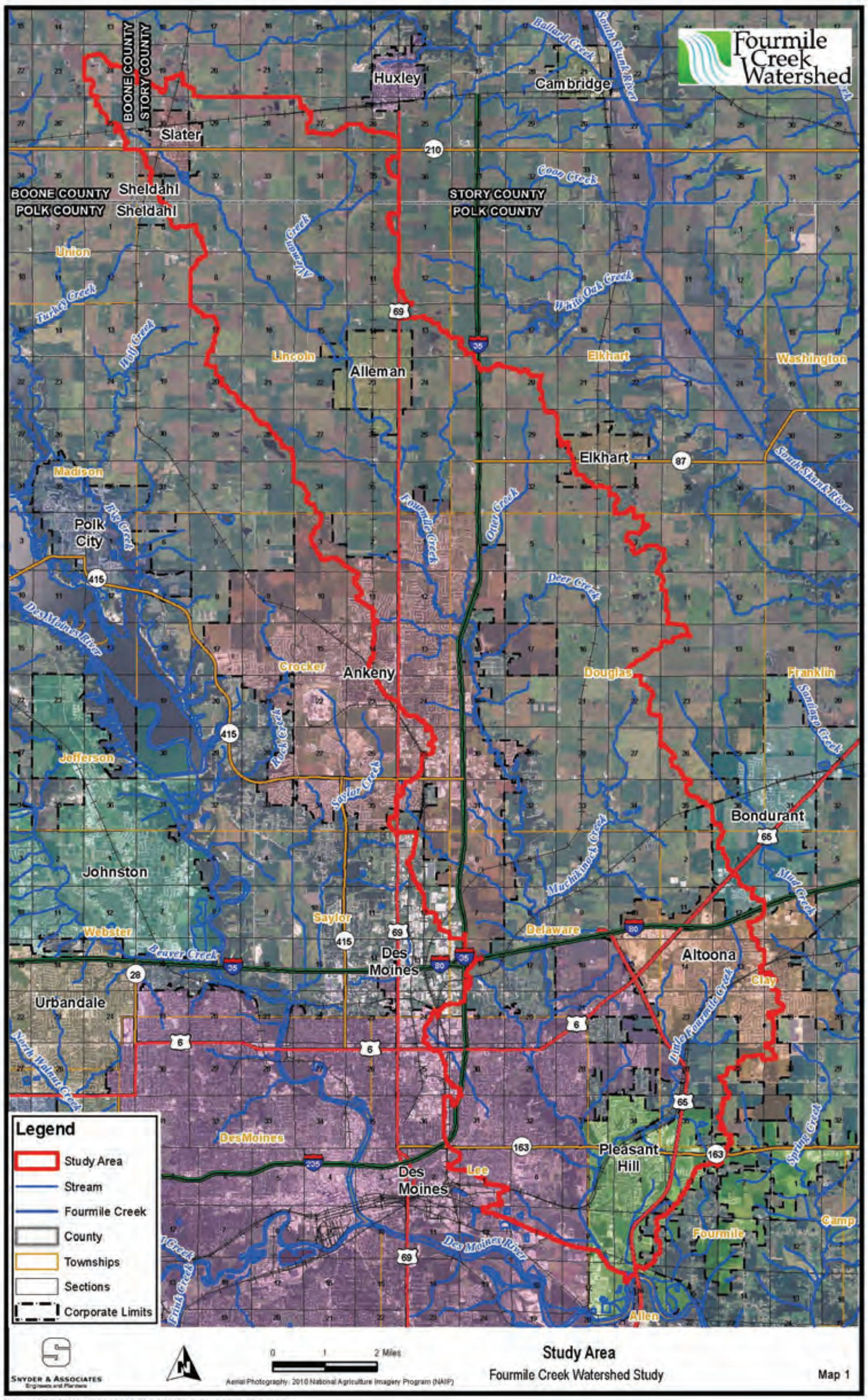
The "Four Mile" version has also been used locally, for example: Four Mile Drive, Four Mile Creek Park, Four Mile Community Center, and Four Mile Creek Greenbelt.

Iowa DNR, FEMA, USGS, Google and others have been using "Fourmile Creek" version:

- USDA. 1921. Soil Survey of Polk County, Iowa. US Department of Agriculture, Bureau of Soils, by E.H. Smies, George E. Corson, and Charles J. Meister. (on line at (http://soils.usda.gov/survey/online_surveys/iowa/polkIA1921/PolkIA1921.pdf; "Fourmile Creek" is cited on page 7 and the map)
- The "Fourmile Creek" version is used in many data sources, such as the US Geological Survey (USGS) topographic maps and streams database; see for example the stream flow data link http://waterdata.usgs.gov/nwis/uv?site_no=05485640

The current Fourmile Creek Watershed Study adopted the "Fourmile Creek" version and logo, which were adopted by consensus during 2008-2009 watershed efforts led by Polk Soil & Water Conservation District through a process that involved the watershed communities with representatives in the Fourmile Creek Advisory Committee.

Figure 1.1: Fourmile Creek Watershed study area



1.2 Purpose and Scope of Study

The purpose of the Fourmile Creek study was to engage the public in watershed issues; to address water quantity and quality issues; develop new hydrologic and hydraulic models for existing and future conditions; prepare alternatives for flood reduction, water quality improvements, and watershed management.

The study included several key tasks including:

- Initial public meetings to gather information, concerns, and opportunities.
- Information gathering and base mapping in GIS.
- Developing a hydrologic model of the watershed to estimate peak discharges.
- Developing a hydraulic model to estimate water surface elevations, complementing previous efforts.
- Developing updated inundation maps.
- Using future land use plans to model future hydrology.
- Evaluating stormwater management opportunities.
- Having public meetings to share study findings.
- Recommending stormwater management strategies.

The geographic scope of the study was limited to the Fourmile Creek Watershed. The main purpose of the modeling was to estimate peak stream flows, water surface elevations, and inundation along the main stem of Fourmile Creek. An additional purpose of the modeling was to assist in the analysis of stormwater management alternatives. As a result, the modeling scale and detail are appropriate for this purpose, but do not explicitly include all features of the watershed (e.g., ponds, culverts, bridges).

1.3 Public Involvement

Since the beginning of the study, a fundamental goal of the project has been to engage the public in the study and watershed management process. This goal has been achieved through a series of public meetings throughout the course of the project, with 50 to over 150 people participating in each individual meeting.

1.3.1 Public Meeting #1

Two similar meetings were held on consecutive days in different parts of the watershed in order to facilitate maximum participation. The first meeting was held at the Four Mile Community Center in Des Moines, Iowa on June 21, 2011. The second meeting was held on June 22, 2011 at Snyder & Associates offices in Ankeny, Iowa. Meeting notices were placed in the area newspapers and mailed to property owners along the creek. The objective of the initial meeting was to engage watershed residents and stakeholders in order to identify concerns and critical issues they may have as they relate to the project.

As attendees arrived at the meeting, they were asked to sign in and were offered a questionnaire to fill out and return. There was not a formal presentation at the first meeting, but rather meeting attendees were given the opportunity to fill out their questionnaire and speak to project representatives. Maps depicting the Preliminary DFIRM (Digital Flood Insurance Rate Map) flood boundaries (FEMA 2009) were available for viewing during the meeting to promote participation and feedback. The 2009 Preliminary DFIRM flood boundaries maps were also posted to the project website (www.fourmilecreekwatershed.org).

1.3.2 Public Meeting #2

Another series of two meetings were held in June of 2012 to update the public on the study's progress. Meeting notices were placed in the area newspapers and mailed to property owners along the creek. The first meeting was held on June 27, 2012 at Snyder & Associates in Ankeny, IA. The second meeting was held on June 28, 2012 at the East Side Library in Des Moines, IA. At this meeting, a formal presentation was held. Included in the presentation was: a thorough examination of the 2008 and 2010 floods, updated hydrologic data for the watershed, and a preview of flood mapping results and stormwater management plans.

1.3.3 Public Meeting #3

A final series of public meetings were held in April of 2013 to share the results of the watershed study and to receive feedback. The first meeting was held on April 3, 2013 at Snyder & Associates in Ankeny, IA. The second meeting was held on April 4, 2013 at the Hy-Vee Euclid Room in Des Moines, IA. At these meetings, a formal presentation was held that detailed the study's findings and recommendations made by Snyder & Associates. Maps depicting the 2009 Preliminary DFIRM flood boundaries were available for viewing and discussion after the meeting. The 2009 Preliminary DFIRM flood boundaries maps were also posted to the project website.

1.4 Watershed Management Authority

In the fall of 2012, the Fourmile Creek Watershed Management Authority (WMA) was established under Chapter 28E of the *Iowa Code* and included the members listed in Table 1.1. This organization was established to provide a common voice, to facilitate inter-jurisdictional cooperation in working together on watershed issues and opportunities. The purpose of this Authority is to:

- Assess the flood risks in the watershed.
- Assess the water quality in the watershed.
- Assess options for reducing flood risk and improving water quality in the watershed.
- Monitor federal flood risk planning and activities.
- Educate residents of the watershed area regarding water quality and flood risks.
- Seek and allocate moneys made available to the Authority for purposes of water quality and flood mitigation.
- Make and enter into contracts and agreements and execute all instruments necessary or incidental to the performance of the duties of the Authority. The Authority shall not have the power to acquire property by eminent domain. All interests in land shall be held in the name of the Party wherein said lands are located.

Table 1.1: Members of Fourmile Creek WMA

Boone County, Iowa
Polk County, Iowa
Story County, Iowa
City of Ankeny, Iowa
City of Alleman, Iowa
City of Altoona, Iowa
City of Bondurant, Iowa
City of Des Moines, Iowa
City of Elkhart, Iowa
City of Pleasant Hill, Iowa
City of Sheldahl, Iowa
City of Slater, Iowa
Boone County Soil and Water Conservation District
Polk Soil and Water Conservation District
Story County Soil and Water Conservation District

2 WATERSHED CHARACTERISTICS

2.1 Watershed Location and General Data

The Fourmile Creek Watershed is located in south central Iowa. Most of the watershed is within Polk County, with small upper areas of the watershed within Story and Boone counties (see Figure 1.1 and Maps 1-4). The watershed includes jurisdictions from upstream to downstream such as Slater, Sheldahl, Alleman, Elkhart, Ankeny, Bondurant, Altoona, Des Moines, and Pleasant Hill. The watershed is mostly rural in the upper areas, while urban in the lower areas. According to 2010 census data, the watershed is home to more than 80,000 people.

Fourmile Creek is a tributary of the Des Moines River, a tributary of the Mississippi River. The watershed is elongated and drains from north-northwest to south-southeast, having an approximate length of 23 miles and a width of 5 miles. The total area of the watershed is approximately 119 square miles based on the natural topography, or 116 square miles (74,240 acres) excluding the area that currently drains to Dean Lake. The Fourmile Creek Watershed is identified with the 10-digit Hydrologic Unit Code (HUC): 0710000801. The length of the stream along the main stem of Fourmile Creek is 38 miles, while the drainage network encompasses more than 132 miles. The watershed's time of concentration (the travel time of a water particle from the most hydraulically remote portion of the watershed to the outlet) ranges from 13.5-15 hours.

2.2 Topographic Data

An elevation data map for the Fourmile Creek Watershed is included in Map 2. Iowa Statewide LiDAR elevation data was processed to generate project topographic data, referenced to the North American Vertical Datum of 1988 (NAVD88) and using the North American Datum of 1983 in feet with the Iowa State Plane South projection. The highest elevation in the watershed is found near the town of Sheldahl at 1060 feet above sea level. The lowest elevation in the watershed is found at the Des Moines River at 750 feet above sea level. As a result, the topographic relief or drop in elevation across the watershed is greater than 300 feet. Generally, the elevation of the watershed decreases from the northwest to the southeast.

2.3 Geomorphology, Geology and Soils

The landscape of the Fourmile Creek Watershed was formed by glacial activity during the Quaternary Period, about 10,000 to 2 million years ago. The primary surface deposits are found in the Wisconsinan-stage form. The glacial deposits are clays, unconsolidated sands, gravels, and some cobbles and boulders. Other climatic events and land use practices that followed the last glaciations have also shaped the landscape, such as contributing to carve a more defined and incised Fourmile Creek stream channel.

The Fourmile Creek Watershed is located in the Des Moines Lobe landform region, near the southern terminus of this lobe that formed during the Wisconsin Glaciation between 12,000 and 15,000 years ago. This region has a poorly drained landscape with a mostly level terrain and occasional bands of crooked ridges. Marshes and ponds are found between these ridges and generally have no drainage outlets. The landforms found in the watershed are ground moraines on uplands, and flood plain and stream terraces. As a result, the upper portions of the watershed have pothole characteristics, which provide depressional areas that pond runoff and help regulate flows. The lower portion of the watershed is characterized by a gently to moderate rolling landscape, such as in the Des Moines, Altoona, and Pleasant Hill areas.

The bedrock of the Fourmile Creek Watershed consists of marine sedimentary rocks, including: sandstones, shales, mudstones, limestones, and dolomites. These rocks were deposited during the Carboniferous period, 354 to 290 million years ago. This period was further divided into two times periods: the Mississippian and the Pennsylvanian. Shallow seas covered the Midwest during the Mississippian and deposited clays, sands, and carbonate materials. The seas receded, allowing water and wind to erode the surfaces of the Mississippian rocks. The seas returned and again receded during the Pennsylvanian. For much of Polk County, Pennsylvanian bedrock is found. (Source: Polk County Comprehensive Plan, URS, February 2005.)

The depth to bedrock in Polk County ranges from less than 50 feet to over 200 feet to the bedrock (Source: Iowa DNR – Geologic Survey, September 2008).

The soils in the watershed are mostly composed of Hydrologic Soil Group B (HSG B), which are generally well drained. However, about half have poorly drained subsoils and are classified as HSG B/D (i.e., with low permeability). Map 5 illustrates the Hydrologic Soil Group distribution.

The majority of the Fourmile Creek Watershed is composed of the Canisteo-Clarion-Nicollet Association. The other parts of the watershed are composed of the following: the east and west edge of the watershed is composed of the Hayden-Storden-Lester Association; the south tip of the watershed is composed of the Downs-Fayette Association and the Nodway-Colo-Nevin Association. Table 2.1 further describes the soils found in the watershed. The major uses of the soils are cropland, woodland, pasture, and hayland. Urban land use has also been shaping the landscape and affecting soil characteristics, such as a thinner top soil resulting from urban development.

The following information is provided by the USDA’s Natural Resource Conservation Service. The greatest percentage of soil in Polk County is Clarion loam (2 to 5% slopes) at 12.2%. The USDA soil textures encountered include silty clay loam, loam, silt loam, clay loam, sandy loam, sandy clay loam, sandy loam, stratified silt loam to silty clay loam, fine sandy loam. The Colo and Nodaway soils have occasional flooding frequencies. Other soil data is also available, such as on capabilities of soils for dwellings and small commercial buildings.

Table 2.1: General soils found in Fourmile Creek Watershed

Composition	Comp. %	Drainage	Parent Material	Major Uses	Land Forms
Canisteo-Clarion-Nicollet Association				Cropland	Ground moraines on uplands
Canisteo and similar soils	25	Poorly drained	Calcareous glacial till or till-derived sediments		
Clarion and similar soils	25	Well drained	Glacial till		
Nicollet and similar soils	25	Somewhat poorly drained	Glacial till		
Soils of minor extent	25	--	--		
Hayden-Storden-Lester Association				Woodland, pasture	Ground moraines on uplands
Hayden and similar soils	30	Well drained	Glacial till		
Storden and similar soils	20	Well drained	Calcareous glacial till		
Lester and similar soils	20	Well drained	Glacial till		
Soils of minor extent	30	--	--		
Downs-Fayette Association				Cropland	Uplands
Downs and similar soils	50	Well drained	Loess		
Fayette and similar soils	30	Well drained	Loess		
Soils of minor extent	20	--	--		
Nodway-Colo-Nevin Association				Cropland, hayland, pasture	Flood plains and stream terraces
Nodaway and similar soils	30	Moderately well drained	Alluvium		
Colo and similar soils	30	Poorly drained	Alluvium		
Nevin and similar soils	15	Somewhat poorly drained	Alluvium		
Soils of minor extent	25	--	--		

2.4 Land Use and Impervious Surfaces

The National Land Cover Database was used to quantify the land use in rural portions of the watershed, while land use plans provided by the jurisdictions, both existing (2010) and future (2030), were used in urban areas. From these sources of data, Snyder & Associates created existing and future land use plans for the watershed. A Hydrologic Curve Number (CN, parameter used to calculate runoff using the Soil Conservation Service, SCS, method) was then estimated for each land use. Utilizing these data and ArcGIS software, composite curve numbers were derived for each drainage area.

Primary land use is different for the three main regions of the watershed.

- The upper, northern portion of the watershed is primarily agricultural, consisting of cultivated row crops along and small amounts of pasture and hay. The area is rural with only a small amount of development.
- The middle portion of the watershed is approximately half agricultural, cultivated crops, pasture, and hay. The other half of this portion of the watershed is urban with low, medium, and high intensity development.
- The lower, southern portion of the watershed is primarily urban with low, medium, and high intensity development. A small amount of deciduous woodland, pasture hay, and cultivated crops can also be found.

Table 2.2 includes the existing (2010) land use distribution and Table 2.3 for future (2030) land use. Additionally, existing and future land use plans are included as Maps 6 and 7, respectively. Note that open space includes lands where green space is preserved mainly through public ownership (e.g., parks, reserves), but also includes lands like golf courses.

Table 2.2: Existing (year 2010) land use

Land Use	Area (Sq. Mi)	Percentage
Woodland	1.4	1.2%
Grassland/Pasture	6.3	5.4%
Agricultural/Rural	60.5	52.2%
Ag Residential	4.8	4.1%
Low Density Residential	3.5	3.0%
Medium Density Residential	17.5	15.1%
High Density Residential	1.1	0.9%
Institutional	4.9	4.2%
Commercial	4.3	3.7%
Industrial	5.2	4.5%
Open Space	6.5	5.6%
Total	**116.0**	**100.0%**

Table 2.3: Future (year 2030) land use

Land Use	Area (Sq. Mi)	Percentage
Woodland	0.7	0.6%
Grassland/Pasture	4.3	3.7%
Agricultural/Rural	48.4	41.7%
Ag Residential	4.0	3.4%
Low Density Residential	2.9	2.5%
Medium Density Residential	27.1	23.4%
High Density Residential	1.4	1.2%
Institutional	5.3	4.6%
Commercial	6.8	5.9%
Industrial	5.7	4.9%
Open Space	9.4	8.1%
Total	**116.0**	**100.0%**

Impervious surfaces such as roads, parking lots and roofs have been directly linked to the instability of streams due to increased stormwater runoff. These impervious surfaces are a contributing factor to streambank erosion.

Table 2.4 includes the average impervious surface within each jurisdiction located in the Fourmile Creek Watershed. The distribution of impervious surfaces is illustrated in Map 8 based on the National Land Cover Dataset. The highest imperviousness is found in the lower areas of the watershed.

Table 2.4. Average impervious area of each jurisdiction based on NLCD 2006 data

Jurisdiction	Percent Impervious Area of Jurisdictional Land Within Fourmile Watershed
Alleman	2.4
Altoona	23.8
Ankeny	19.4
Bondurant	4.7
Des Moines	23.4
Elkhart	0.1
Pleasant Hill	15.6
Sheldahl	0.2
Slater	13.1

Notes:

Derived from calculating average "impervious value" from impervious raster dataset.

Source: NLCD Impervious Layer of Iowa 2006

3 HYDROLOGIC AND HYDRAULIC ASSESSMENT

3.1 Drainage Area Estimates

The Fourmile Creek Watershed is identified as a HUC-10 watershed by the USGS. The boundary established by the USGS identifies Fourmile Creek Watershed as a 119.16 square mile watershed. Additionally, the Polk County Soil and Water Conservation District estimates the area of Fourmile Creek Watershed as 119.75 square miles on their website.

Snyder & Associates utilized 3m-LiDAR (Light Detection and Ranging) elevation data and field inspection to delineate the Fourmile Creek Watershed. The 3m-LiDAR Digital Elevation Model was carefully reconditioned to reflect major drainage paths such as culverts under roads. The final topographic watershed area established by Snyder & Associates was 118.8 square miles. Closer inspection of storm sewer data from the cities of Ankeny and Des Moines revealed that the effective drainage area of Fourmile Creek to be 116.0 square miles (74,240 acres). The reduction from the topographic to the effective drainage area is largely due to an area within the topographic watershed that actually drains to Dean Lake due to storm sewer. Figure 3.1 and Map 3 display the differences in the topographic and effective drainage areas.

There are five named tributaries to Fourmile Creek. Table 3.1 includes a summary of the size of their drainage areas. Additionally, Figure 3.2 and Map 4 show their location.

Table 3.1: Drainage areas of named tributaries

Name	Drainage Area (mi^2)
Alleman Creek	8.7
Deer Creek	9.5
Little Fourmile Creek	11.9
Muchikinock Creek	12.0
Otter Creek	6.0

Figure 3.1: Fourmile Creek Watershed map

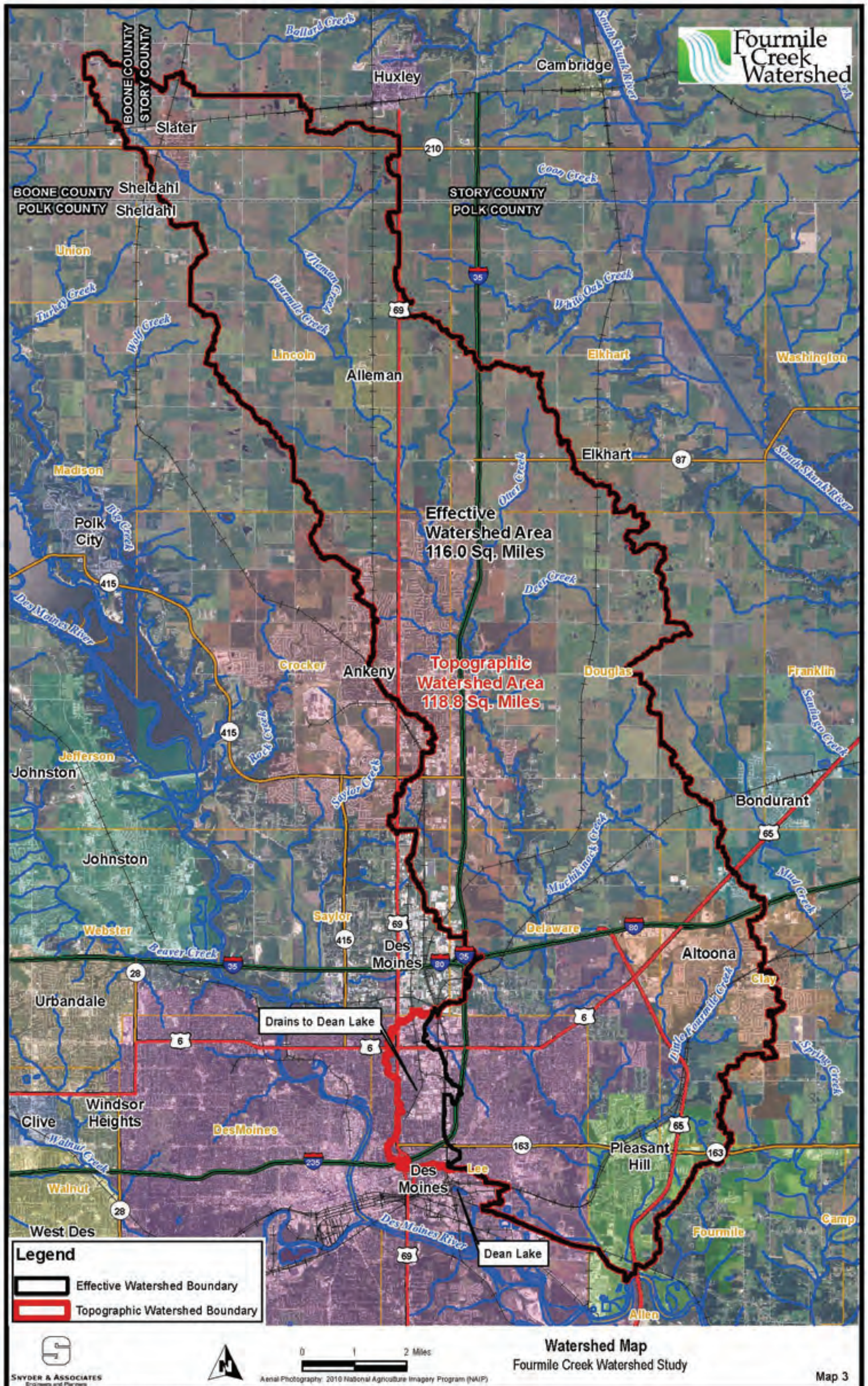
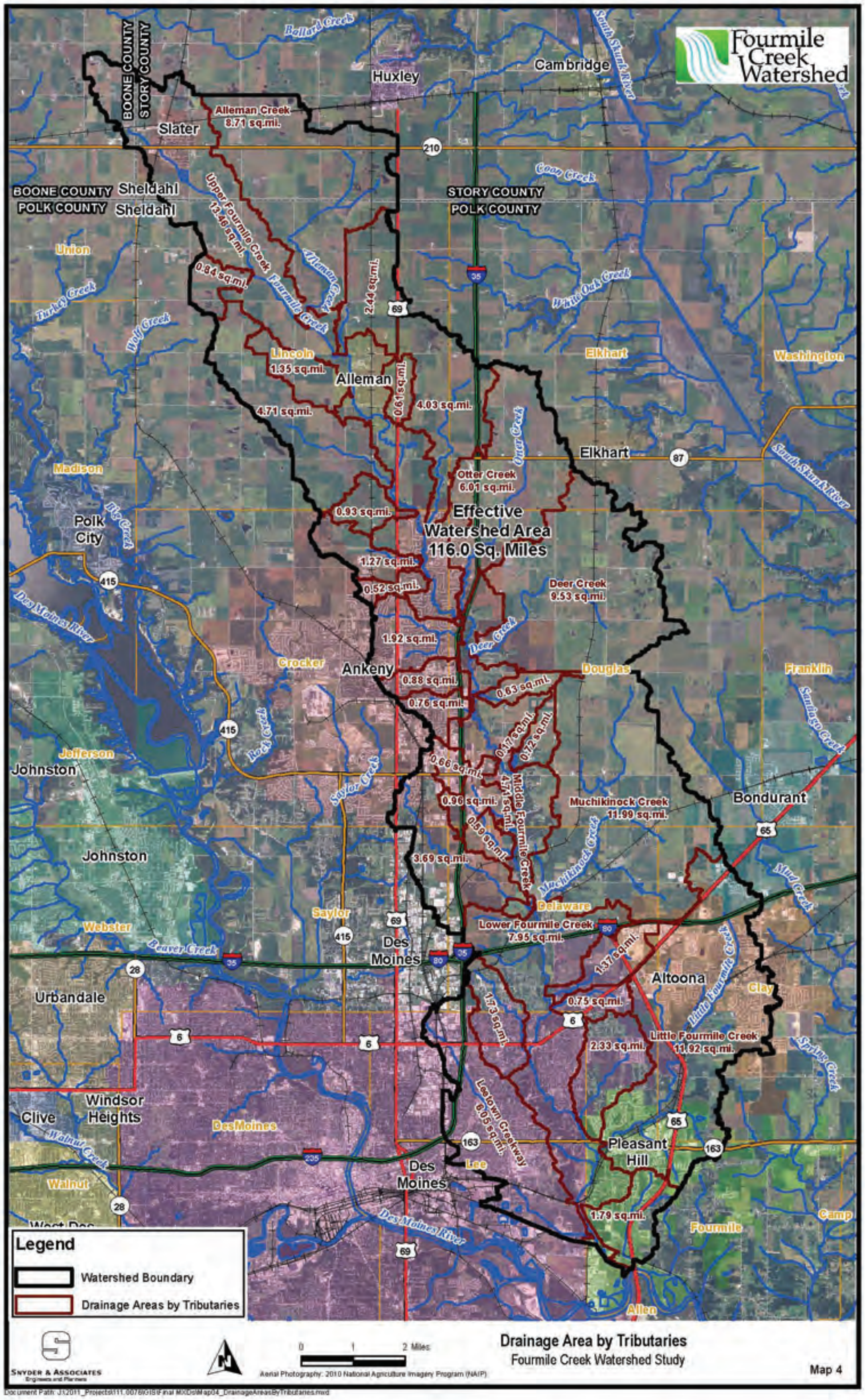


Figure 3.2: Drainage areas by tributaries



3.2 Previous Hydrologic and Hydraulic Studies

Polk County, and the cities of Des Moines, Pleasant Hill, and Ankeny have flood insurance studies (FIS) for their communities. These flood insurance studies identify peak flow rates along Fourmile Creek for various recurrence intervals. The following is a list of hydrologic and hydraulic studies of Fourmile Creek.

- FEMA Flood Insurance Study – City of Pleasant Hill – November 3, 1981
- FEMA Flood Insurance Study – City of Des Moines – July 15, 1988
- FEMA Flood Insurance Study – City of Ankeny – December 6, 1999
- FEMA Flood Insurance Study – Polk County – July 19, 2000
- Feasibility Report – Flood Damage Reduction for Des Moines and Raccoon Rivers Project Des Moines, Iowa with Integrated Environmental Assessment – Volume 1 – December 2005 – US Army Corps of Engineers – Rock Island District
- Preliminary FEMA Flood Insurance Study – Polk County – May 22, 2009
- Fourmile Creek Stormwater Management Plan – City of Ankeny – December 2004

Table 3.2 includes a summary of discharges at selected locations along Fourmile Creek with the corresponding estimated drainage areas. Note that the current regulatory flows are those reported on the Polk County FIS of 2000, which are based on flows estimated in the FIS of 1983.

A preliminary digital flood insurance rate map (DFIRM) was created as part of the preliminary 2009 Polk County Flood Insurance Study (FEMA 2009). This DFIRM has been used by the communities within Polk County to estimate flood hazard but has not been officially adopted.

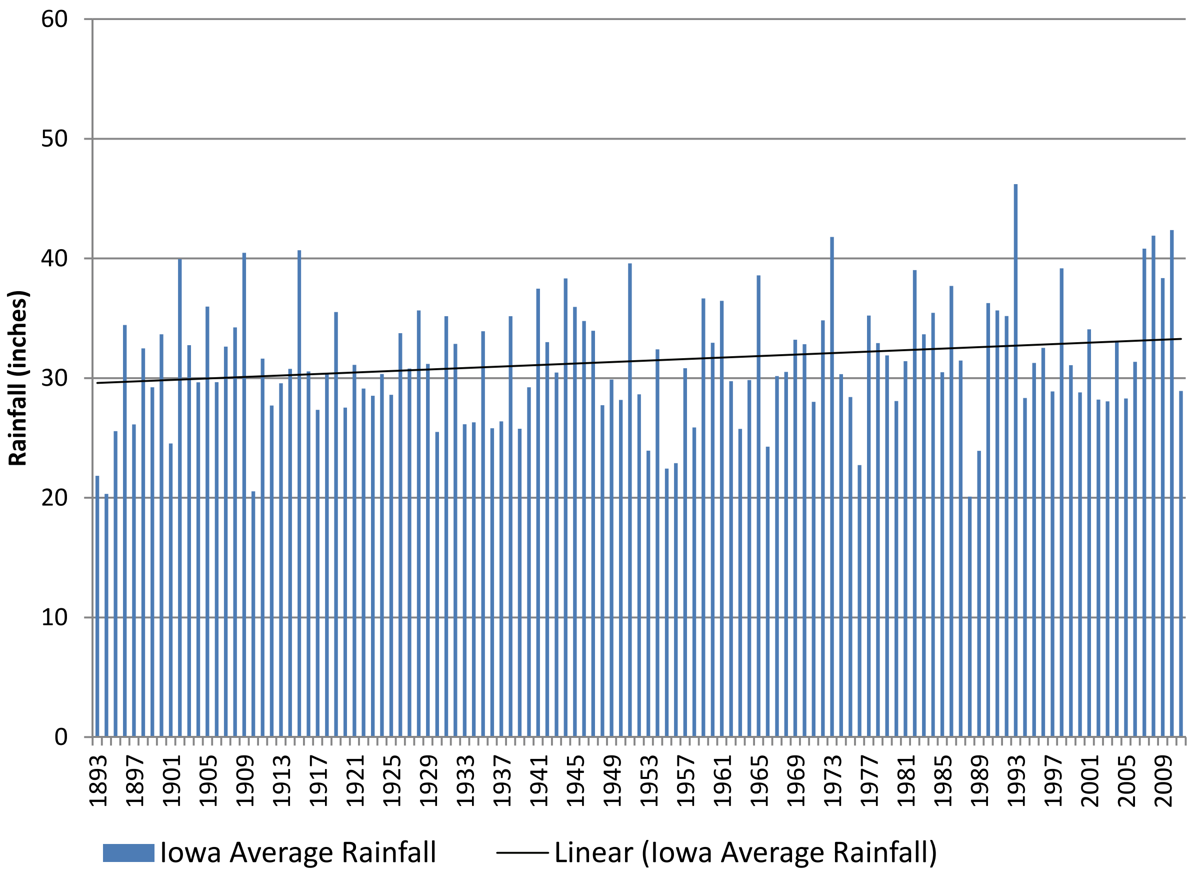
Table 3.2: Summary of previous discharges for Fourmile Creek

Flooding Source and Location	Data Source	Drainage Area (square miles)	Peak Discharges (cubic feet per second)			
			10-Percent-Annual-Chance (10-year)	2-Percent-Annual-Chance (50-year)	1-Percent-Annual-Chance (100-year)	0.2-Percent-Annual-Chance (500-year)
Fourmile Creek at or Near Discharge to the Des Moines River						
Fourmile Creek just upstream of Chicago Rock Island & Pacific Railroad Bridge	City of Pleasant Hill FIS (November 3, 1981) Table 1	116.0	3,800	6,200	7,300	10,400
Fourmile Creek at the Chicago, Rock Island & Pacific Railroad bridge	City of DM FIS (July 15, 1988) Table 1	116.0	3,800	6,200	7,300	10,400
Fourmile Creek at Scott	DM and Raccoon Rivers Flood Damage Reduction Feasibility Report (2005) Table A-9	108.4	5,240	7,760	8,850	11,370
Fourmile Creek at Easton Boulevard and Vicinity						
Fourmile Creek at University	DM and Raccoon Rivers Flood Damage Reduction Feasibility Report (2005) Table A-9	95.7	4,940	7,360	8,400	10,830
Fourmile Creek at Williams Street	City of DM FIS (July 15, 1988) Table 1	93.0	3,120	5,170	6,140	8,720
Fourmile Creek at Easton Blvd. (gage)	DM and Raccoon Rivers Flood Damage Reduction Feasibility Report (2005) Table A-4	92.7	4,870	7,260	8,290	10,700
Fourmile Creek at Easton Blvd. (gage)	DM and Raccoon Rivers Flood Damage Reduction Feasibility Report (2005) Table A-11	92.7	5,000	8,000	9,400	--
Fourmile Creek at Easton Blvd. (gage)	DM and Raccoon Rivers Flood Damage Reduction Feasibility Report (2005) Table A-12	92.7	4,800	7,800	9,200	--
Fourmile Creek at Hubbell	DM and Raccoon Rivers Flood Damage Reduction Feasibility Report (2005) Table A-9	89.9	4,800	7,170	8,180	10,570
Fourmile Creek at Des Moines	City of Ankeny FIS (November 16, 1982 / December 6, 1999) Table 1	89.2	3,120	5,170	6,140	8,720
At Des Moines city limit, Section 20, Delaware Township	Polk Co. FIS (September 1, 1983 / July 19, 2000) Table 1	89.2	3,120	5,170	6,140	8,720
Fourmile Creek upstream of Interstate 80						
Fourmile Creek Above Otter Creek confluence	Polk Co. FIS (September 1, 1983 / July 19, 2000) Table 1	40.7	1,680	2,820	3,380	4,880
Fourmile Creek at Alleman	Polk Co. FIS (September 1, 1983 / July 19, 2000) Table 1	22.4	900	1,470	1,750	2,480
Tributaries to Fourmile Creek						
Muchikinock Creek at mouth	Polk Co. FIS (July 19, 2000) Table 3	11.2	N/A	N/A	5,300	N/A
Muchikinock Creek about 2,000 feet upstream of Northeast 62nd Avenue	Polk Co. FIS (July 19, 2000) Table 3	4.8	N/A	N/A	2,585	N/A
Tributary A at mouth	Polk Co. FIS (September 1, 1983 / July 19, 2000) Table 1	5.7	1,100	2,100	2,700	4,200
Tributary A at Interstate Highway 35	City of Ankeny FIS (November 16, 1982) Table 1	2.2	550	870	1,030	1,450
Tributary A at Interstate Highway 35	City of Ankeny FIS (December 6, 1999) Table 1	2.2	--	--	2,100	2,750
Tributary A at Fountain View Estates Lake	City of Ankeny FIS (December 6, 1999) Table 1	1.3	--	--	1,300	1,700
Tributary A at confluence of Unnamed Tributary	City of Ankeny FIS (November 16, 1982) Table 1	1.3	230	380	460	660

3.3 Rainfall Data

Annual precipitation in the state of Iowa averages approximately 34 inches. Precipitation varies across the state with the extreme northwest corner of the state averaging as little as 26 inches per year while extreme southeastern Iowa averages as much as 38 inches per year. Analysis of statewide rainfall data shows that the average annual rainfall for the state is trending upward as displayed in Figure 3.3, although not necessarily in a linear manner as suggested by the trend line. The figure also demonstrates a high variability in annual rainfall and an extremely wet period from 2007-2010.

Figure 3.3: Iowa Average Yearly Rainfall



Ankeny, Iowa (located near the center of the Fourmile Creek Watershed) averages 33.12 inches of rainfall a year (see Appendix B for monthly and yearly rainfall records). A figure depicting the upward trend of annual rainfall totals at the Ankeny Airport is displayed in Figure 3.4. In major flood years, such as of 1993, 2008, and 2010, the gage recorded more than 50 inches of rainfall. The largest yearly rainfall was in 2010 with 57.18 inches. Although 2010 had the largest yearly rainfall and highest recorded flood flow in Fourmile Creek, note that 2010 only ranked tenth in the top ten daily rainfalls (Table 3.3).

Figure 3.4: Ankeny airport yearly rainfall (1951-2010)

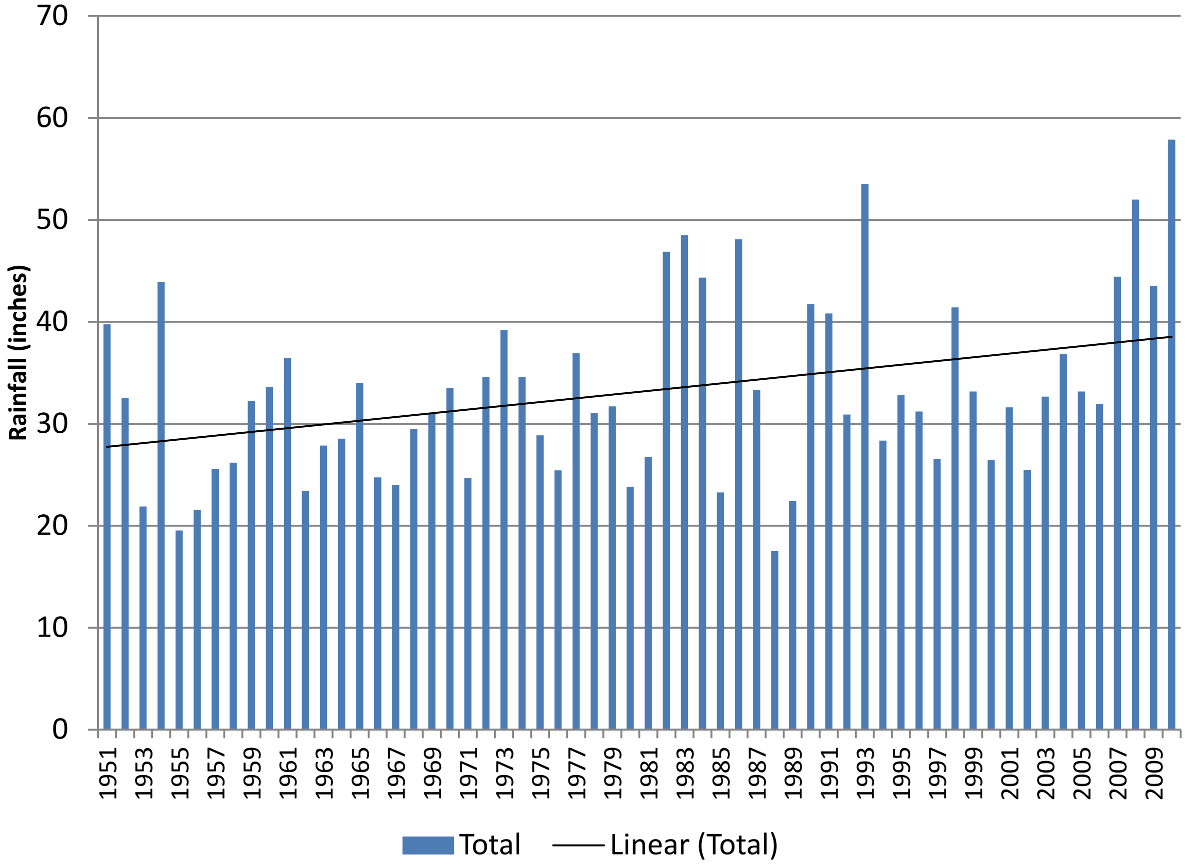


Table 3.3: Top ten daily rainfalls based on Ankeny Jan. 1951 – Dec. 2012 record

Rank	Month	Day	Year	Rain (inches)
1	6	20	1954	5.25
2	6	17	1990	4.63
3	8	28	1977	4.59
4	4	30	1986	4.5
5	7	28	2008	3.93
6	9	7	2007	3.92
7	6	28	1983	3.9
8	7	9	1993	3.7
9	9	12	1961	3.69
10	8	11	2010	3.66

Des Moines, Iowa averages approximately 105 days of measurable rainfall a year (defined as at least 0.01 inches). Despite the frequent rainfall, most rainfall events are small; 90.60% of the daily rainfall was estimated to be 1.25 inches or less based on Ames data for the period 1960-2006 (Iowa Stormwater Management Manual, Iowa DNR 2009, Table 1). On average, Des Moines has 20 days a year in which rainfall exceeds 0.5 inch and 7 days a year in which rainfall exceeds 1 inch. However, at times very large localized rainfall events do occur and amounts in excess of 10 inches per day are possible. Table 3.4 includes a few of Iowa's largest daily rainfall totals.

Table 3.4: Iowa's historic rainfall events

Daily Rainfall	Location	Date
13.18	Atlantic, IA	6/14/1998
12.52	Audubon, IA	7/2/1958
12.02	Castana, IA	7/17/1996
10.62	Dubuque, IA	24 Hrs 7/27/2011-7/28/2011

3.4 Streamflow Gage Data

Streamflow data for Fourmile Creek is maintained by two USGS gages:

- NE 86th Avenue Gage (USGS 05485605 Fourmile Creek near Ankeny)
- Easton Boulevard Gage (USGS 05485640 Fourmile Creek at Des Moines)

Note that streamflow data has also been or is starting to be collected at other gages, including the gages at Interstate-80 in Altoona (NWS ID ATNI4) and US Highway 69 near Ankeny (NWS ID AKNI4), as well as the Iowa Flood Center bridge sensors at NE 54th Avenue/County F52 in Altoona and at 47th Street NE in Ankeny.

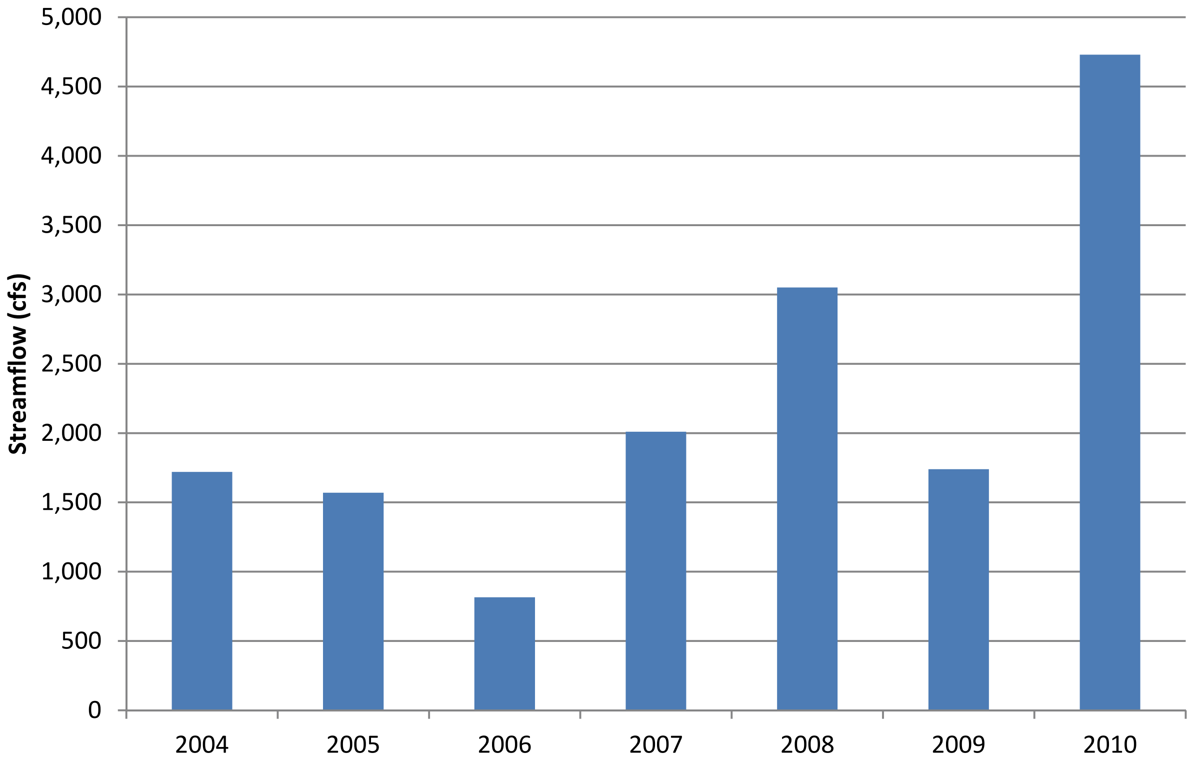
3.4.1 NE 86th Avenue Gage

USGS streamflow gage 05485605 is located along the right bank of Fourmile Creek at the bridge on NE 86th Avenue. According to the USGS National Water Information System the gage is 1.0 mile southeast of Ankeny, 1.4 miles downstream from Deer Creek, 6.0 miles upstream from Muchikinock Creek, and 15.6 miles upstream from the mouth of Fourmile Creek. The drainage area at this gage station is 62.0 square miles. The gage is a water-stage recorder and the datum is 864.91 ft above NGVD 1929 (Water-Data Report 2010), which is equivalent to 865.01 feet in the NAVD of 1988 datum. The largest peak flow on record occurred on August 11, 2010 in which the maximum gage height was 12.98 feet and the peak flow rate was 4,730 cubic feet per second (cfs). Table 3.5 and Table 3.6 include the yearly peak flow data observed at the NE 86th Avenue Gage.

Table 3.5. Fourmile Creek NE 86th Avenue gage (USGS 05485605) yearly peak flow data

Water Year	Date	Gage Height (ft)	Streamflow (cfs)
2004	May 23, 2004	10.60	1,720
2005	May 13, 2005	9.99	1,570
2006	Apr. 02, 2006	7.18	815
2007	Apr. 25, 2007	10.05	2,010
2008	Jul. 28, 2008	12.19	3,050
2009	Apr. 27, 2009	9.35	1,740
2010	Aug. 11, 2010	12.98	4,730

Figure 3.5: Fourmile Creek NE 86th Avenue gage (USGS 05485605) yearly peak flow data



3.4.2 Easton Boulevard Gage

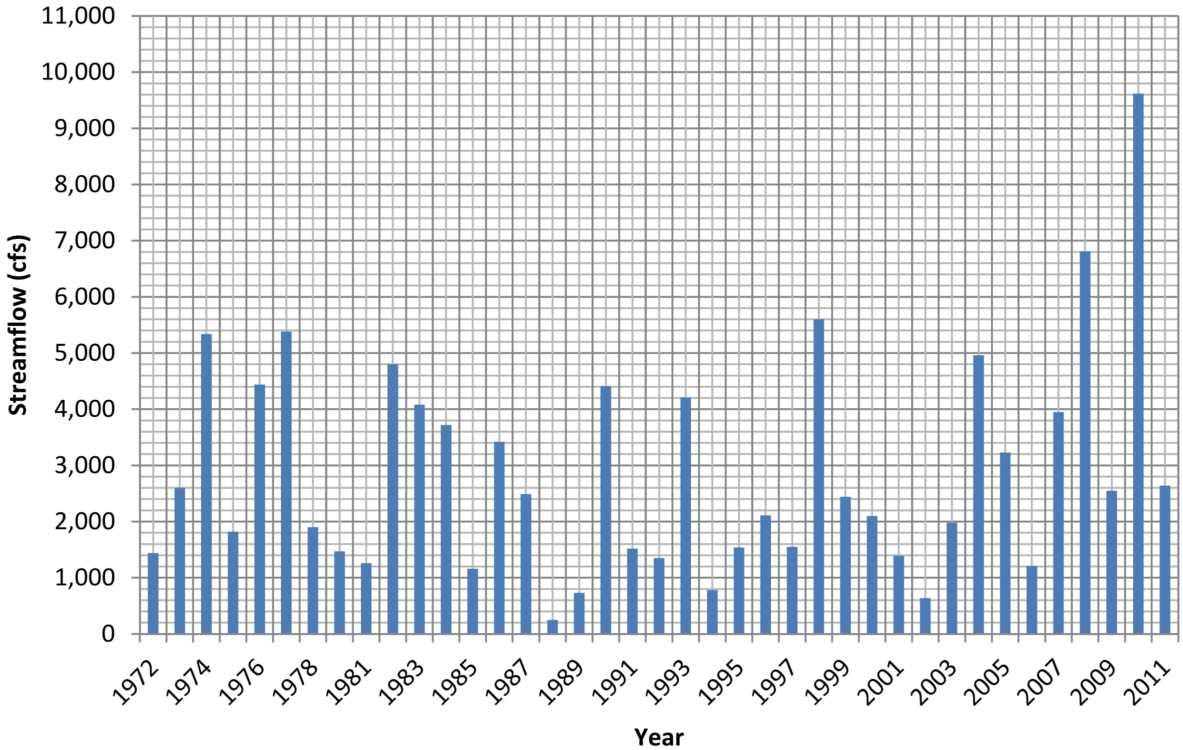
USGS streamflow gage 05485640 is located on the right bank 20 ft downstream from the bridge on Easton Boulevard in the City of Des Moines, 4.4 miles downstream from Muchikinock Creek, and 5.2 miles upstream from mouth, according to the USGS National Water Information System. The drainage area to the Easton Boulevard station is 92.7 mi^2. The gage is a water-stage recorder and the datum is 795.87 feet above NGVD of 1929, which is equivalent to 795.96 feet in the NAVD of 1988 datum.

This gage has been providing valuable streamflow data, as listed in Table 3.6 for the 1972-2011 period of record. The largest peak flow occurred on August 11, 2010, when the gage height was 16.14 feet and the streamflow was 9,620 cfs.

Table 3.6: Fourmile Creek Easton Boulevard gage (USGS 05485640) yearly peak flow data

Water Year	Data	Gage Height (ft)	Streamflow (cfs)
1972	Jun. 20, 1972	9.54	1,440
1973	Feb. 01, 1973	12.71	2,600
1974	Jun. 09, 1974	14.84	5,340
1975	Jun. 18, 1975	10.95	1,820
1976	Apr. 18, 1976	14.20	4,440
1977	Aug. 28, 1977	14.64	5,380
1978	Mar. 19, 1978	11.43	1,900
1979	Mar. 19, 1979	10.00	1,470
1981	May 23, 1981	9.68	1,260
1982	Jul. 16, 1982	14.46	4,800
1983	Jun. 29, 1983	13.92	4,080
1984	Jul. 15, 1984	13.62	3,720
1985	Mar. 04, 1985	9.10	1,160
1986	Apr. 30, 1986	13.55	3,420
1987	Aug. 26, 1987	12.13	2,490
1988	Nov. 28, 1987	5.58	250
1989	May 24, 1989	7.80	731
1990	Jun. 16, 1990	14.18	4,410
1991	May 21, 1991	10.30	1,520
1992	Jul. 25, 1992	9.90	1,350
1993	Jul. 09, 1993	14.02	4,210
1994	Jun. 08, 1994	7.98	779
1995	May 09, 1995	10.15	1,540
1996	May 10, 1996	11.77	2,110
1997	Feb. 18, 1997	10.16	1,550
1998	Jun. 18, 1998	15.00	5,600
1999	May 21, 1991	12.39	2,440
2000	May 31, 2000	11.73	2,100
2001	Apr. 09, 2001	9.66	1,390
2002	Jun. 13, 2002	7.02	636
2003	May 04, 2003	11.41	1,980
2004	May 23, 2004	14.57	4,960
2005	May 13, 2005	13.19	3,230
2006	Apr. 03, 2006	8.90	1,210
2007	Apr. 25, 2007	13.80	3,950
2008	Jun. 06, 2008	15.14	6,810
2009	Apr. 27, 2009	12.54	2,550
2010	Aug. 11, 2010	16.14	9,620
2011	Jun. 14, 2011	11.89	2,640

Figure 3.6: Fourmile Creek Easton Boulevard gage (USGS 05485640) yearly peak flow data



3.4.3 Peak Flow Analysis with Gage Streamflow Data

Table 3.7 includes a summary of the peak flow frequency analysis conducted using the Bulletin 17-B methodology (US IACWD, 1982) for the NE 86th Avenue, and Easton Boulevard gage using data through 2010. To understand the 95% confidence limits on these estimates, see the Annual Exceedance Probability chart developed by the USGS and included in Hydrologic Data Appendix B.

Table 3.7: Bulletin 17-B peak flow frequency analysis for NE 86th Avenue gage and Easton Boulevard gage

Annual Exceedance Probability	Recurrence Interval (years)	Generalized Skew	NE 86th Gage	Easton Gage
0.04	25	-0.094	5,115	7,549
0.02	50	-0.094	6,026	9,172
0.01	100	-0.094	6,981	10,910

Notes:
- NE 86th Avenue Gage is USGS Gage 05485605
- Easton Boulevard Gage is USGS Gage 05485640
- Generalized Skew of -0.094 is taken from USGS Water-Resources Investigations Report 00-4233
- Version 5.2

3.5 History of Flooding on Fourmile Creek

Floods are a natural part of Fourmile Creek's history and have been occurring for thousands of years, where a flood is defined as a stream flow event that exceeds the channel capacity and also conveys water along its floodplain. Floods have periodically occurred on Fourmile Creek throughout recent times and tend to occur in the months of June through August.

3.5.1 Pre-1972/Gage

Major floods that have affected the Fourmile Creek watershed prior to installing the Easton Boulevard gage in 1972 include, in chronological order:

- August 1877
- June 1902
- June 1947
- June 1966

The 1877 flood made the news due to a "railroad accident on the Chicago, Rock Island and Pacific Railroad at the east branch of Four Mile Creek" where the train fell into the stream (The Evening Gazette Port Jervis New York 1877-08-30, posted at www3.gendisasters.com).

The Des Moines FIS of 1988 reported (based on USACE 1975) discharges of 7,430 cfs for June 1966 and 5,900 cfs for June 1947. However, the "estimated flood damage for the City of Des Moines was $116,000 for the 1947 flood and $43,000 for the 1966 flood." This information, together with monthly rainfall data for Ames, seems to indicate that the 1947 flood was more extensive, while the 1966 flood was more localized and likely due to higher rainfall intensity.

3.5.2 Post-1972 Recorded Gage

Floods exceeding 5,000 cfs at Easton Boulevard in Des Moines, Iowa have occurred 5 times since the USGS gage was installed at that location in October of 1971. The largest of these floods occurred on August 11, 2010. A summary of these floods is provided below in Table 3.8.

Table 3.8: History of flooding at Easton Boulevard in Des Moines (USGS 05485640)

Water Year	Date	Gage Height (feet)	Streamflow (cfs)
2010	Aug. 11, 2010	16.14	9,620
2008	Jun. 06, 2008	15.14	6,810
1998	Jun. 18, 1998	15.00	5,600
1977	Aug. 28, 1977	14.64	5,380
1974	Jun. 09, 1974	14.84	5,340

3.5.3 Flooding Correlation to Long-Duration Rainfall

The statistical correlation of yearly peak flows on Fourmile Creek showed a higher correlation to long-duration rainfall amounts than to 24-hour precipitation totals. Floods are likely correlated to years with annual rainfall near or exceeding 40 inches (in decreasing order: 2010, 1993, 2008, 1983, 1986, 1982, 2007, 1984, 1954, 2009, 1990, 1998, and 1991). Monthly rainfall totals that have exceeded 10 inches at the Ankeny gage also correlate with flood events (in decreasing order: 2010, 1993,1954, 2008, 1977, 1998, 1967, and 1983). However, high rainfall volumes of a few days coupled with a high peak intensity also produced higher peak flows. This occurred, for example, in 1998 when comparing with the higher annual and monthly rainfall of 1993. As a result, major floods are more likely in the Fourmile Creek Watershed when a high-intensity rainfall is preceded by precipitation that saturates the soils and other water storage features, such as ponds and prairie potholes.

3.6 Existing Conditions Hydrologic Model

3.6.1 Hydrologic Model Methodology

Detailed hydrologic analyses were performed with the USACE Hydrologic Engineering Center Hydrologic Modeling System (HEC-HMS) computer program. The primary modeling objective was to develop a model for estimating peak flows for base flood estimation and mapping; that is, focusing on the 1% annual probability storm (a.k.a. the 100-year storm). While the focus was not to model the small storm hydrology, several features were incorporated into the model to approximate observed receding flows that result from existing landscape characteristics (e.g., prairie potholes and floodplain connectivity to stream channel). However, the model is most appropriate for single storm events and short-term simulations, since it does not model elements like initial abstraction or soil moisture variations in time.

For this study, the watershed was subdivided into 115 drainage areas, targeting an average drainage area size between one and two square miles.

The SCS curve number (CN) method was used for modeling. Composite CN values were derived for each drainage area based on land use. Note that the curve numbers are representative of larger areas. For example, while cropland could justify using higher values characteristic of plot-scale analyses, CNs of 72 were used to reflect conditions associated with larger-area modeling and to allow modeling the increased runoff due to urban development (e.g., single family residential CNs ranging from 72 to 76). A summary of model inputs is included in Appendix B.

The model was developed to run single storm events using the SCS Type 2 rainfall distribution. For calibration, time-series rainfall data was used for select rainfall gages to estimate the spatial distribution within the Fourmile Creek Watershed. These gages included data from gages at the Ames airport, the Ankeny airport, and the City of Des Moines gage near East 33rd Street and Hubbell Avenue. Gages at schools (such as SchoolNet stations in Ankeny, Polk City, and Madrid) were considered, but they were not used due to accuracy concerns as some sensors may be too close to structures. Initial analysis showed that these SchoolNet stations under-recorded regional rainfall.

Two terms commonly used when describing a watershed's hydrologic characteristics are lag time and time of concentration. Lag time is defined as the difference in time between the center of mass of rainfall excess and the center of mass of peak flow rate at an analysis point in the watershed. The time of concentration is defined as the travel time of a water particle from the most hydraulically remote portion of the watershed to the point of analysis. Table 3.9 includes lag time and time of concentration for two useful points of analysis: Easton Boulevard and the outlet of Fourmile Creek into the Des Moines River.

Table 3.9: Watershed lag time and time of concentration

Analysis Point	Lag Time (hrs)	Time of Concentration (hrs)
Easton Boulevard	7-8	11.5-13.5
Outlet of Fourmile Creek	8-9	13.5-15.0

3.6.2 Calibration Elements

Calibration of the hydrologic model was achieved using the two streamflow gages in Fourmile Creek:

- Easton Boulevard Gage (USGS 05485605)
- NE 86th Avenue Gage (USGS 05485640)

The 2010 and 2008 floods were used as reference for calibration (see Table 3.5, Table 3.6, and Table 3.8).

Using HEC-HMS model features, the following elements were incorporated and adjusted for model calibration:

- Lumping depressional storage areas by drainage area.
- Temporary ponding storage at key locations, such as road crossings.
- Increasing time lag to reflect other storage features not directly modeled or to approximate flows estimated with more detailed studies.
- Base flow to reflect flows sustained by ground water contributions and modeled as flow per drainage area based on average dry-weather flows from the Easton Boulevard gage.

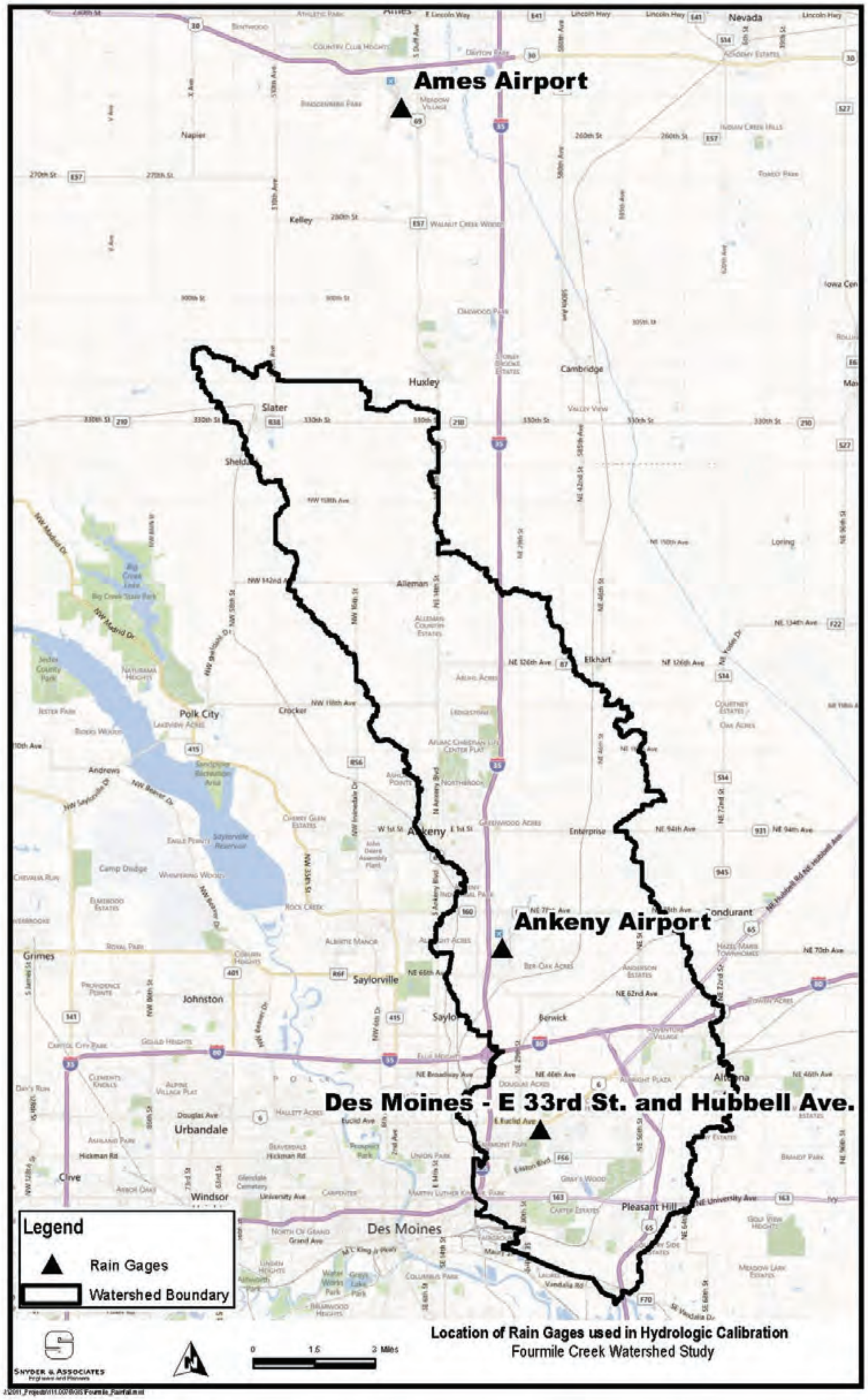
The current model concentrates on estimating flows in the main channel of Fourmile Creek. Therefore, results for tributaries are only approximations and should be used with caution.

3.6.3 Calibration to 2010 Flood

The hydrograph observed by the USGS gauging station during the 2010 flood was the primary event used for calibration. The 2010 flood event consisted of three distinct rainfall events on three consecutive nights ultimately producing the largest flows ever recorded on Fourmile Creek.

In order to calibrate the hydrologic model to this flooding event, a rainfall sequence was developed to mimic the rainfall leading up to the flood from August 9, 2010 thru August 11, 2010. Three rainfall gages from different locations were selected in order to account for the spatial variability of rainfall throughout the watershed. The rainfall gages selected were located at the Ames airport, Ankeny airport and in the City of Des Moines near the intersection of E 33rd St. and Hubbell Ave. The rainfall gage located at the Ames airport is not within the Fourmile Creek Watershed, but was used because of its accuracy and proximity to the upper part of the watershed. Locations of all three rainfall gages are shown below in Figure 3.7.

Figure 3.7: Rain gage locations



When the gage rainfall sequence for the 2010 flood is applied to the hydrologic model, the resulting hydrographs produced are very similar to what was observed at the USGS gages. The resulting hydrographs are illustrated in Figure 3.8 for upstream at NE 86th Avenue and in Figure 3.9 for Easton Boulevard. In these figures, the blue line represents the modeled hydrograph and the black line (with dots) represents the hydrograph as observed by the gaging station. These hydrographs show a good match of peak flow rates for all the storms. The portion of the modeled hydrograph prior to the first rainfall illustrates that the base flow component matches the observed dry-weather/base flow.

Figure 3.8: 2010 hydrographs comparing modeled and observed flow at 86th Avenue

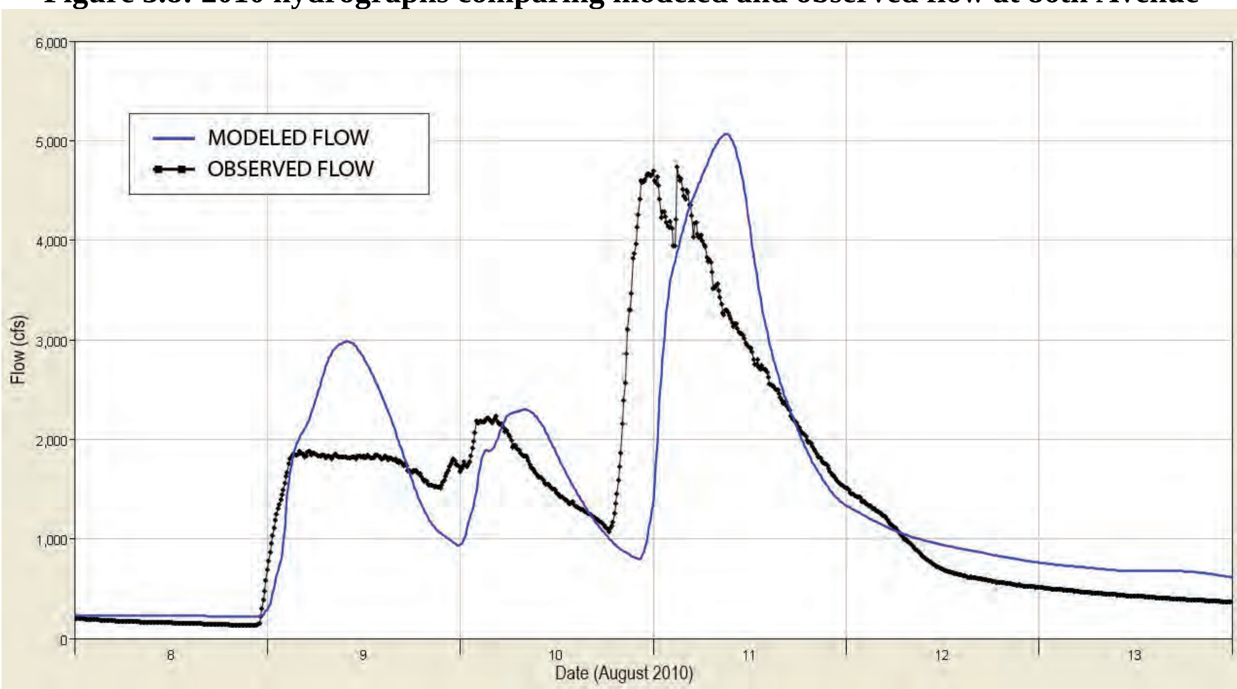
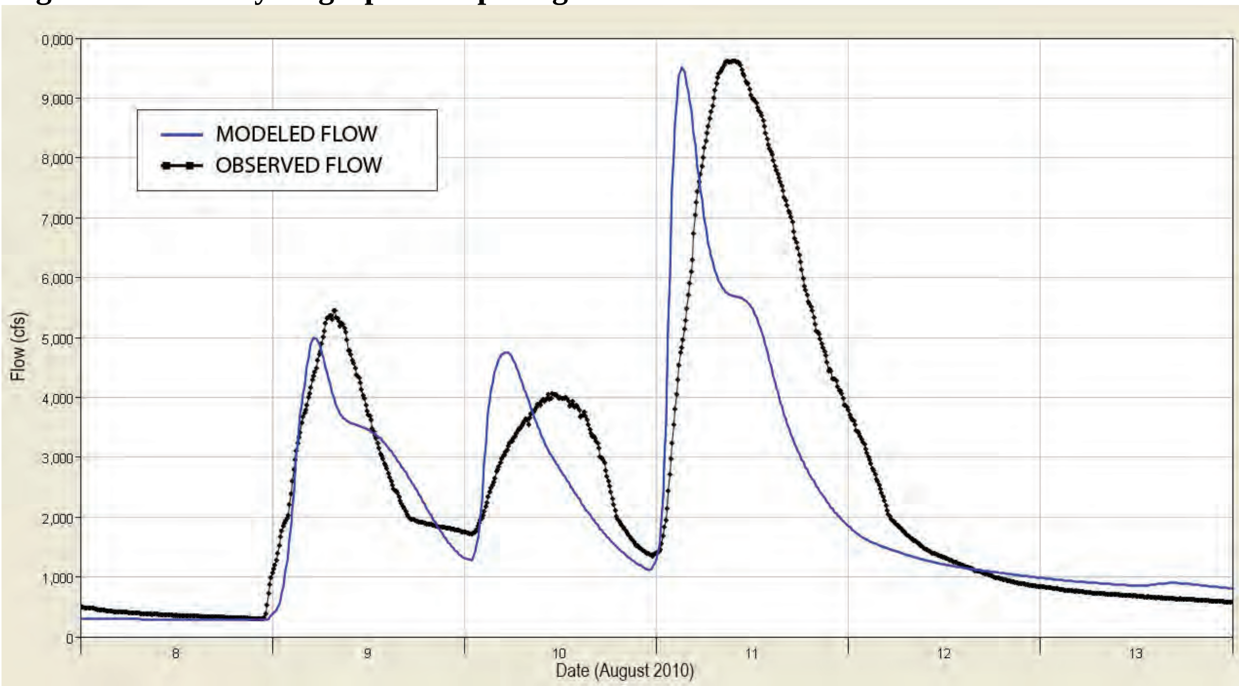


Figure 3.9: 2010 hydrographs comparing modeled and observed flow at Easton Boulevard



3.6.4 Calibration to 2008 Flood

After the model was calibrated to the 2010 flood, the 2008 flood was used to check the performance of the calibration. Rainfall records for the 2008 flood were gathered from the same three gaging stations and input to the hydrologic model. The simulation period used was from June 3, 2008 thru June 8, 2008. Results indicate that the model again matches observed flow well as seen in Figure 3.10 for NE 86th Avenue and in Figure 3.11 for Easton Boulevard. Additional runs of varying durations indicate that the model is best suited for short storm simulations (2-3 days). It becomes more difficult for the model to match streamflow observations when long term simulations are performed.

The model struggles to accurately model long term (5+ days) events because it is unable to reset its initial abstraction. Additionally, modeling a 1-day event is difficult because matching the antecedent moisture condition becomes very important.

Figure 3.10: 2008 hydrographs comparing modeled and observed flow at NE 86th Avenue

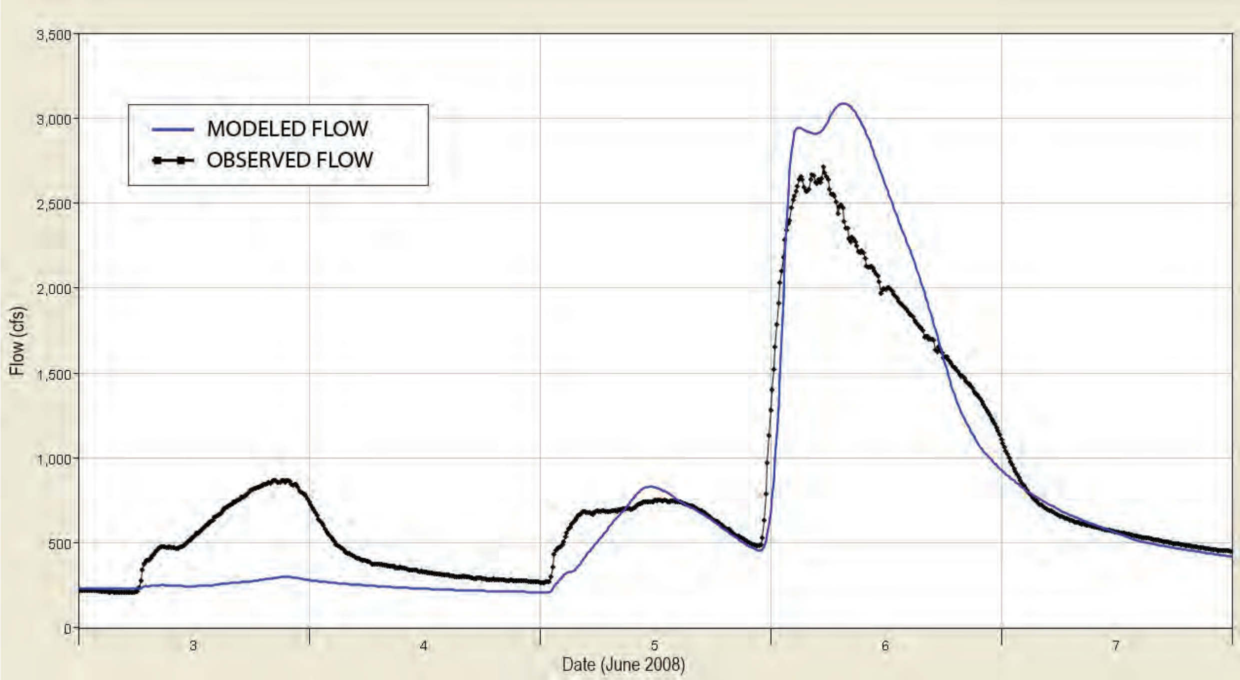
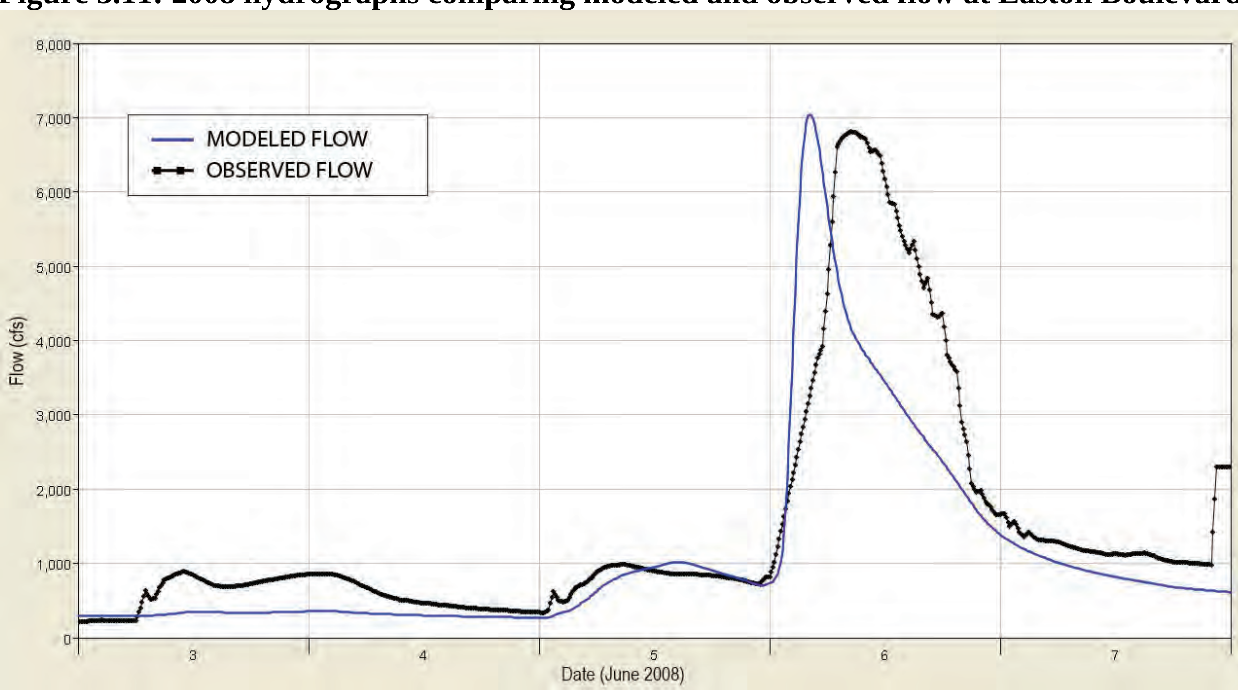


Figure 3.11: 2008 hydrographs comparing modeled and observed flow at Easton Boulevard



3.6.5 1% Annual Chance (100-year) Hydrographs

Modeling results are included for single rainfall events based on the SCS Type 2 rainfall distribution. The 1% annual probability (100-year) hydrographs were modeled using area adjusted rainfall. Fourmile Creek is a large enough area to apply a rainfall reduction factor of 8% to the point rainfall (i.e., 92% of the point rainfall); based on Figure13-1 Area-adjustment of point rainfall in USACE Publication No.EM 1110-2-1417, *Engineering and Design Flood-Runoff Analysis* (31 August 1994). The resulting hydrographs with the area-adjusted rainfall are included in for 86th Avenue, Figure 3.13 for Easton Boulevard, and Figure 3.14 for Fourmile Creek at the mouth. The resulting peak flow at Easton Boulevard decreased from about 13,000 cfs to less than 12,000 cfs due to the area-adjusted rainfall.

Figure 3.12. NE 86th Avenue 1% annual probability (100-year) hydrograph using area-adjusted rainfall (92%)

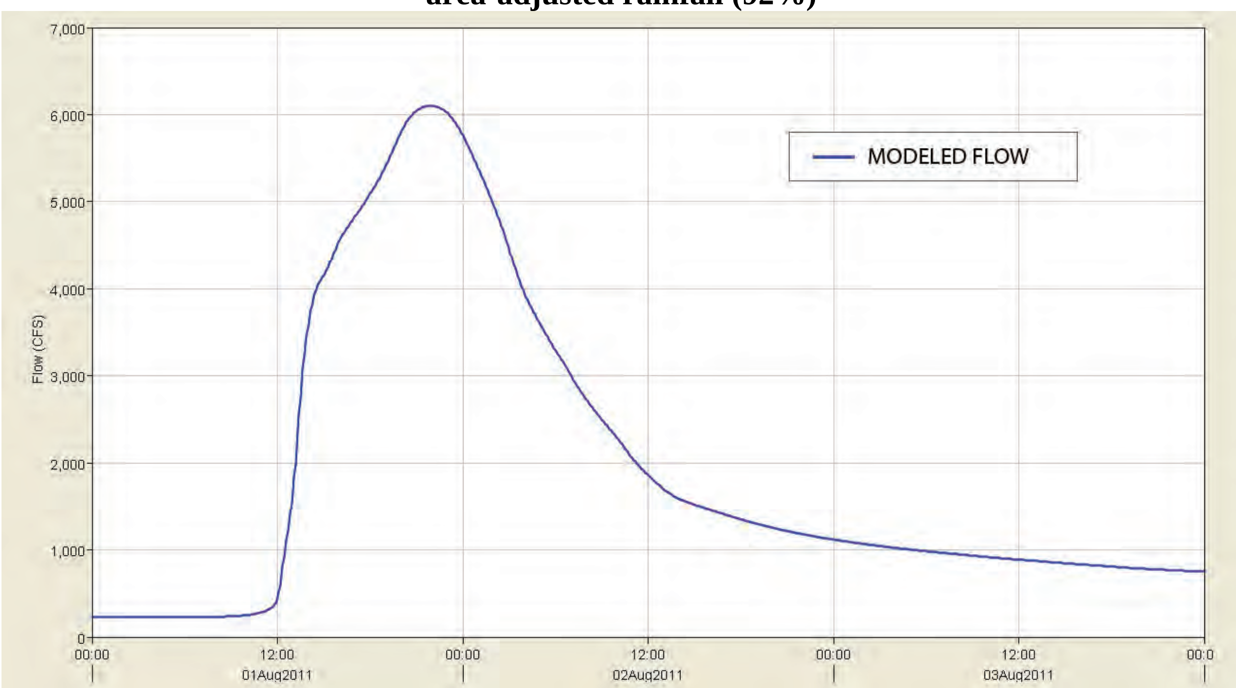


Figure 3.13. Easton Boulevard 1% annual probability (100-year) hydrograph using area-adjusted rainfall (92%)

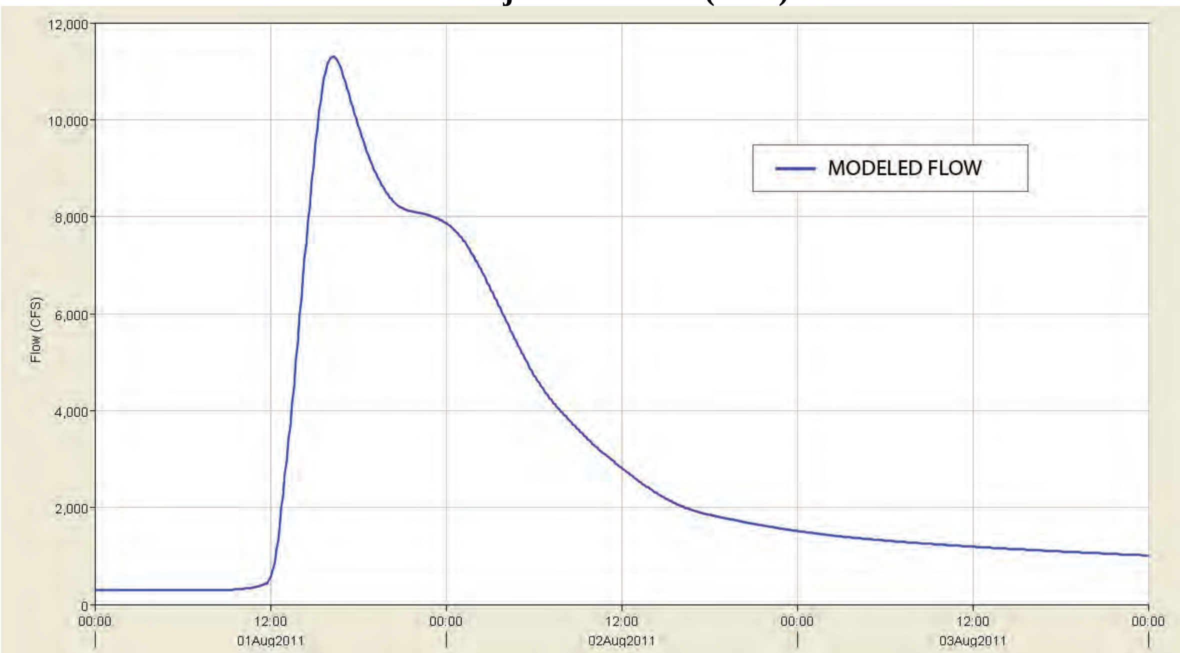
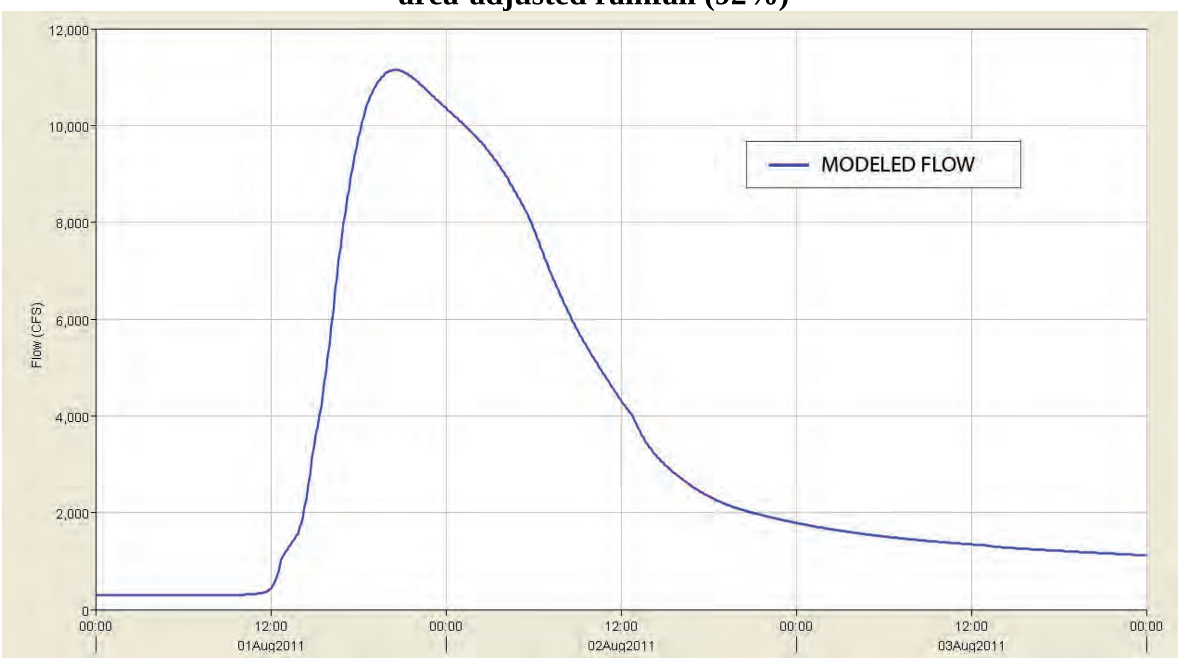


Figure 3.14. Fourmile Creek at-mouth 1% annual probability (100-year) hydrograph using area-adjusted rainfall (92%)



3.6.6 Existing Conditions Hydrologic Results

Table 3.10 includes a summary of the 24-hour rainfall depths used for modeling, which show the SUDAS 2010 point rainfall values and their 92% area-adjusted values to be used for the Fourmile Creek Watershed. This 92% adjustment was derived using Figure13-1 Area-adjustment of point rainfall in USACE Publication No.EM 1110-2-1417, *Engineering and Design Flood-Runoff Analysis* (August 31, 1994).

Table 3.10: 24-hour rainfall depths based on SUDAS 2010 and applying 92% area-adjusted estimate for Fourmile Creek Watershed

Iowa Region	Annual Probability (%)	Recurrence (Year)	Depth (Inches)	92% Depth (Inches)
5	50	2	2.91	2.68
5	20	5	3.64	3.35
5	10	10	4.27	3.93
5	4	25	5.15	4.74
5	2	50	5.87	5.40
5	1	100	6.61	6.08
5	0.2	500	8.06	7.42

Source:
- 2010 SUDAS (Statewide Urban Design and Specifications Program, Design Manual)
- 0.2% probability (500-year) is extrapolated value
- 92% factor to point rainfall for area adjustment for Fourmile Creek

Table 3.11 includes the hydrologic modeling results for existing conditions, based on current land use plans.

Table 3.11: Existing conditions hydrologic results

Road/Location	Drainage Area (Mi^2)	Cross Section Station	Miles above Mouth	2010 Land Use Peak Flows*					
				2 Year	5 Year	10 Year	50 Year	100 Year	500 Year
NW 166th Ave. Story/Polk Line	4.29	177848	33.68	154	244	354	747	929	1,397
NW 158th Ave.	5.95	170610	32.31	224	359	502	1,007	1,283	1,802
NW 150th Ave.	8.00	162266	30.73	296	456	617	1,201	1,494	2,106
NW 16th St.	8.61	160186	30.34	501	781	1,016	1,817	2,283	3,217
NW 142nd Ave.	17.95	154081	29.18	517	793	997	1,588	2,002	2,872
NW 134th Ave.	22.78	145117	27.48	621	1,061	1,380	2,233	2,789	4,038
Hwy 69: 1/4 Mile North of NE 126th Ave.	24.10	133704	25.32	643	1,088	1,418	2,291	2,848	4,084
Hwy 69: 1/4 Mile South of NE 126th Ave.	24.66	130044	24.63	653	1,099	1,429	2,315	2,873	4,119
Hwy 69: 3/4 Mile South of NE 126th Ave.	29.56	125779	23.82	765	1,264	1,635	2,631	3,237	4,572
NE 118th Ave.	30.00	122223	23.15	804	1,311	1,694	2,720	3,335	4,701
NE 47th St.	35.51	118373	22.42	961	1,533	1,994	3,266	3,980	5,624
NE 36th Ave.	37.49	113548	21.51	1,018	1,611	2,097	3,426	4,161	5,867
NE Delaware Ave.	38.66	104462	19.78	1,041	1,645	2,138	3,482	4,205	5,885
Otter Creek Junction	44.88	102446	19.40	1,268	1,986	2,615	4,304	5,141	7,069
Interstate-35	44.93	101907	19.30	1,269	1,987	2,615	4,302	5,141	7,057
E. 1st St.	57.33	93725	17.75	1,457	2,254	2,944	4,959	5,960	8,102
NE 86th Ave.	60.13	85874	16.26	1,505	2,323	3,032	5,075	6,101	8,258
NE 78th Ave.	63.05	75716	14.34	1,553	2,391	3,118	5,190	6,238	8,420
NE 62nd Ave.	66.15	58494	11.08	1,596	2,458	3,206	5,305	6,378	8,587
Muchikinock Creek Junction	82.10	53207	10.08	1,903	2,960	4,166	7,967	9,882	13,794
NE 54th Ave.	82.98	49838	9.44	1,931	3,046	4,301	8,220	10,189	14,233
NE Broadway Ave.	85.35	43560	8.25	1,949	3,105	4,653	8,431	10,462	14,638
Hubble Ave.	88.63	34913	6.61	2,041	3,328	4,711	9,033	11,264	15,856
Easton Blvd.	91.46	29918	5.67	2,054	3,337	4,726	9,062	11,297	15,910
Williams St.	92.13	23376	4.43	2,078	3,393	4,635	8,880	11,109	15,158
Little Fourmile Creek Junction	106.61	17471	3.31	2,110	3,545	5,068	9,987	12,582	17,228
Dean Ave./Fairview Dr.	107.28	14060	2.66	2,113	3,549	5,077	9,992	12,587	17,252
Scott Ave.	107.51	10920	2.07	2,114	3,550	5,081	9,992	12,583	17,268
S of Scott where Leetown Conbines	114.60	7334	1.39	2,115	3,506	4,883	9,050	11,194	15,643
Vandalia Rd.	114.68	3364	0.64	2,115	3,505	4,885	9,051	11,194	15,642
Near Mouth of Fourmile	115.90	609	0.12	2,109	3,497	4,882	8,999	11,150	15,678

*Derived with area adjusted rainfall

3.7 Future Conditions Hydrologic Model

The hydrologic model was modified to reflect the future conditions based on the future land use plans for the year 2030. Model parameters were modified accordingly for each drainage area in which change is anticipated from existing conditions; that is, drainage areas that changed land use, such as from agricultural to urban land use (residential or commercial categories).

Table 3.12 includes the hydrologic modeling results for future conditions, based on future land use plans.

Table 3.12: Future conditions hydrologic results

Road/Location	Drainage Area (Mi^2)	Cross Section Station	Miles above Mouth	2030 Land Use Peak Flows*					
				2 Year	5 Year	10 Year	50 Year	100 Year	500 Year
NW 166th Ave. Story/Polk Line	4.29	177848	33.68	156	246	359	754	936	1,329
NW 158th Ave.	5.95	170610	32.31	227	362	507	1,017	1,291	1,813
NW 150th Ave.	8.00	162266	30.73	299	459	621	1,182	1,503	2,119
NW 16th St.	8.61	160186	30.34	505	786	1,022	1,828	2,296	3,233
NW 142nd Ave.	17.95	154081	29.18	522	798	1,002	1,597	2,013	2,883
NW 134th Ave.	22.78	145117	27.48	626	1,073	1,391	2,247	2,806	4,057
Hwy 69: 1/4 Mile North of NE 126th Ave.	24.10	133704	25.32	647	1,101	1,429	2,305	2,865	4,103
Hwy 69: 1/4 Mile South of NE 126th Ave.	24.66	130044	24.63	658	1,111	1,440	2,330	2,890	4,138
Hwy 69: 3/4 Mile South of NE 126th Ave.	29.56	125779	23.82	769	1,277	1,647	2,646	3,254	4,592
NE 118th Ave.	30.00	122223	23.15	808	1,324	1,704	2,732	3,349	4,715
NE 47th St.	35.51	118373	22.42	969	1,551	2,008	3,280	4,002	5,643
NE 36th Ave.	37.49	113548	21.51	1,033	1,636	2,119	3,451	4,193	5,889
NE Delaware Ave.	38.66	104462	19.78	1,056	1,668	2,161	3,507	4,236	5,910
Otter Creek Junction	44.88	102446	19.40	1,301	2,027	2,662	4,358	5,191	7,097
Interstate-35	44.93	101907	19.30	1,302	2,027	2,663	4,354	5,191	7,087
E. 1st St.	57.33	93725	17.75	1,564	2,432	3,192	5,151	6,118	8,163
NE 86th Ave.	60.13	85874	16.26	1,616	2,513	3,299	5,296	6,278	8,341
NE 78th Ave.	63.05	75716	14.34	1,667	2,589	3,399	5,437	6,432	8,518
NE 62nd Ave.	66.15	58494	11.08	1,713	2,660	3,495	5,581	6,591	8,704
Muchikinock Creek Junction	82.10	53207	10.08	2,039	3,328	4,685	8,795	10,753	14,688
NE 54th Ave.	82.98	49838	9.44	2,070	3,433	4,830	9,058	11,085	15,153
NE Broadway Ave.	85.35	43560	8.25	2,089	3,502	4,948	9,289	11,388	15,605
Hubble Ave.	88.63	34913	6.61	2,250	3,784	5,331	10,003	12,291	16,913
Easton Blvd.	91.46	29918	5.67	2,262	3,794	5,351	10,033	12,331	16,983
Williams St.	92.13	23376	4.43	2,299	3,787	5,236	9,817	12,131	16,119
Little Fourmile Creek Junction	106.61	17471	3.31	2,449	4,077	5,779	11,040	13,714	18,198
Dean Ave./Fairview Dr.	107.28	14060	2.66	2,454	4,088	5,787	11,042	13,718	18,230
Scott Ave.	107.51	10920	2.07	2,456	4,093	5,790	11,041	13,714	18,250
S of Scott where Leetown Conbines	114.60	7334	1.39	2,427	3,996	5,446	9,775	12,059	16,747
Vandalia Rd.	114.68	3364	0.64	2,426	3,996	5,446	9,775	12,062	16,748
Near Mouth of Fourmile	115.90	609	0.12	2,396	3,957	5,392	9,707	12,032	16,798

*Derived with area adjusted rainfall

3.8 Existing Conditions Hydraulic Model

Detailed hydraulic analyses were performed with the USACE Hydrologic Engineering Center River Analysis System (HEC-RAS) computer program (Version 4.1). Geometry data—cross sections of channel and floodplain with LiDAR elevation data, stream and overbank flow paths, ineffective areas, bridge deck data, and other data–were also generated using the ArcGIS extension HEC-GeoRAS, a suite of GIS tools for support of HEC-RAS.

The hydraulic model is georeferenced to the North American Datum of 1983, Iowa State Plane South. Cross sections were drawn left to right looking downstream

3.8.1 Methodology

The hydraulic modeling was performed in HEC-RAS using the steady-state features based on the HEC-HMS estimated peak flows at different points along the main stem of Fourmile Creek. This methodology is the standard for FEMA floodplain modeling. Steady-state means the modeled flows do not vary in time, which means the hydrograph is not routed through the modeling reaches. As discussed in the hydrologic modeling methodology, the HEC-HMS model estimated and routed the hydrographs generated by each drainage area and its features (e.g., ponds and storage areas at road crossings) to accurately estimate the peak flows to be used in the hydraulic model to estimate water surface elevations along the creek.

The existing conditions model utilized a hydraulic model developed by the United States Army Corps of Engineers in 2004 for the City of Des Moines. The 2012 Snyder & Associates model tied into the 2004 USACE model north of E. Douglas Avenue at cross section 36861. Cross Sections 609 through 36861 were left as they were created in 2004 by the USACE with the exception of cross sections 30007, 30121, and the Easton Boulevard Bridge. These areas were revised to account for the 2010 Easton Boulevard Bridge replacement.

3.8.2 Cross Sections

Channel and floodplain cross sections were placed at critical locations with additional sections added where needed for model stability. Cross section geometry was developed from field survey and Iowa Statewide LiDAR topography. Dimensions for all bridges and structures were obtained by field survey.

3.8.3 Manning's "n" Values

Overbank Manning's "n" (hydraulic roughness coefficient) values were determined from 2011 color aerial imagery of Polk County and were set to values appropriate for a given land use. Channel "n" values were set to 0.038 for the portions of channel upstream of E. Douglas Avenue. Table 3.13 shows the range of "n" values used for the various overbank land types encountered.

Table 3.13: Manning "n" value ranges

Land Type	Description	"n" value
Pasture Land	No Brush or trees	0.04-0.06
	Light brush or trees	0.06-0.08
Crop Land	Corn or Soybeans	0.07-0.09
Brush and Trees	Heavy weeds, scattered brush	0.08-0.10
	Medium to dense brush and trees	0.09-0.12
	Dense brush and trees	0.10-0.15
	Heavy Stand of Timber, a few downed trees, little undergrowth	0.07-0.10

3.8.4 Steady Flow File

The steady flow file used in the existing conditions hydraulic model contained 48 flow change locations for six profiles. These allowed the simulation of water surface elevations at cross sections along the creek to generate a profile for each probability estimate (such as the 1% annual exceedance). Flow change locations were created at every location that flow rate information was available from the hydrologic model. This large number of flow changes allowed more accurate modeling of hydraulic conditions at the many bridge locations along Fourmile Creek. The six profiles modeled were the 2, 5, 10, 50, 100, and 500 year flow rates. Normal depth was selected for use in establishing boundary conditions. The normal depth slope was determined from LiDAR data.

3.8.5 Quality Control

The cHECk-RAS 2.0.1 software program was utilized for quality control and reporting purposes. Warnings generated by cHECk-RAS were categorized and carefully inspected. A systematic approach was taken based on this review to refine the hydraulic model, which included for example adding some cross sections and comparing to 2010 Flood observed high waters.

3.8.6 Existing Conditions Hydraulic Model Results

Results of the existing (year 2010) land use condition hydraulic model are shown in Appendix C.

3.9 Future Conditions Hydraulic Model

The hydraulic geometry was maintained from the existing conditions model to the future conditions model. The only difference between the current and future land use hydraulic models is the flow rates used in the steady flow file. The future hydraulic model incorporates the flow rates developed by the future condition hydrologic model.

3.9.1 Future Conditions Hydraulic Model Results

Results of the future (year 2030) land use condition hydraulic model are shown in Appendix C.

3.10 Inundation Mapping

The conditions evaluated included the inundation risks associated with the 1% and 0.2% annual exceedance probability peakflows (a.k.a. the 100- and 500-year floods) for current (2010) and future (2030) land use conditions.

Note the hydraulic analysis was limited to the main stem of Fourmile Creek. As a result, these results do not estimate peak flood elevations that could be associated with flows along tributaries or drainage features adjacent to the main creek and overbank area. Additionally, it should be noted the area downstream of Dean Avenue in Des Moines is also subject to flooding from the Des Moines River. Its exclusion from the Snyder Inundation boundaries does not suggest a low level of flood risk. Lines entitled “flood mapping limits” are included on the map in order to demonstrate flood mapping boundaries.

3.10.1 Methodology

Water surface elevation data for all profiles were exported from the HEC-RAS 1-dimensional model into ArcGIS and mapped using HEC-GeoRAS. All floodplain mapping was delineated using current Iowa Statewide LiDAR data.

3.10.2 Existing Conditions Inundation Mapping

The existing conditions inundation maps are included in Maps 12.0-12.24, where Map 12.0 is the index map showing the location of the detailed maps.

3.11 Future Conditions Inundation Mapping

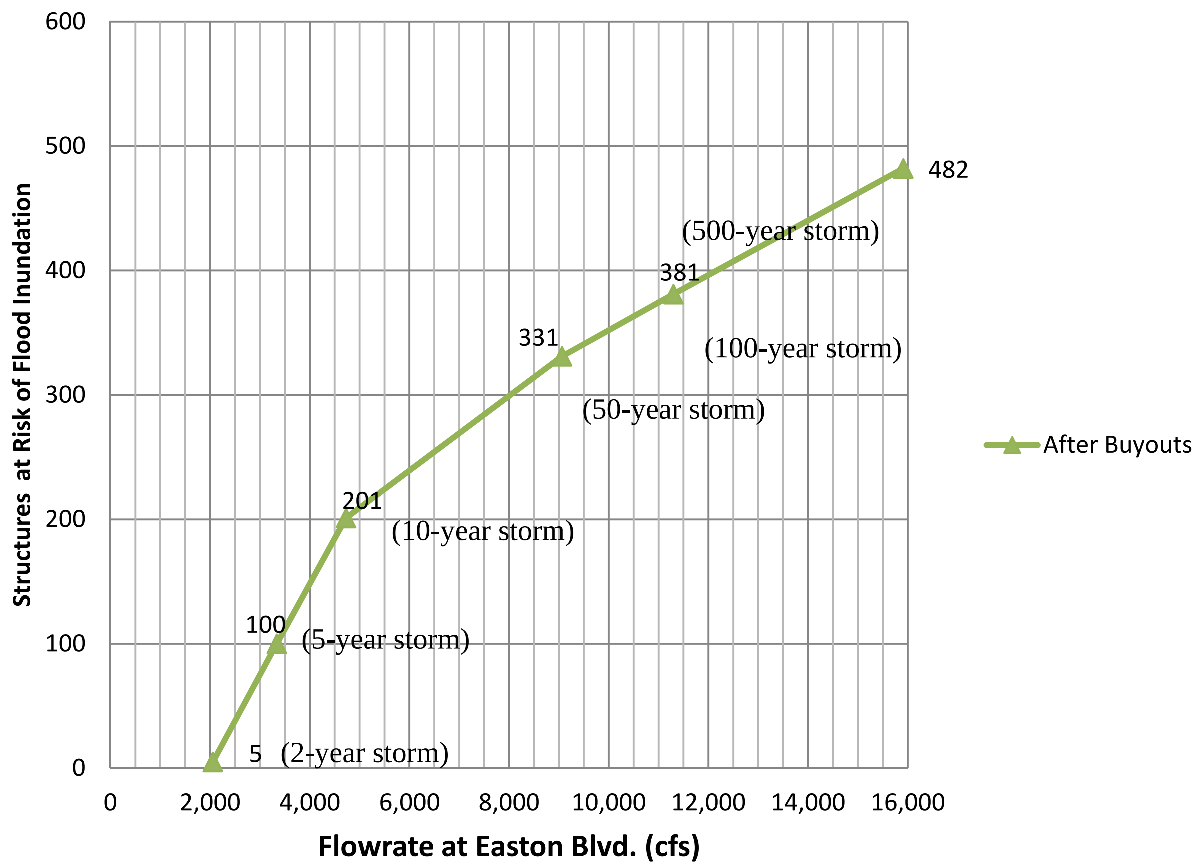
The future conditions inundation maps are included in Maps 13.0-13.24, where Map 13.0 is the index map showing the location of the detailed maps.

3.12 Structures at Risk of Inundation

For planning and analysis purposes it became necessary to develop a simple way to estimate the number of homes and businesses at risk of inundation from various flow rates. To do this, a database of "structures" along the Fourmile Creek was created. A Polk County shape file layer served as the original source of the geospatial data. The shape file database contained a polygon drawn to represent each structure (house, trailer, business) in Polk County. The database was then thinned down to include only structures within the creek's potential inundation area. The polygons were then buffered in order for them to slightly overlap the footprint of the structures they represent.

Using the inundation maps, a relationship was developed that paired the number of structures at risk of inundation to a particular peak flow rate at Easton Boulevard in Des Moines. It also became necessary to cross this information with Polk County Parcel data in order to remove the structures already purchased by the City of Des Moines from this tabulation (called in this report "after buyouts"). The result of these efforts was a curve that relates the flow rate at Easton Boulevard to the number of structures at risk of inundation from specific storm events, as illustrated in Figure 3.15. The curve plots the number of structures at risk of inundation from stream flows generated by the 2, 5, 10, 50, 100, and 500-year storms for the existing (2010) land use condition and then connects these data points with straight lines. Note the lines connecting the data points reflect a trend, which is not necessarily linear. As a result, these estimates should only be used for approximation purposes.

Figure 3.15: Number of structures at risk by flow rate at Easton Boulevard



4 WATERSHED CONCERNS

Concerns expressed by the public, who primarily included residents adjacent to the stream, are included in this section. In addition, the causes of flooding and streambank erosion in Fourmile Creek, based on analyses performed during this study and the experience of the contributing professionals, are discussed in more detail.

4.1 Public Concerns

4.1.1 General Concerns

As described in Section 3.5, Fourmile Creek has a long history of flooding. The most recent floods occurred in 2008 and 2010, which were also among the largest recorded floods and therefore heightened the concern of residents about flooding. In fact, flooding was the main concern expressed by residents throughout the study. Streambank erosion was another frequently noted concern.

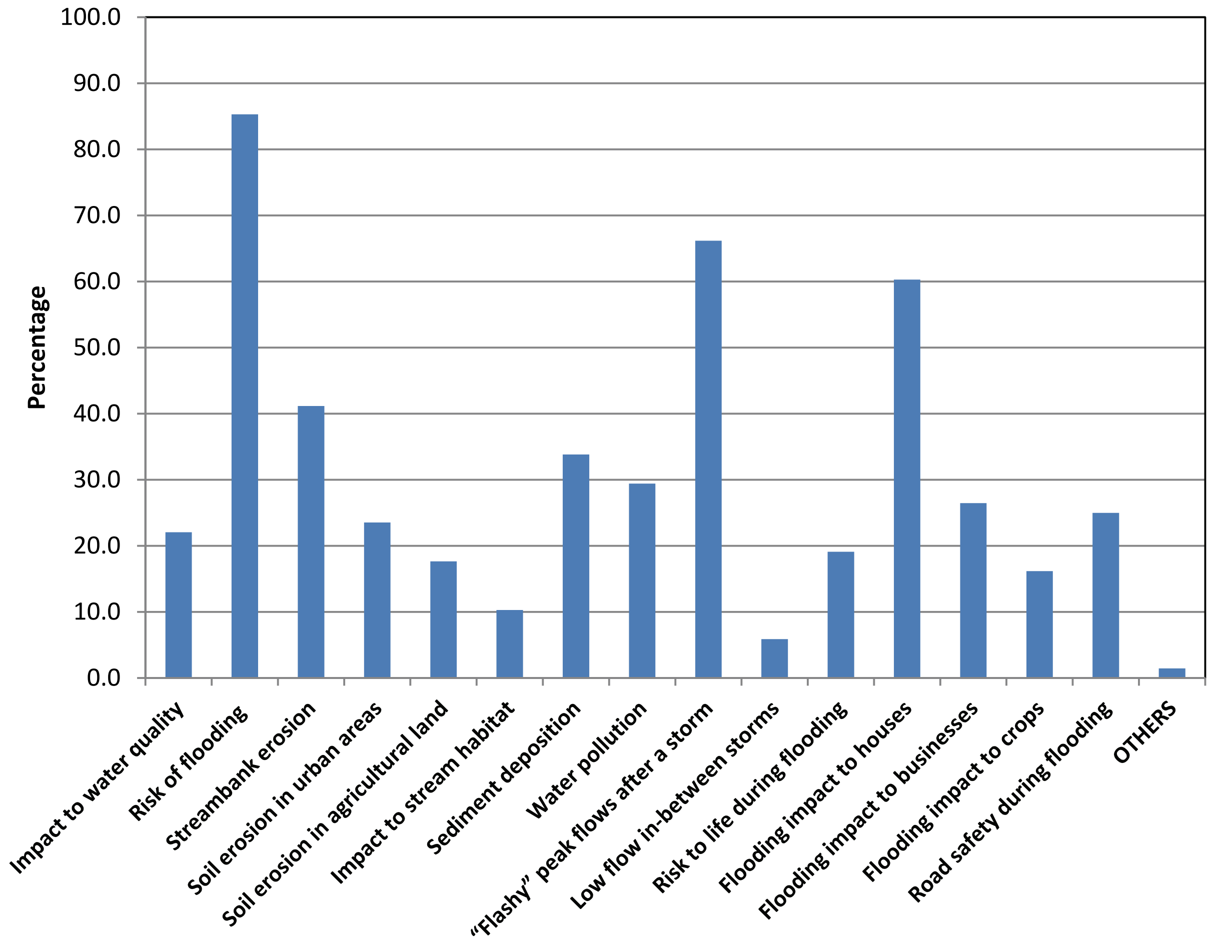
It is important to note flooding concerns included direct flooding of homes and businesses from the creek and from sanitary sewer backups. Other concerns expressed by residents included environmental impacts, urbanization, water quality, and water seepage into basements outside the creek areas.

4.1.2 2011 Public Meeting Questionnaires

The first set of public meetings for the Fourmile Creek Watershed Study were held on June 21, 2011 at the Four Mile Creek Community Center in Des Moines, Iowa and June 22, 2011 at the Snyder & Associates' offices in Ankeny, Iowa. Participants attending the first series of meetings were asked to complete and return a short questionnaire that was designed to gather their input on watershed issues. Snyder & Associates' Inc. received 38 completed questionnaires from the meeting held in Des Moines and 30 completed questionnaires from the meeting in Ankeny. A blank copy of the questionnaire distributed at the June 2011 public meetings is available in the appendix. The following is a summary of responses received through the questionnaire. A full summary of questionnaire responses is provided in Appendix A.

- Questionnaire takers stated that their main concern with the watershed was risk of flooding. "Flashy" peak flows after a storm and flooding impact to houses were also main concerns with those who submitted questionnaires. A summary of responses is provided in Figure 4.1.

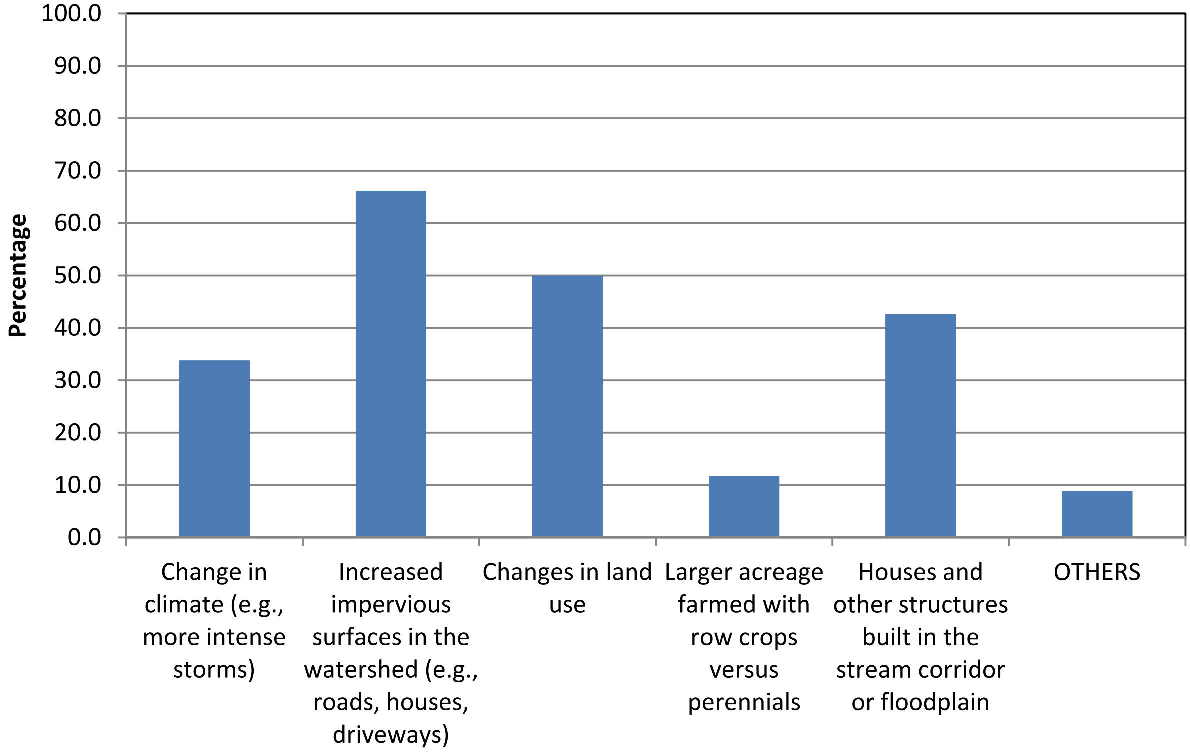
Figure 4.1: Questionnaire - main watershed concerns



- Many residents of both Des Moines and Ankeny experienced "flashy" peak flows after a storm on their properties. In Des Moines, many properties also experienced flooding impacts to houses and basement flooding. In Ankeny, many properties experienced streambank erosion.

- When asked about the causes of flooding along Fourmile Creek, increased impervious surfaces within the watershed were identified by the public as the largest contributor. Other responses included: changes in land use, houses and other structures built in the stream corridor or floodplain, and change in climate. A summary of responses is provided in Figure 4.2.

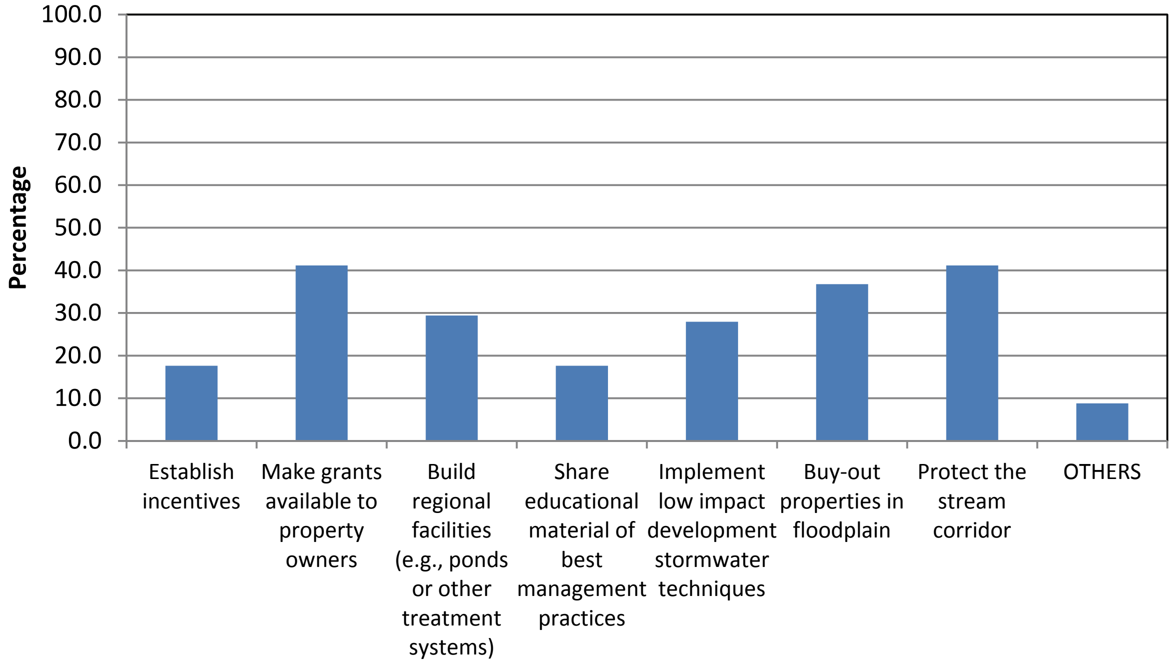
Figure 4.2: Questionnaire - flooding perceptions



- The main concerns related to water quality in Fourmile Creek were: bacteria or other pathogens; nitrates, phosphates, or other agricultural pollutants; chemicals or other pollutants; and stagnant water. Many stated that the main contributor to water quality problems in the watershed is urban development.

- When asked how watershed improvements should be financed, the most popular response was to make grants available to property owners and to protect the stream corridor. Many residents in Des Moines stated that they were in favor of voluntary property buyouts within the flood plain. Most felt the improvements of Fourmile Creek and its watershed should be built in conjunction with other projects. A summary of responses is provided in Figure 4.3.

Figure 4.3: Questionnaire - opportunities to reduce flooding



4.2 Causes of Flooding in Fourmile Creek

4.2.1 Flooding is a Natural Process

All rivers and streams flood. Streams that have not been altered from their natural condition generally overtop their banks frequently (around the 2-year flows or 50% annual chance), although often having minor impacts. However, less-frequent floods can inundate extensive areas and cause great damage, such as the 1993 floods that affected Des Moines.

A stream corridor is an ecosystem that usually consists of three major elements—stream channel; floodplain; and transitional upland fringe—functioning together as a dynamic and valued crossroads in the landscape (FISRWG, 1998). While conceptually a stream corridor is well defined, its spatial boundary in the landscape is not necessarily precise. The transition can be gradual and depend on many factors, such as the prevailing climatic regime that determines the magnitude and variability of flows in the stream.

Fourmile Creek is no exception for this process. Unfortunately, past floods have affected many homes and structures. However, defining the extent of the Fourmile Creek stream corridor is not easy, especially in areas such as Des Moines that have been affected by floods. Further complicating matters is climatic uncertainty and variability, as well as land use changes in the watershed.

In the pages that follow, the causes of flooding on Fourmile Creek will be reviewed. The 2010 Flood will be used for illustration purposes since 2010 is the largest recorded flood on Fourmile Creek. Many factors contributed to the extreme flood, but the two most prominent are: precipitation and land use changes.

4.2.2 Precipitation

4.2.2.1 2010 Rainfall

The flood of 2010 was due in large part to the extreme amount of rainfall central Iowa received in August of 2010, which saturated soils, reduced infiltration, and increased runoff to streams. The year began with normal precipitation. Des Moines received an above average amount of snowfall from January through March. There was slightly above average rainfall for the months of April and May. June and July of 2010 brought rainfall amounts that were much greater than average and by August 1, 2010 the City of Des Moines was approximately 12 inches above normal precipitation for the year. Fourmile Creek watershed then received three small rainstorms of 0.5-1.0 inches each in the early morning hours of August 3, 4 and 7. The overnight hours August 8/9 brought 3-5 inches of rainfall to the watershed. The following night (August 9/10) another storm delivered 2 inches to most parts of the watershed. A third storm in three nights delivered between 1-3.5 inches of rainfall on the night of August 10/11. A summary of cumulative rainfall from August 1st through August 12th is shown in Figure 4.4. The three consecutive nightly rainfalls are summarized in Table 4.1.

Figure 4.4: August 2010 cumulative rainfall

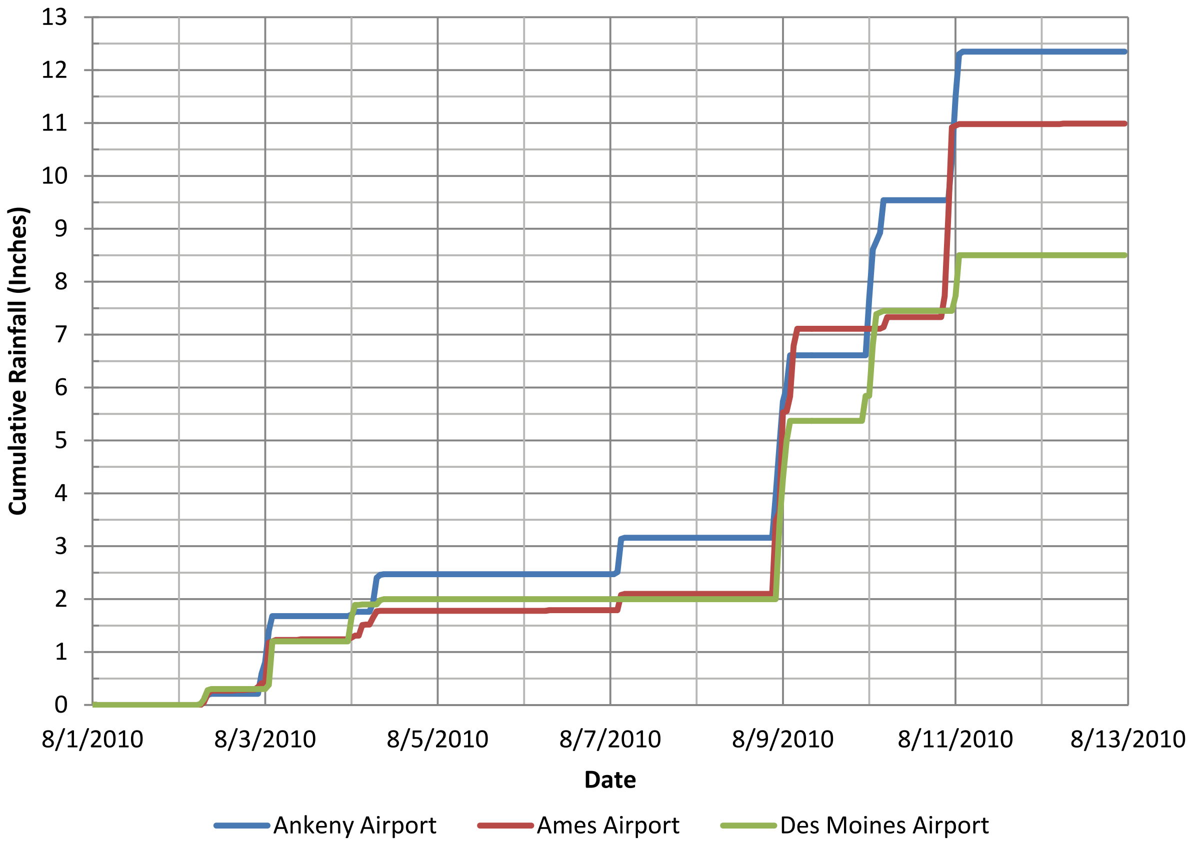
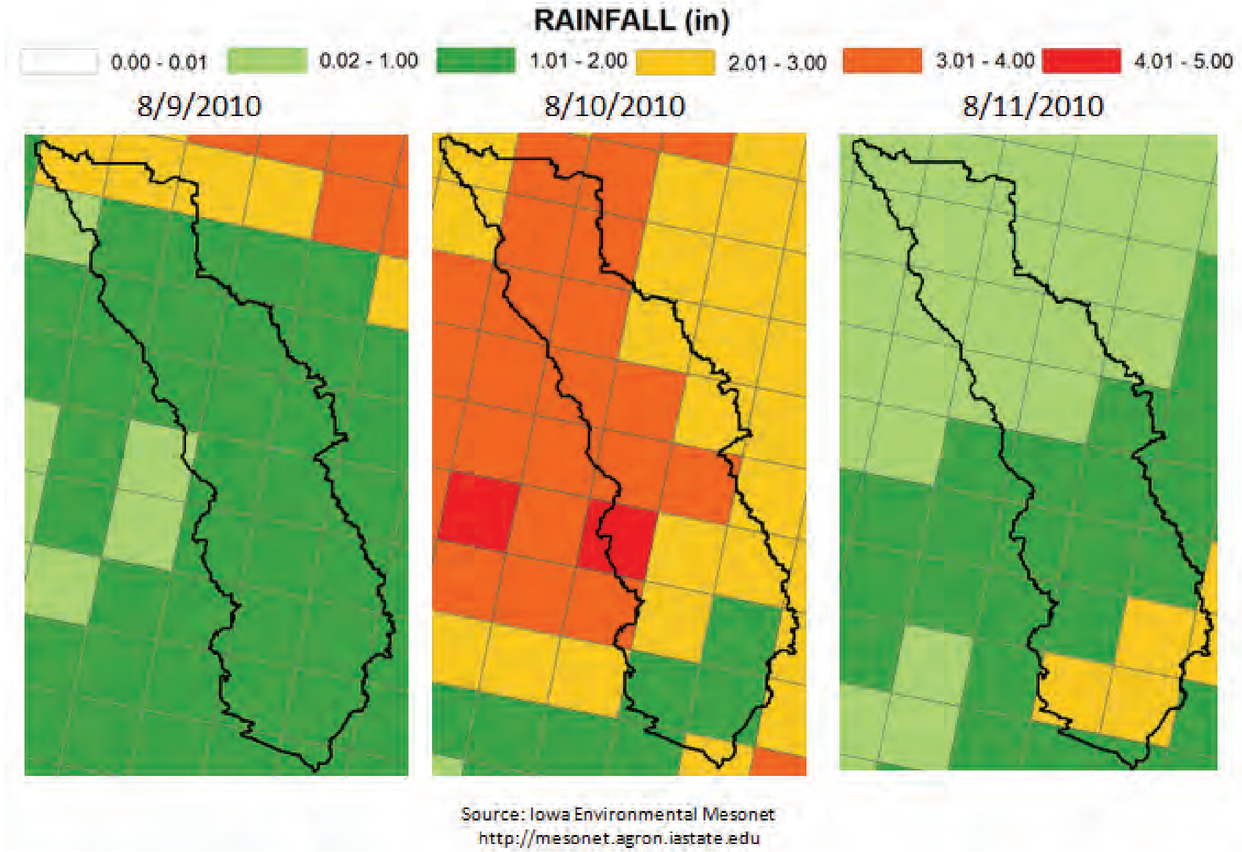


Table 4.1: Summary of three major rainfalls contributing to the flood of 2010

	August 2010 Overnight Rainfall (inches)			
Location (Gage)	8th - 9th	9th - 10th	10th - 11th	3-Night Total
Ankeny Airport (IKV)	3.45	2.93	2.81	9.19
Ames Airport (AMW)	5.01	0.22	3.65	8.88
Des Moines Airport (DSM)	3.37	2.08	1.05	6.50

The distribution and timing of the three consecutive rainstorms resulted in highly variable stream flows. The spatial variability of rainfall between these storms can be observed in Figure 4.5.

Figure 4.5: 24-hr radar indicated rainfall – August 8-11, 2010



4.2.2.2 The August 9-11, 2010 Flood

The result of the extreme rainfall on the nights of August 8-10, 2010 was widespread flooding along Fourmile Creek. The USGS gages at NE 86th Avenue near Ankeny and Easton Boulevard in Des Moines recorded record flows during the morning of August 11, 2010.

The first two nights of heavy rainfall thoroughly saturated the soils and filled the potholes and detention basins in the watershed. By the third night of heavy rainfall, the soils were so saturated they functioned like impervious surfaces. Similarly, the potholes and detention basins that were fully filled by two nights of rainfall began to overtop on the third night producing extreme amounts of runoff that ultimately led to record flooding. The Easton Boulevard gage peaked at 9,620 cfs on the morning of August 11, 2010 at 9:30 AM. The hydrographs observed at the NE 86th Avenue and Easton Boulevard stream gage stations during the August 2010 flood are shown in Figure 4.6 and Figure 4.7.

Figure 4.6: August 2010 flood hydrograph at NE 86th Avenue

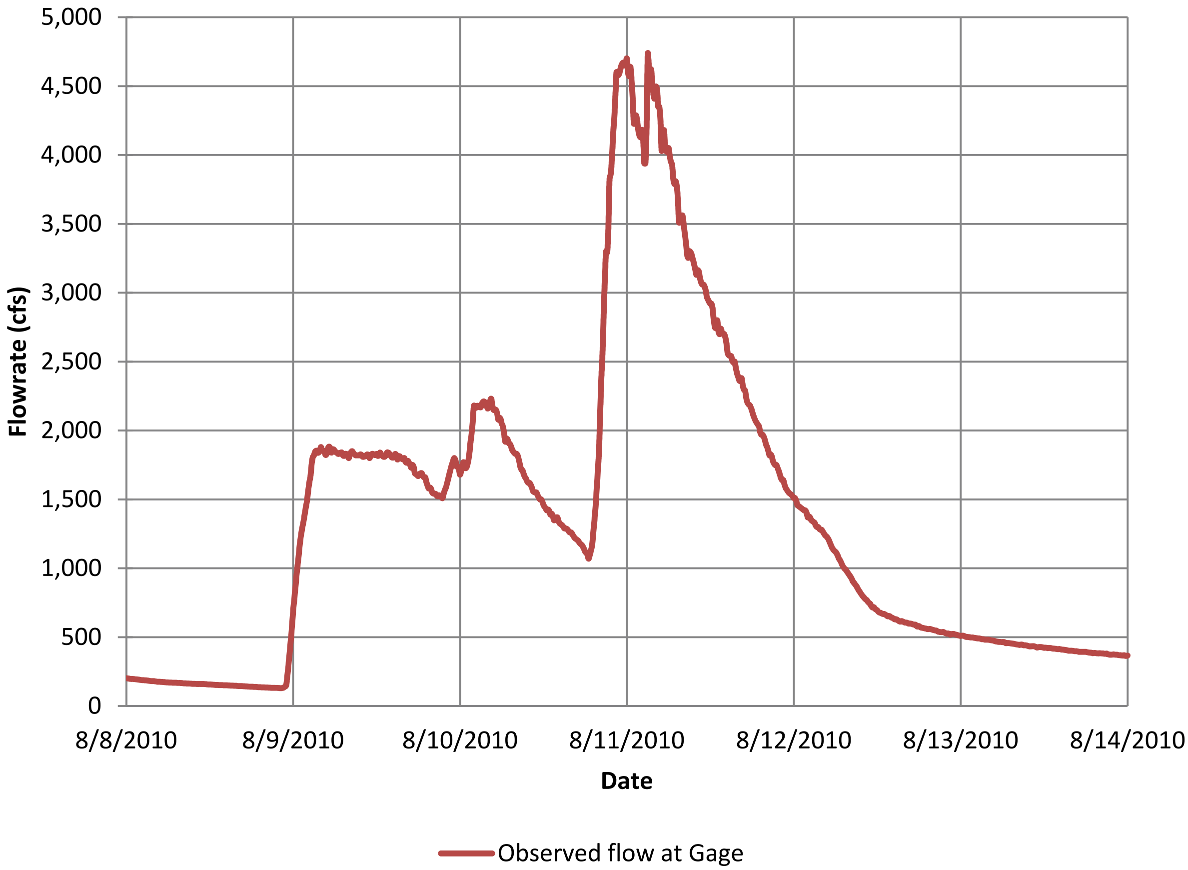
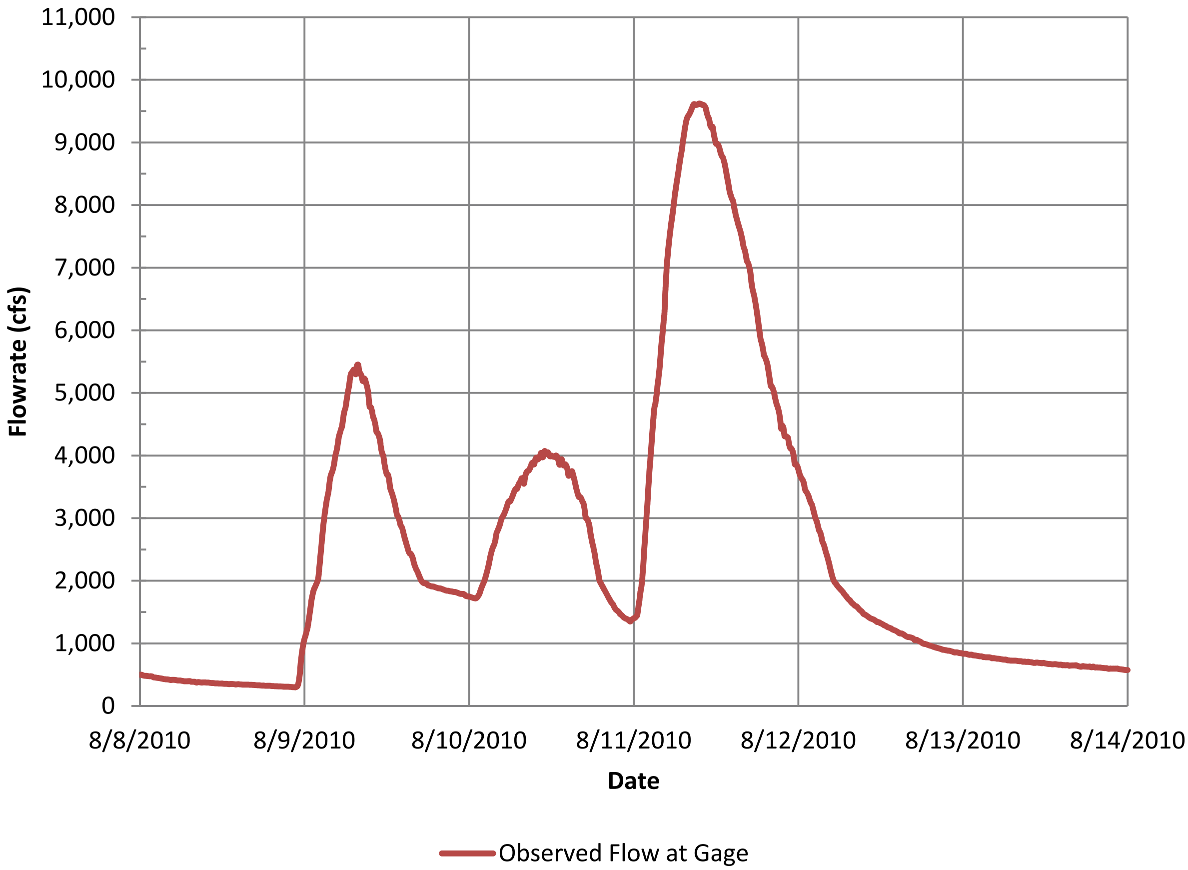


Figure 4.7: August 2010 flood hydrograph at Easton Boulevard



4.2.3 Land Use Changes

Many land use changes can affect flooding, the hydrologic response of the watershed. These changes can, for example:

- Affect the landscape matrix, such as increasing runoff (decreasing infiltration) by converting prairies to cropland or cropland to urban land use with more impervious surfaces.
- Alter the watershed drainage network, such as increasing conveyance capacity of surface drainage (channels and ditches) and accelerating the rate at which subsurface flows discharge to channels and streams.

4.2.3.1 Effect of Urbanization and Modeling the 2010 Rainfall with 1950s Land Use

The effect of urbanization on runoff has been covered by technical literature for many decades. Particularly, increasing impervious surfaces (streets, driveways, roofs, and others) yield higher runoff, as illustrated in Figure 4.8. The higher runoff volume and faster-draining urban landscape can increase the risk of flash flooding and streambank erosion in the absence of adequate stormwater management facilities to address changes in land use.

Figure 4.8: Effects of urbanization

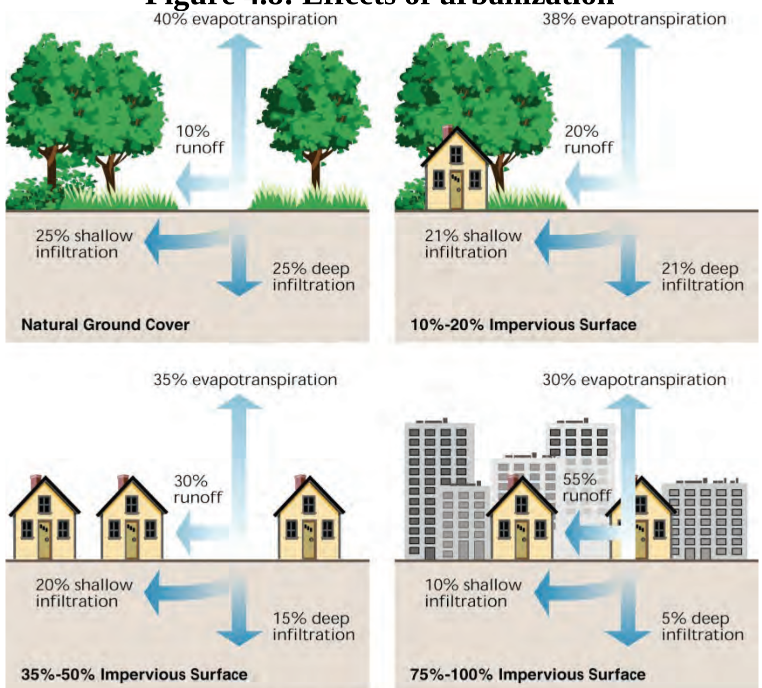


Fig. 3.21 -- Relationship between impervious cover and surface runoff. Impervious cover in a watershed results in increased surface runoff. As little as 10 percent impervious cover in a watershed can result in stream degradation.
In Stream Corridor Restoration: Principles, Processes, and Practices (10/98).
By the Federal Interagency Stream Restoration Working Group (FISRWG) (15 Federal agencies of the U.S.)

The Fourmile Creek Watershed has seen many changes since the 1850s. Analysis of historic vegetation mapping conducted by Iowa State University and the Iowa DNR indicates that the Fourmile Creek Watershed was predominantly prairie in pre-settlement times with scattered wetlands. A small amount of the southern portion of the watershed and the Fourmile Creek stream corridor appear to have supported forest. A map of Fourmile Creek Watershed's historic vegetation is provided in the Maps section.

Analysis of 1950s USDA aerial imagery indicates that by 1950, nearly all native prairie vegetation in the watershed was converted to row crops. The 1950 imagery also shows the establishment of significant urban development in the watershed within the City of Des Moines. Minor urban areas at this time included the Cities of Alleman, Altoona, Ankeny and Slater. Since that time, a rapidly growing metropolitan population has dramatically increased the urban area within the watershed. Urbanization of the watershed has increased the amount of impervious surfaces. Impervious surfaces create stormwater runoff by not allowing soil an opportunity to absorb moisture. A map depicting impervious surfaces in the watershed is provided in the Maps section. Figure 4.9 provides a graphical interpretation of urbanization within the watershed based on parcel data from 1850-2010. Figure 4.10 compares the urban area of six jurisdictions and rural Polk County from 1860-2011. The term “urban area” refers to the area that is not zoned as agricultural.

Figure 4.9: Watershed urbanization

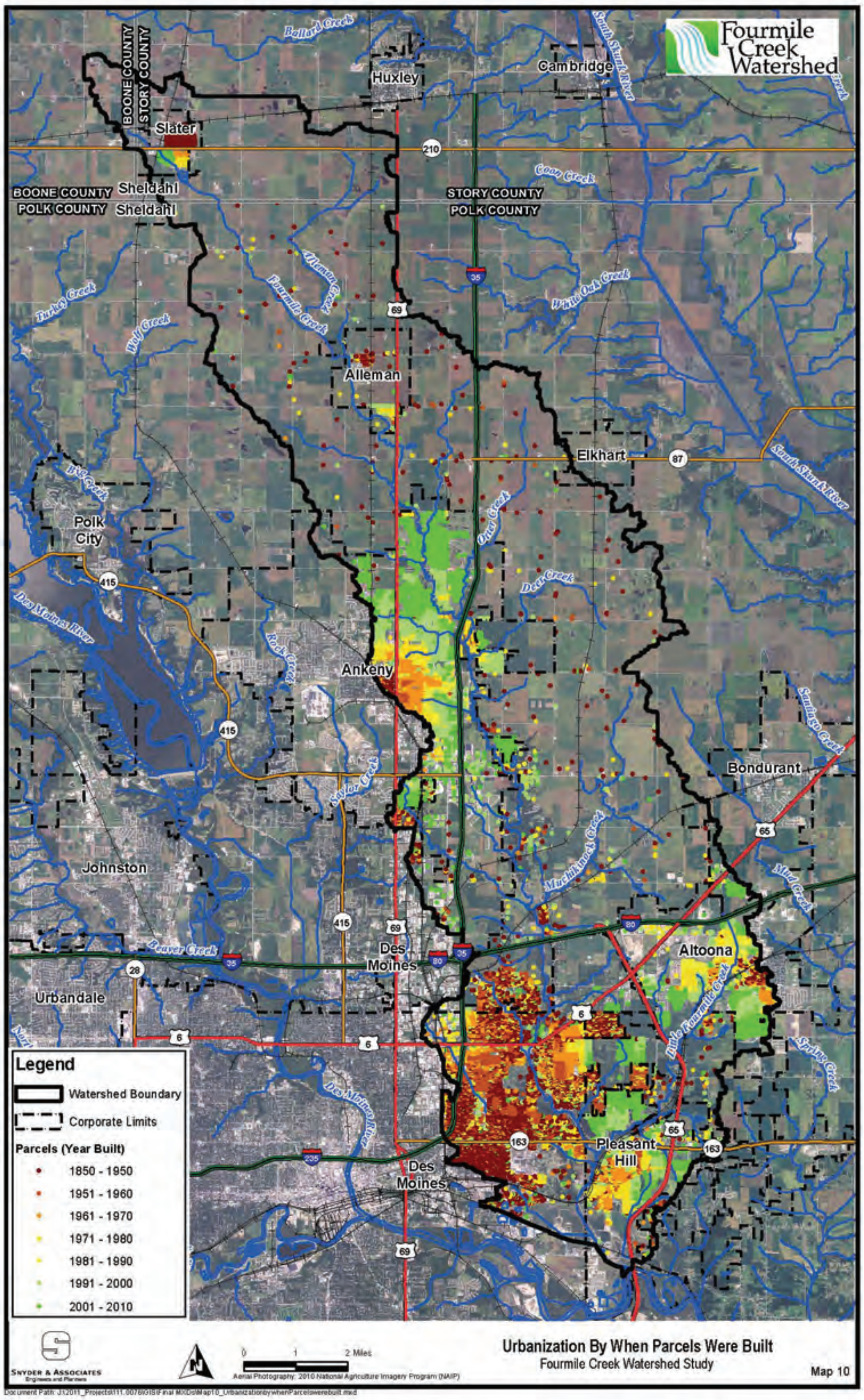
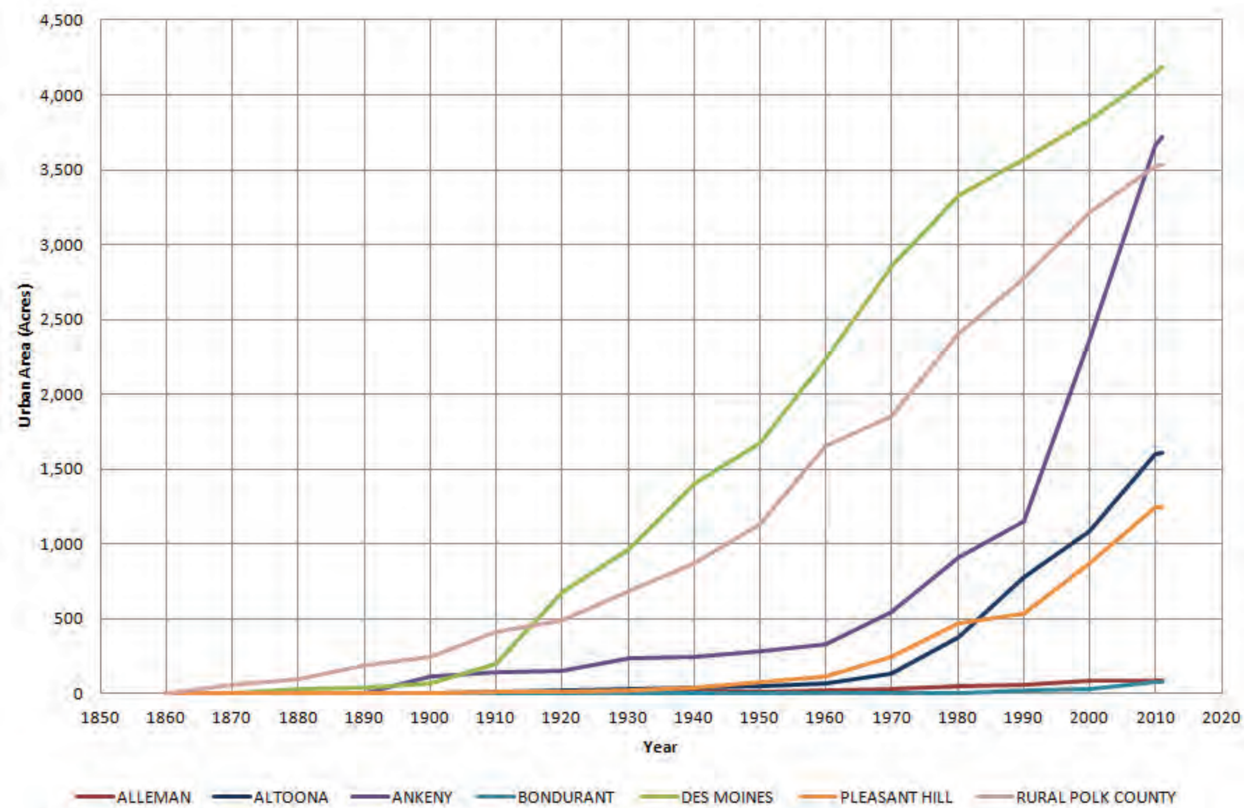


Figure 4.10: Cumulative urban area through time



4.2.3.2 Changes to the Surface Drainage Systems

Channel modifications including straightening, widening and deepening can increase peak flood flow rates due to losses in overbank storage and faster travel times. In the Fourmile Creek Watershed, the effect of channel modifications on peak flow rates is dependent on the resulting timing of peak flows from different contributing tributaries. However, modifications that drain the upper reaches more rapidly are likely to increase peak flows in the lower, flood sensitive areas of the watershed. An example of channelization is shown in Figure 4.11.

Figure 4.11: Example of a drainage modification

Note, channel modifications can occur by direct excavation work, but can also result from high volumes of rainfall and runoff during wet periods (such as 2008 and 2010). Channel modifications can also be induced by changes in land use that increase runoff, such as in changes from pasture to row crops or urbanization.

The surface drainage systems also include the numerous stream crossings (roads, bridges, culverts and dams) that are part of the current landscape. These structures can help attenuate peak flows when temporary storage is available, potentially off-setting faster drainage induced by land use changes and channel modifications since pre-settlement times. For example, a bridge or culvert replacement in the upper watershed that increases conveyance capacity may reduce floodplain storage, which can potentially increase flooding downstream.

4.2.3.3 Drain Tiles

Currently, the upper part of the Fourmile Creek Watershed is intensively farmed. Analysis of the current land use shows us that over 50% of the entire watershed is row cropped. In order to increase the agricultural productivity of this part of the watershed, subsurface drainage has been widely implemented. This study did not include an investigation of the extent to which this part of the watershed has been tiled and the effect it has had on the watershed’s hydrology.

A summary of findings regarding drain tiles is presented distinguishing those that have surface inlets or risers.

- Subsurface field drain tiles:
    - Increases soil water storage available for rains, reducing overland flow volume and peak (Source: Fausey, et al 1995) (Source: Agricultural Drainage, Agronomy Monograph No. 38)
    - Are designed to drain about 0.5 inches per day (Dr. Matthew Helmers, personal communication, March 6, 2013)
    - Help improve soil quality, allowing deeper root zones and biological activity that enhance soil structure
    - Can increase nitrate-nitrogen loading to streams.

- Drain tiles with inlets/risers (surface drains) that connect “prairie” potholes (low spots, depressional storage areas or topographical depressions) to the stream:
    - Increase runoff volume reaching the stream (Source: Agricultural Drainage, Agronomy Monograph No. 38)
    - Can reduce peak flows by restoring depressional storage between rains (Source: Agricultural Drainage, Agronomy Monograph No. 38)
    - Can increase sediment and phosphorous loading to the stream

Due to their limited capacity and slow release, drain tiles have a minimal impact on peak flow associated with major flooding events (such as in 2010). Note that the capacity of drain tiles can also be reduced during floods where the tile outlets are submerged by flows in the channel. Research in the Midwest supports that subsurface drainage helps reduce total and peak surface runoff from agricultural fields. However, the total volume of water drained from the field is likely to increase, such as from drawing down the water table. Reducing surface runoff also reduces sediment loading and attached pollutants, such as phosphorous. However, subsurface drainage can increase the loading of nitrate-nitrogen from the root zone to surface waters. A report that summarizes some of these findings for the Midwest is the “Report of a Technical Forum to discuss the **Hydrologic Impacts of Drainage**” held June 4, 1997 at the University of Minnesota-St. Paul Campus. Dr. Matthew Helmers and other researchers at Iowa State University have also done extensive work in this area.

4.2.4 Summary of What Caused Floods

After a detailed analysis of the 2008 and 2010 floods, Snyder & Associates, Inc. found that the most dominant contributor to flooding was the extreme precipitation volume that saturated the watershed. While urbanization and agricultural land use were factors, had land conditions been the same as in 1950, flooding would have still occurred in August of 2010 due to the extreme precipitation. August, 2010 was a record setting month for precipitation in central Iowa. A recurrence interval analysis of the rainfall associated with the 2010 flood is provided in Table 4.2. This table shows that the 3-day (72-hour), 5-day and 10-day precipitation totals for the Ankeny and Ames gage stations exceeded the 100-yr rainfall recurrence interval (1% annual exceedance probability).

Table 4.2: Analysis of August 2010 rainfall recurrence intervals

	Ankeny Airport		Ames Airport		Des Moines Airport	
Duration	Rainfall (Inches)	Recurrence Interval (yrs)	Rainfall (Inches)	Recurrence Interval (yrs)	Rainfall (Inches)	Recurrence Interval (yrs)
10-Day	12.35	306	10.98	120	8.50	22
5-Day	9.88	207	9.19	122	6.50	16
72-Hr	9.19	287	8.82	209	6.50	29
48-Hr	6.38	44	7.28	101	5.45	19
24-Hr	3.82	6	5.01	20	3.37	4

In summary, factors that particularly contributed to the 2010 record flood included:

- Extreme preceding rainfall volume, which:
  - Saturated soils and reduced infiltration capacity resulting in rainfall contributing “directly” to surface runoff (e.g., making pervious areas like cropland and grassland act as nearly impervious surfaces)
  - Filled available storage areas that attenuate peak flows (e.g., prairie potholes or depressional areas; ponds and reservoirs)
  - Resulted in high low-flow conditions (base flow) at the start of the rain producing the peak flood

- Rainfall distribution and peak intensity of the event producing the peak flood due to the landscape limited capacity to absorb and attenuate the rain in a saturated condition.

As a result, Fourmile Creek is particularly vulnerable to flooding from long-duration, high-volume rainfall in the watershed coupled with moderate to high intensity rainfall events. Note however, that “flash floods” can still affect some areas during high-intensity rainfall events in urbanized areas.

4.3 Causes of Streambank Erosion

Streambank erosion has been a concern for landowners along Fourmile Creek and its tributaries for many years. Polk SWCD previously identified the bank erosion issue and conducted in the summer of 2006 a RASCAL assessment (Rapid Assessment of Stream Conditions Along Length). However, the extremely wet years of 2008 and 2010 exacerbated the streambank erosion problem, both in urban and rural creeks. An example of streambank erosion is illustrated in Figure 4.12.

Two key factors that have contributed to bank erosion in the watershed are discussed:

- Above normal precipitation and runoff volumes
- Impervious surfaces

Many other factors, such as agricultural practices, also may contribute to stream degradation and erosion. For more information on some of these other factors see Stream Corridor Restoration: Principles, Processes, and Practices (FISRWG 10/1998). Some of the discussed practices include impact to riparian vegetation and the drainage system of the land.

Figure 4.12: Fourmile Creek streambank erosion example

4.3.1 Above Normal Precipitation and Runoff Volumes

Above normal precipitation and runoff volumes have contributed to considerable streambank erosion, particularly where sustained erosive flows affected the banks for long periods. For example, 2008 and 2010 had extreme amounts of precipitation that exceeded the yearly normal by 60 to 80%. This also produced extreme runoff volumes that sustained high flows in the stream channels that accelerated streambank erosion, particularly in outside bends and areas not protected by vegetation or other materials. High erosion rates have also been observed where the stream channel has become more entrenched (deeper) and disconnected from its floodplain. When a stream is disconnected from its floodplain, the concentration of flow in the channel results in higher flow velocities and shear stresses along the bed and banks, triggering erosion that otherwise may not occur if the flow were spread over a wider area with lower velocities.

4.3.2 Impervious Surfaces

Impervious surfaces associated with urbanization have also contributed to bank erosion in the watershed. As noted previously, impervious surfaces generate more runoff than natural land cover. High frequency storms (1 inch or less) that would have been absorbed with natural ground conditions produce runoff under impervious conditions. Thus, additional runoff from impervious surfaces, which often drains directly to our streams, can affect stream stability. The “new” flow regime can erode the channel banks and incise a deeper channel, until the channel reaches a new equilibrium.

5 STORMWATER MANAGEMENT ASSESSMENT

This chapter includes the stormwater management context, such as the regulatory framework, sustainable approaches, and resources. Stormwater management opportunities in the Fourmile Creek Watershed are numerous and are illustrated in this chapter organized by management components (such as in rural and urban lands), although all these have to be integrated under the watershed approach umbrella to support stormwater management objectives.

5.1 Stormwater Management Context

5.1.1 Change in Paradigm

Stormwater management has been evolving from "drain it fast" to sustainably managing water as a resource that serves many functions, including supporting a healthy aquatic ecosystem and watershed. Sustainable management of our water resources is vital, particularly in the context of climate change and variability (USGCCRP, 2009).

Stormwater management has been evolving to include integrated systems that address:

- **Source control**—help reduce pollutants and runoff peak and volume that degrade streams and other water bodies or affect flood risk (e.g., reducing impervious surface to reduce runoff; reducing pollutant loading such as phosphorous-free fertilizers for lawns).
- **Peak flow reduction—**help restore hydrologic conditions that reduce flood risk, particularly to address changes in land use from presettlement conditions (e.g., limiting post-development peak flow to pre-development peak flow rates).
- **Runoff volume control**—help reduce runoff volume associated with changes in land use, particularly from increased impervious surfaces, to reduce stream and water quality degradation (e.g., using infiltration practices to reduce post-development runoff volume).

5.1.2 Regulatory Framework

Numerous regulatory instruments have been developed that deal with stormwater management, either directly or indirectly. This section only presents a few highlights to illustrate key national instruments that serve as a framework for state and local regulations to address the need for sustainable stormwater management.

5.1.2.1 National Pollutant Discharge Elimination System (NPDES)

The National Pollutant Discharge Elimination System (NPDES) was authorized in 1972 by the federal Clean Water Act. The NPDES protects water quality by controlling point sources that discharge pollutants. The NPDES Stormwater Program covers the following types of stormwater discharges:

- **MS4s—**Operators of large, medium and regulated small Municipal Separate Storm Sewer Systems (MS4s) may be required to obtain authorization to discharge stormwater.

- **Construction Activities**—Operators of construction sites that are one acre or larger (including smaller sites that are part of a larger common plan of development) may be required to obtain authorization to discharge stormwater under an NPDES construction stormwater permit.
- **Industrial Activities**—Industrial sectors may require authorization under an NPDES industrial stormwater permit for stormwater discharges.

NPDES requires municipalities to obtain permit coverage for their stormwater discharges. Coverage is available through either Phase I (1990) or Phase II (1999) permits.

NPDES Stormwater Phase II Rule's six minimum control measures are:

1. **Public Education**—Best Management Practices (BMPs) for MS4s to inform individuals and households about ways to reduce stormwater pollution.
2. **Public Involvement**—BMPs for MS4s to involve the public in the development, implementation, and review of an MS4's stormwater management program.
3. **Illicit Discharge Detection & Elimination**—BMPs for identifying and eliminating illicit discharges and spills to storm drain systems.
4. **Construction**—BMPs for MS4s and construction site operators to address stormwater runoff from active construction sites.
5. **Post-construction**—BMPs for MS4s, developers, and property owners to address stormwater runoff after construction activities have completed.
6. **Pollution Prevention/Good Housekeeping**—BMPs for MS4s to address stormwater runoff from their own facilities and activities.

To support NPDES efforts, the US EPA has been maintaining a National Menu of Best Management Practices (BMPs) for Stormwater Phase II, first released in October 2000. This Menu of BMPs (http://cfpub.epa.gov/npdes/stormwater/menuofbmps/) is organized based on the Stormwater Phase II Rule's six minimum control measures.

More information on NPDES is available at: http://cfpub.epa.gov/npdes/

The Iowa Department of Natural Resources (DNR) manages the NPDES program in the State of Iowa (http://www.iowadnr.gov/InsideDNR/RegulatoryWater.aspx).

In the Fourmile Creek Watershed, the NPDES regulations work to protect water quality by providing framework to manage and reduce stormwater pollution. For example, construction sites where more than one acre of soil is being disturbed are monitored in order to ensure erosion and sediment control. These activities are required to develop and implement a Stormwater Pollution Prevention Plan (SWPPP) that needs to include the practices to be used. These regulations only apply to point sources of pollution. Therefore, agricultural activities are exempt as they are not considered a point source.

5.1.2.2 National Flood Insurance Program (NFIP)

The National Flood Insurance Program was created by the United States Congress in 1968. The program, which is administered by the Federal Emergency Management Agency (FEMA), assesses flood risk for specific properties and offers flood insurance for owners and renters. To qualify for flood insurance, your community must join the NFIP and agree to enforce floodplain management standards. Higher standards that a community must adopt when joining the NFIP include but are not limited to: establishing a floodway, requiring setbacks from river channels and requiring buildings to be elevated above the 1-percent-annual-chance flood.

5.1.2.3 Local Stormwater Regulations

The stormwater related regulations for local jurisdictions vary widely in the watershed. For instance, Des Moines has adopted the 1.25” water quality volume as a requirement for all new development and redevelopment (detained and released over a 24-hour period) while other jurisdictions in the watershed have no specific requirements. Understanding the local regulations is important when looking at a watershed approach to solving stormwater issues. Table 5.1 and Table 5.2 summarize the local stormwater requirements for each jurisdiction in the watershed. Note, however, there are some exceptions where detention may not be required, such as downtown Des Moines. Some of the regulations refer to “pre-developed” conditions, which in the Fourmile Creek Watershed can often refer to row-crop land use and not the pre-settlement prairie conditions.

Table 5.1: Local stormwater regulations for residential development

Jurisdiction	Water Quality Volume	Stormwater Detention
	Provide treatment for rainfalls up to 1.25 inches.	Detention of 100-yr post development flow rate to 5-yr pre-developed flow rate
Alleman	No Requirement	No Requirement
Ankeny	No Requirement	No Requirement
Altoona	No Requirement	Required
Bondurant	No Requirement	No Requirement
Boone County	No Requirement	No Requirement
Des Moines	Required	Required
Elkhart	No Requirement	No Requirement
Pleasant Hill	No Requirement	Required
Polk County	No Requirement	No Requirement
Sheldahl	No Requirement	No Requirement
Slater	No Requirement	No Requirement
Story County	Required	Required

Table 5.2: Local stormwater regulations for commercial development

Jurisdiction	Water Quality Volume	Stormwater Detention
	Provide treatment for rainfalls up to 1.25 inches.	Detention of 100-yr post development flow rate to 5-yr pre-developed flow rate
Alleman	No Requirement	Required
Ankeny	No Requirement	Required
Altoona	No Requirement	Required
Bondurant	No Requirement	Required
Boone County	No Requirement	No Requirement
Des Moines	Required	Required
Elkhart	No Requirement	Required
Pleasant Hill	No Requirement	Required
Polk County	No Requirement	Required
Sheldahl	No Requirement	No Requirement
Slater	No Requirement	Required
Story County	Required	Required

5.1.3 Sustainable Approaches

Many names have been used in Iowa and nation-wide to describe and promote sustainable watershed and stormwater management. These approaches and concepts are also applicable in the Fourmile Creek Watershed, such as to foster safer communities and healthier streams and environments. A few of these approaches are summarized below, which are also available on the internet together with other vast resources on stormwater management.

5.1.3.1 Iowa Smart Planning

The Iowa Smart Planning act was signed into law in the spring of 2010. The act contains three main components that require communities and state agencies to consider Smart Planning Principles when planning for the future, as listed in Table 5.3.

Table 5.3: Iowa Smart Planning

Principles of the Iowa Smart Planning Act	
1	Establishes ten Iowa Smart Planning Principles for application in local comprehensive plan development and public investment decision making.
2	Provides comprehensive planning guidance for cities and counties.
3	Establishes the Iowa Smart Planning Task Force.

5.1.3.2 EPA Smart Growth

"Smart growth" covers a range of development and conservation strategies that help protect our natural environment and make our communities more attractive, economically stronger, and more socially diverse. The EPA smart growth program helps communities improve their development practices to promote their desired type of development. Through this program, the EPA works with local, state, and national experts to discover and encourage successful, environmentally sensitive, development strategies. Smart growth principles are listed in Table 5.4.

Table 5.4: Smart Growth

Smart Growth Principles	
1	Mixed land uses
2	Take advantage of compact building design
3	Create a range of housing options and choices
4	Create walkable neighborhoods
5	Foster distinctive, attractive communities with a strong sense of place
6	Preserve Open space, farmland, natural beauty, and critical environmental areas
7	Strengthen and direct development towards existing communities
8	Provide a variety of transportation choices
9	Make development decisions predictable, fair, and cost effective
10	Encourage community and stakeholder collaboration in development decisions

For more information on the Smart Growth program see http://www.epa.gov/dced/index.htm.

5.1.3.3 EPA Healthy Watersheds

EPA's Healthy Watersheds Initiative was created to protect the nation's remaining healthy watersheds, prevent them from becoming impaired, and to accelerate restoration of impaired watersheds. The healthy watersheds conceptual framework encourages interested parties to take a strategic and holistic approach to watershed assessment and protection that recognizes the dynamics and interconnected nature of aquatic ecosystems. Watersheds are practical management units to integrate ecological functions and uses of the landscape with the resulting quality of the natural and human environment. Watershed functions and attributes, for example, define the flow response in our streams to precipitation volume and distribution, thus affecting the magnitude of floods as well as low flows that sustain the aquatic ecosystem and the quality of water. Healthy Watersheds Program goals and objectives are included in Table 5.5 and key elements in Table 5.6.

Table 5.5: Healthy Watersheds Program Goals and Objectives

Goal 1	Identify, protect, and maintain a network of healthy watersheds and supportive green infrastructure habitat networks across the United States.
Goal 2	Integrate protection of healthy watersheds into EPA programs.
Goal 3	Increase awareness and understanding of the importance of protecting our remaining healthy watersheds and the range of management actions needed to protect and avoid adverse impacts to those healthy watersheds.

Table 5.6: Healthy Watersheds Program Key Elements

1	Establish partnerships to identify and implement protection of healthy watersheds.
2	Identify healthy watersheds and intact components of altered watersheds state-wide through integrated assessments.
3	Implement state-wide strategic protection plans and programs based on vulnerability and other opportunities.
4	Implement local protection programs based on priorities from state and local assessments.
5	Provide information to inform ecological recoverability and help set priorities for restoration of impaired waters.
6	Provide information to the public on healthy watersheds, including the socio-economic benefits of their protection.

For more information on the EPA's Healthy Watersheds Program see:
http://water.epa.gov/polwaste/nps/watershed/index.cfm

5.1.3.4 Bluebelts

Bluebelts are the interconnected corridors defined by areas where site conditions adverse to development (steep slopes, hydric soils, and periodic flooding) intersect with desirable resources to protect (wetlands, stream corridors, and quality open spaces). These areas may seem similar to greenbelt parks but have a different focus related to habitat protection and both the conveyance and treatment of stormwater. In the past, these areas would have typically been the responsibility of private landowners. Often these areas become overgrown with trees and brush and are prone to streambank erosion. Lack of maintenance in these critical areas can result in reduced stormwater conveyance during flood events.

The City of Ankeny defined their Bluebelt areas in their 2010 Comprehensive Plan with the desire to achieve the goals listed in Table 5.7.

Table 5.7: Goals of Ankeny's "Bluebelts" Program

1	Provide a safe path of conveyance up to the 500-year flood event
2	Construct improvements that provide rainwater management for small and large storms
3	Prevent extensive narrowing or channelization of the stream corridor
4	Promote landscapes and design feature that are resistant to bank erosion
5	Install features that provide a quality, balanced habitat for wildlife
6	Provide access for recreation and long-term maintenance

5.1.3.5 Multi-Objective Stormwater Management

Integrating stormwater treatment for water quality, channel protection, and flood control is becoming an important strategy in sustainable stormwater management. This means that stormwater systems need to perform for a range of storms and conditions, such as to optimize the capture and treatment of stormwater pollutants from the "first flush" or small frequent storms, as well as to achieve the objectives of reducing downstream impacts to stream channels and infrastructure vulnerable to flooding. This includes a combination of practices that seek to control runoff volume and peak flows.

5.1.4 Stormwater Management Resources

There are numerous resources to assist with the implementation of stormwater management practices. Several of the most utilized by the jurisdictions in the Fourmile Creek Watershed are outlined below.

5.1.4.1 Iowa Stormwater Management Manual

The Iowa Stormwater Management Manual produced by the Iowa Department of Natural Resources is a resource for stormwater management strategies. The manual provides information on: unified sizing criteria, low impact development, urban development, and design guidelines that protect water quality and reduce stream corridor erosion. The manual presents a unified sizing criteria approach for sizing stormwater BMPs to cover the entire range of stormwater flows in order to improve pollutant removal, maintain groundwater recharge, reduce channel erosion, prevent overbank flooding, and pass extreme floods. A main focus of the manual is infiltrating small rainfall events in order to protect water quality. Unified stormwater sizing criteria are summarized in Table 5.8, adapted from the Iowa Stormwater Management Manual.

Table 5.8: Unified stormwater sizing criteria adapted from the Iowa Stormwater Management Manual

Sizing Criteria	Recommended Method
Water Quality Volume, WQv	Treat the runoff from 90% of the storms that occurs in an average year. For Iowa, this equates to providing water quality treatment for the runoff resulting from a rainfall depth of 1.25 inches or less. Goal is to reduce average annual post-development total suspended solids loading by 80%.
Channel Protection Storage Volume, Cpv	Provide 24 hours of extended detention of the runoff from the 1 year 24 hour duration storm event to reduce bank-full flows and protect downstream channels from erosive velocities and unstable conditions.
Overbank Flood Protection, Qp	Provide peak discharge control of the 5 year storm event such that the post-development peak rate does not exceed the downstream conveyance capacity and/or cause overbank flooding in local urban watersheds. Some jurisdictions may require peak discharge control for the 2 year storm event.
Extreme Flood Protection, Qf	Evaluate the effects of the 100 year storm on the stormwater management system, adjacent property, and downstream facilities and property. Manage the impacts of the extreme storm event through detention controls and/or floodplain management. Reduce post-development 100 year peak flow to pre-development 5 year peak flow level or provide an overland flow corridor to a regional detention basin.

5.1.4.2 Statewide Urban Design and Specifications (SUDAS) Design Manual

The Statewide Urban Design and Specifications (SUDAS) Design Manual is another resource for engineers and planners in Iowa. Developed by numerous stakeholders across the state and maintained by the Institute for Transportation at Iowa State University, SUDAS has a wealth of stormwater management information. As an example, SUDAS stormwater detention release recommendations are summarized in Table 5.9.

Table 5.9: SUDAS stormwater detention release recommendations

1. **General:** The major storm drainage system should be designed to reduce the risk of substantial damage to the primary structure from stormwater runoff expected from the major storm The effects of the major storm on the minor drainage system should be noted.
2. **2 Year Pre-Developed:** After development, the release rate of runoff for rainfall events having an expected return frequency of two years should not exceed the existing, pre-developed peak runoff rate from that same storm.
3. **5 Year Pre-Developed:** For rainfall events having an expected return frequency of 5, 10, 25, 50, and 100 years, the rate of runoff from the developed site should not exceed the existing, pre-developed peak runoff from a 5 year frequency storm of the same duration. Allowable discharge rate may be restricted due to downstream capacity.
4. **Upstream Pass-Through:** Detention of runoff generated by upstream land is not required on the new development site. Release of runoff generated off-site and routed through the detention basin should not be made in such a manner as to increase the combined off-site and on-site release rate.
5. **Staged Discharge:** Because the allowable release rate varies depending on the storm frequency, multiple outlets or a multi-stage control structure may be necessary to comply with these requirements. This is especially true for sites with off-site pass through.

Source: Statewide Urban Design and Specifications (SUDAS) Design Manual (2013, Section 2G-1, pg.2)

5.1.4.3 Stormwater BMPs and Other Resources

Table 5.10 includes a list of selected resources for stormwater best management practices (BMPs), covering types, performance data, and implementation guidance and criteria. Many other sources of information are available through the internet and publications on stormwater. Practice names can vary; for example, rain gardens could be implicitly included as part of bioretention or infiltration/filtration practices, while some sources distinguish them by size or runoff source being treated (e.g., roof versus road/parking lot). Performance data, for example, support the fact that wet ponds yield, in general, higher nutrient removal than dry ponds (e.g., phosphorous treatment) in meeting water quality goals.

Table 5.10: Selected resources on stormwater best management practices (BMPs)

Resource	Description
Rainscaping Iowa **www.rainscapingiowa.org**	Rainscaping Iowa is a statewide educational campaign that promotes urban stormwater management practices to protect water quality and reduce runoff. Includes information/links to several practices, such as rain gardens, bioretention cells
Iowa Stormwater Management Manual (2009)	Iowa Stormwater Management Manual. Includes criteria and information about specific practices At Iowa DNR site: http://www.iowadnr.gov/Environment/WaterQuality/WatershedImprovement/WatershedBasics/Stormwater/StormwaterManual.aspx
Iowa DNR resources on stormwater	Links to several manuals (e.g., stormwater management, erosion control, rain gardens); loans; regulations. http://www.iowadnr.gov/Environment/WaterQuality/WatershedImprovement/WatershedBasics/Stormwater.aspx
US EPA National Menu of Stormwater Best Management Practices	US Environmental Protection Agency National Menu of Best Management Practices (BMPs) for addressing NPDES Stormwater Phase II Rule's six minimum control measures. http://cfpub.epa.gov/npdes/stormwater/menuofbmps/
International Stormwater Best Management Practices (BMP) Database	International Stormwater Best Management Practices (BMP) Database. Includes BMP studies, data, and performance analysis results. Started in 1996 under a cooperative agreement between the American Society of Civil Engineers (ASCE) and the US Environmental Protection Agency (USEPA); now with support and funding from a broad coalition of partners including the Water Environment Research Foundation (WERF), ASCE Environmental and Water Resources Institute (EWRI), USEPA, Federal Highway Administration (FHWA) and the American Public Works Association (APWA) Database maintained by Wright Water Engineers, Inc. and Geosyntec Consultants. www.bmpdatabase.org
Center for Watershed Protection (CWP) stormwater manuals and resources	The Center for Watershed Protection (CWP) maintains an on-line library of stormwater manuals, performance of practices, and other resources. For example, the Urban Subwatershed Restoration Manual Series with Manual 3 on retrofit practices and Manual 8 on pollution source control practices. http://www.cwp.org/online-watershed-library www.cwp.org

5.2 Stormwater Management Opportunities In Fourmile Creek Watershed

Many opportunities exist to manage stormwater more sustainably in the Fourmile Creek Watershed. Some of the opportunities that are highlighted in this section include:

- Preservation and Enhancement of Hydrologic Function of Landscape Features
- Opportunities in Rural Land Management
- Opportunities in Urban Land Management
- Opportunities in Land Development
- Opportunities for Stormwater Detention

5.2.1 Preservation and Enhancement of Hydrologic Function of Landscape Features

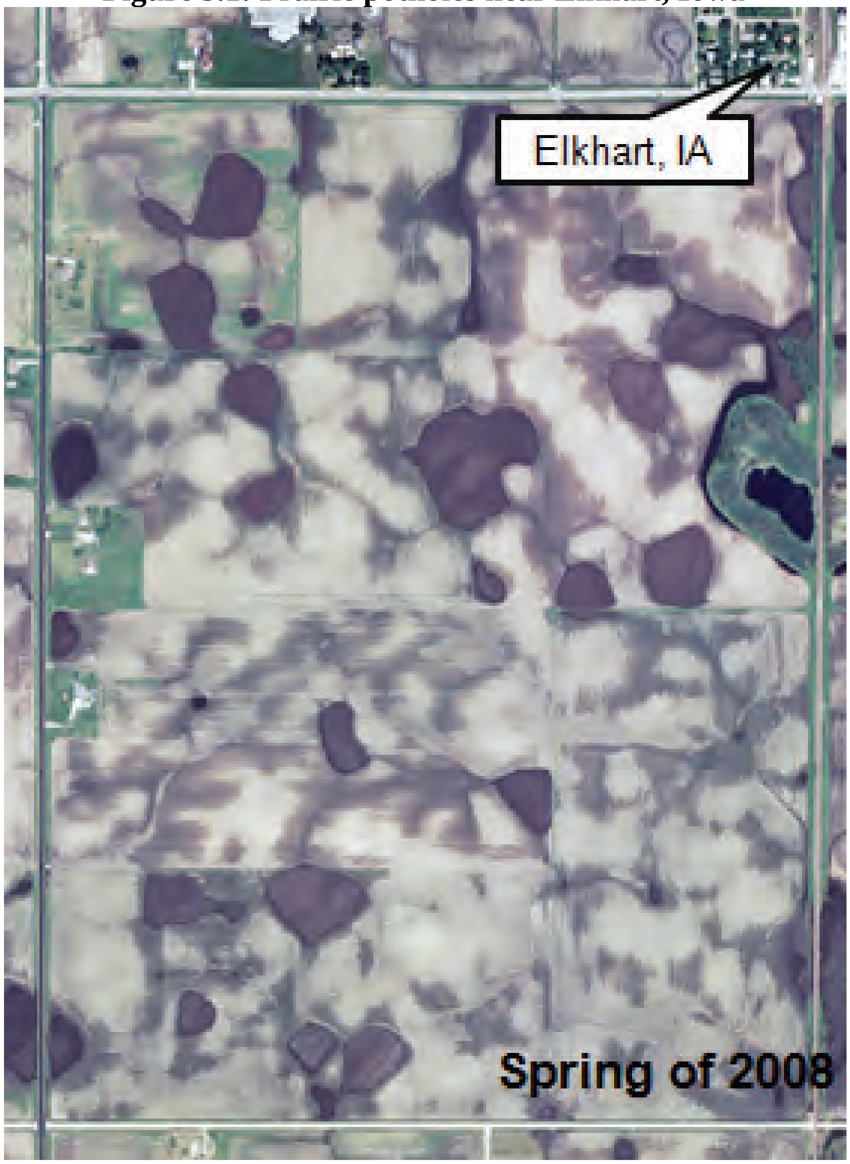
The hydrologic function of many landscape features can be preserved and enhanced, such as to mimic a more sustainable pre-settlement flow regime. Features that are highlighted include:

- Potholes, Depressional Storage, and Wetlands
- Stream buffers

5.2.1.1 Potholes, Depressional Storage, and Wetlands

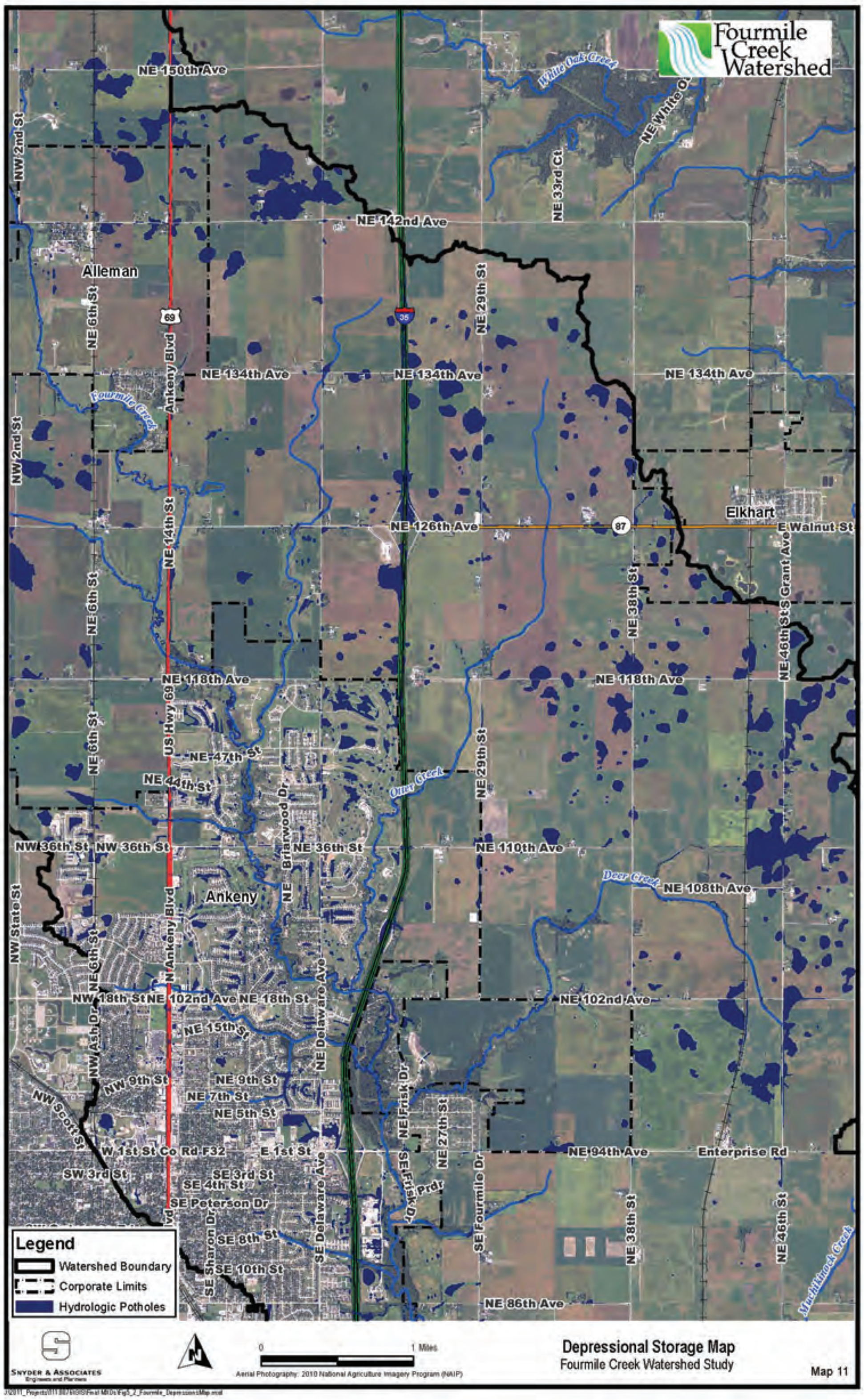
The Fourmile Creek Watershed is located near the southern terminus of the Des Moines Lobe. The Des Moines lobe was formed during the Wisconsin Glaciation between 12,000 and 15,000 years ago. As the ice sheets retreated, a poorly drained landscape with sporadic sand and gravel deposits was left behind. The large region of poorly drained land created by this recent glaciation is known as the prairie pothole region. The upper portion of the Fourmile Creek Watershed contains many traits indicative of the prairie pothole region, as illustrated in Figure 5.1 by the aerial photo taken in the spring of 2008 southwest of Elkhart, Iowa within the Fourmile Creek Watershed. The photo shows the numerous potholes of this region during a wet spring.

Figure 5.1: Prairie potholes near Elkhart, Iowa



In order to determine the pothole's effect on the watershed hydrology, Snyder & Associates located and measured the area of the potholes in the watershed using LiDAR data. Figure 5.2 is an example of potholes identified using LiDAR data. This figure also illustrates some of the depressions and ponds established by urban development. Using these data, prairie potholes were estimated to make up 3.5%-5% of the watershed area and provide 5,000 to 8,800 Ac-Ft of stormwater storage. This stormwater storage volume is equivalent to 0.9-1.4 inches of rainfall on the entire watershed—i.e., watershed inches.

Figure 5.2: Prairie potholes identified using LiDAR data



Prairie potholes and other depressional storage areas play a vital role in the watershed. These areas store tremendous amounts of stormwater during wet periods that would otherwise drain to the creek and contribute to flooding. It is important to maintain and enhance the function of the prairie potholes in the watershed. The best remaining prairie potholes should be considered for public ownership and possible wetland restoration. In addition to the hydrologic benefits wetlands provide, wetlands are rich in biodiversity and provide habitat to many animals including migratory waterfowl. Wetland creation, preservation, and enhancement projects should consider ecological goals in addition to stormwater management objectives. An example wetland mitigation project is shown below in Figure 5.3.

Figure 5.3: Example wetland mitigation project

Attempts should be made to have the basic hydrologic function of potholes and depressional storage maintained and preserved. When urban development expands into an area with prairie potholes, the development should be designed around the pothole, if possible. All efforts should be made to prevent the pothole from be graded out. Farm ponds can also be beneficial to the watershed. Farm ponds are able to attenuate high flows and provide water quality benefits as well.

5.2.1.2 Stream Buffers

Research has identified numerous benefits to protecting and restoring stream buffer areas. Buffers have been found to: increase groundwater infiltration, provide cooler water and air temperatures, decrease streambank erosion, filter sediments and pollutants commonly found in runoff, provide floodwater storage, increase wildlife habitat, and provide recreation areas. Currently, much of the Fourmile Creek corridor in agricultural areas has stream buffers on both sides of the creek. A potential area of improvement in the adoption of buffer strips would be along the many tributaries to Fourmile Creek as many of them do not have them. One of the most critical benefits of maintaining an undeveloped stream corridor is the reduction of flood risk by providing an unobstructed location for the conveyance of floodwater. Pleasant Hill, for example, has a stream buffer ordinance.

5.2.2 Opportunities in Rural Land Management

There are multiple types of opportunities to manage stormwater more sustainably in rural areas. While many practices have been established over many decades, many opportunities still exist to benefit, for example, agricultural production as well as healthy watershed objectives. Practices can range from soil quality restoration (e.g., no-till, cover crops) to establishing buffers (e.g., stream and field buffers, prairie restoration) or other stormwater management infrastructure (e.g., ponds, wetland restoration). The primary goals of these practices would be to support productive land uses while optimizing to improve water quality and reduce peak flows.

5.2.2.1 Conservation Farming

Soil and water conservation efforts since the 1930s have contributed to more sustainable agricultural practices throughout the Midwest. This can be observed in Fourmile Creek Watershed in many established practices that owners have adopted with support of the NRCS and the Soil and Water Conservation Districts (SWCDs), such as grassed waterways, terracing, and ponds. Many programs are available to support sustainable agricultural production with the implementation of conservation farming practices.

Currently, the majority of the Fourmile Creek Watershed rural area is intensively row cropped. Because of this fact, additional conservation practices should be incorporated into farming practices whenever possible. There are many conservation practices that are proven to help protect water quality and quantity. The NRCS and the Polk Soil and Water Conservation District are great resources for further information; some of the resources are also listed later in the report.

Based on NRCS and SWCD experiences in the watershed, the recommended conservation farming practices include:

- No-Till
- Buffer Strips
- Cover Crops
- Terracing

Many other conservation practices can be used, depending on the interest of the land owners, and may include establishing farm ponds, wetland restorations, or wildlife habitats. Practices like comprehensive nutrient management and drainage water management can also help improve water quality in Fourmile Creek.

5.2.2.2 Modeling of Rural Conservation Practices

The benefit of rural conservation practices was modeled utilizing the hydrologic and hydraulic models to determine their impact on stormwater management. To accomplish this, curve numbers for cropland areas were modified in order to simulate the widespread use of buffer strips, terracing, and wetland restoration. The sum change in curve numbers under this opportunity corresponds to approximately 10% of row cropped land to a tall grass prairie condition.

The results are summarized below in Table 5.11. The implementation of rural conservation practices reduces the 100-yr peak flow rate from 12,300 cfs with the "do nothing" future conditions model to 11,800 cfs at Easton Boulevard. This results in a flow ratio with respect to the current model of 1.04 at Easton Boulevard.

Table 5.11: Rural conservation modeling results

		100-yr Peak Flow rates (cfs)		Flow Ratio with respect to current model	
Land use	**Model**	**NE 86th Ave.**	**Easton Blvd.**	**NE 86th Ave.**	**Easton Blvd.**
Current	Current Model	6,100	11,300	1.00	1.00
Future	Future Model	6,300	12,300	1.03	1.09
Future	Rural Conservation	6,000	11,800	0.98	1.04

5.2.3 Opportunities in Urban Land Management

There are multiple types of opportunities to manage stormwater more sustainably in urban areas. Opportunities range from simple landscaping and rainscaping techniques within residential lots, to retrofits of existing infrastructure (e.g., ponds, ditches, waterways). The primary goals of these practices would be to optimize water quality and reduce peak flow.

5.2.3.1 Non-Structural Improvement Opportunities

Many stormwater BMPs are low cost and easy to implement. These types of improvements can be utilized by property owners at the individual lot level, and are appropriate for both residential and commercial properties. Examples of these BMPs are:

- Native turf
- Native landscaping
- Rainwater harvesting
- Rain gardens
- Soil quality restoration

Figure 5.4: Example of a rain garden

Many resources are available to understand, select, and implement these practices, including on-line internet resources and information from local cities and the local Soil and Water Conservation District (SWCD). One particularly useful resource is Rainscaping Iowa (www.rainscapingiowa.org), which offers detailed information for the BMPs listed above.

Funding for these types of improvements is also available to property owners on a limited basis through the Cities of Des Moines and Ankeny as well as the Polk County Soil and Water Conservation District.

5.2.3.2 Structural Improvement Opportunities

Opportunities also exist for retrofits that optimize existing stormwater infrastructure. These opportunities may be particularly beneficial in areas with more impervious surfaces. Examples include:

- Creating bioretention units to treat runoff from large impervious surfaces such as roads and parking lots.
- Optimizing existing stormwater detention ponds for water quality, channel protection, and peak flow reduction.

A local example of such a project can be found at Summerbrook Park in Ankeny, Iowa. The City of Ankeny created bioretention units to collect and treat runoff from SE Delaware Avenue. These bioretention units seen below are useful tools for improving water quality and reducing peak flows. Many resources are available to help interested parties understand, select, and implement these practices.

Figure 5.5: Bioretention units at Summerbrook Park in Ankeny

5.2.4 Opportunities in Land Development

The Fourmile Creek Watershed, prior to settlement, would have been dominated by tall-grass prairies and pothole wetlands, particularly in the upper watershed. The deep roots of the plants in these prairies would have absorbed much of the rainfall. As settlement occurred, prairies were tilled, agricultural tiles were installed, and drainage paths were straightened. Over time, this has resulted in bank erosion and widening of streams. These symptoms have recently been even more noticeable due to the trend toward increased rainfall.

An understanding of the pre-settlement condition is important when looking at the impacts of land development on stormwater runoff, especially when looking at the standards with which the development is allowed to occur. Most jurisdictions and developments require the runoff from a development to mimic the pre-development runoff conditions. This has traditionally been defined as looking at the land based on agricultural development. As noted above, the volume of runoff increased as agricultural uses dominated the landscape due to the removal of deep rooted prairie plants and the installation of drainage tiles. Changing the definition for stormwater hydrology from pre-development to pre-settlement would promote both an improvement in water quality and a reduction in flood related volumes. While this may not be possible for all developments, it is a much more sustainable urban development approach and should be considered for all developments.

Land development needs to learn from previous developments by consider opportunities to reduce future issues and cost associated with protecting and maintaining infrastructure. For example, the Brook Run Development in Des Moines is now affecting the neighborhood association, who is dealing with properties that encroach into the stream corridor and have buildings that are at increased risk from streambank erosion as illustrated in Figure 5.6. This association is facing the challenge of financing stream stabilization, as well as the maintenance of ponds that are filling with sediment.

Figure 5.6: Brook Run development

5.2.4.1 Sustainable Urban Development Approaches

Sustainable land use and stormwater management approaches and techniques have been promoted using many names, such as Smart growth, Low Impact Development (LID), Better Site Design, and Green Infrastructure. These approaches have in essence the common objective of managing the urban land and stormwater to have healthier watersheds and ecosystems, and reduce environmental impacts associated with urban land use. As discussed above, theses approaches aim at reducing runoff volume and peak flow to mimic pre-settlement hydrology.

For the purpose of this report, these sustainable urban development approaches are referred to as Low Impact Development (LID). The EPA (2007) and others cover the benefits of low impact development approaches in reducing stormwater treatment costs. For example, reducing impervious surfaces through narrower streets and establishing rain gardens or bioretention units can help reduce costs in storm sewer conveyance systems (e.g., culverts). The principle is that it is less expensive to control runoff and pollution at the source (where rain falls), than at the end of the pipe. However, many stormwater practices implemented through low impact development that are adequate to achieve water quality goals do not necessarily achieve extreme flood protection, as needed in the Fourmile Creek Watershed. That is, larger stormwater detention facilities (or oversized bioretention systems) are often still necessary to achieve flood protection goals.

5.2.4.2 Modeling of Low Impact Development (LID)

Low impact development is a design approach applied to urban areas that mimics the way that the natural environment stores and infiltrates stormwater. LID decreases risk of flooding and streambank erosion by reducing stormwater runoff volumes and peak flow rates. Examples of commonly applied low impact development practices include vegetated filter strips, bioretention swales, rain barrels, cisterns, narrower streets and pervious pavement.
Future land use maps were used to model all areas of future development in the Fourmile Creek watershed as if they incorporated a moderate level of low impact practices into their development. The period for future development analyzed under this option was through the year 2030. Reductions in curve numbers were chosen that represented combinations of LID practices, such as impervious surface reduction in conjunction with bioretention systems.

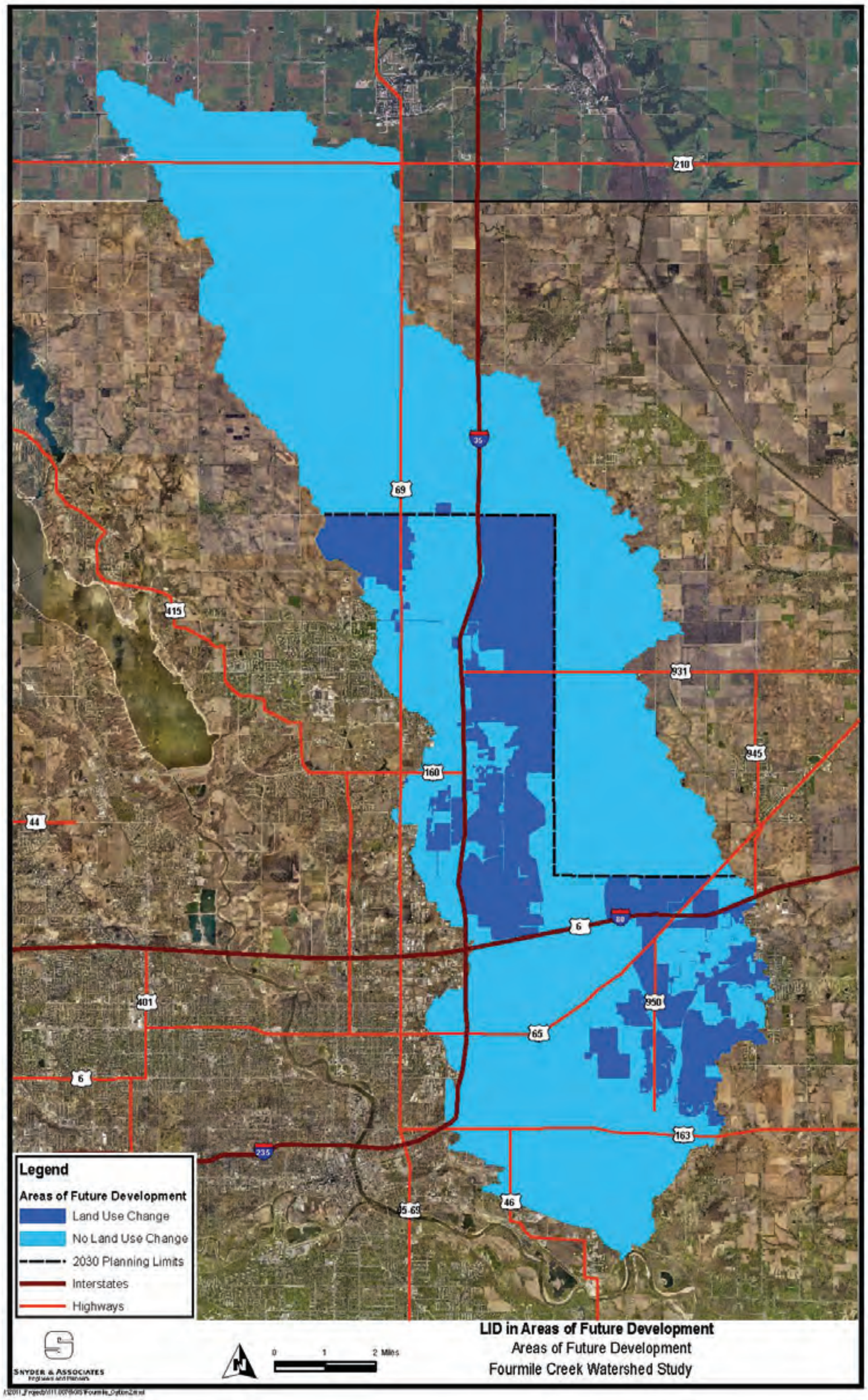
Table 5.12 compares standard curve numbers with the curve numbers used to model LID.

Table 5.12: LID curve numbers

Land Use	Standard CN	LID CN
High Density Residential District	84	81
Light Industrial District	82	80
Medium Density Residential District	80	78
Park, Open Space or Floodway District	69	68
Single Family Residential District	75	73
Civic	82	80
Condominium	85	82
Duplex/Bi-attached	85	82
Golf Course	70	69
Government-ROW	85	82
Office	85	82
Parks and Recreation	69	68
Retail/Commercial	92	89
School	88	85
Single Family Residential	72	71
Heavy Industrial District	94	90
Townhomes	85	82
Vacant	72	71
Agricultural District - Cropland	72	71
Agricultural District - Grassland/Pasture	58	x
Agricultural District - Rural Developed	74	x
Agricultural District - Water	98	x
Agricultural District - Woodland	60	x

Figure 5.7 shows in dark blue shading, the areas of future development modeled as LID.

Figure 5.7: Future development areas modeled as LID



The modeling results are summarized in Table 5.13. This modeling indicates the 100-yr peak flow rate could be reduced from 12,300 cfs with the "do nothing" future conditions model to 10,900 cfs at Easton Boulevard resulting in a flow ratio with respect to the current conditions model of 0.96 at Easton Boulevard.

Table 5.13: Potential benefit of low impact development

		100-yr Peak Flow rates (cfs)		Flow Ratio with respect to current model	
Land use	**Model**	**NE 86th Ave.**	**Easton Blvd.**	**NE 86th Ave.**	**Easton Blvd.**
Current	Current Model	6,100	11,300	1.00	1.00
Future	Future Model	6,300	12,300	1.03	1.09
Future	Low Impact Development	6,200	10,900	1.02	0.96

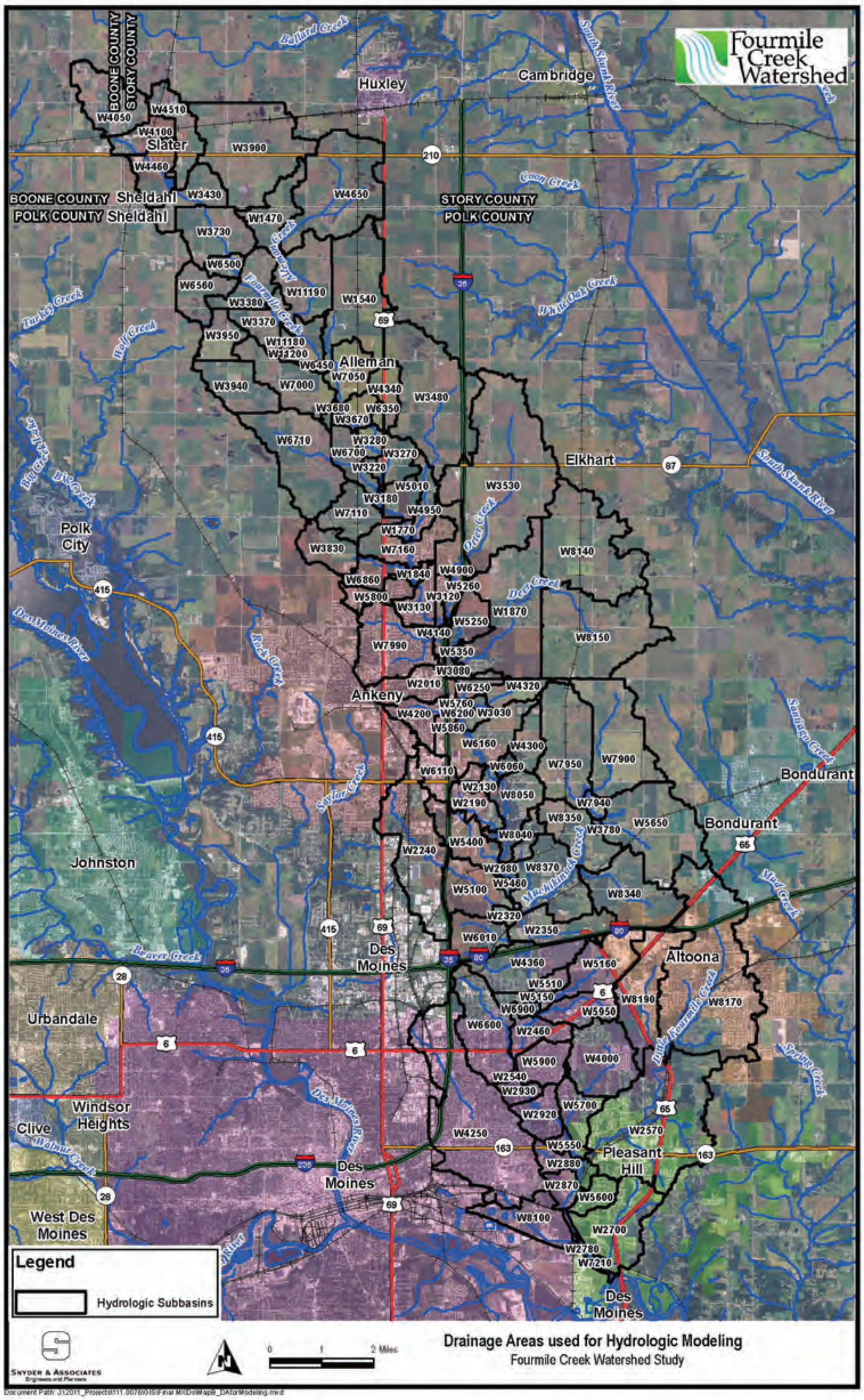
5.2.4.3 Modeling of Development Ponds

As noted previously, low impact development itself does not always mitigate the effects of the extreme flood (100 yr.) on existing waterways, particularly understanding the trend toward larger, more intense rainfall events. Future development in the watershed should be planned in a manner that reduces the peak flow rate of stormwater during precipitation events. Currently, some jurisdictions require certain types of development to reduce the post-development 100-yr peak flow rate to a level equal to or less than the pre-development 5-yr peak flow rate. The use of this criterion was explored for all future development, including future residential development. Modeling results indicate this criterion is an effective way to lessen the impacts of extreme flood events. Depending on the specific characteristics of the site, this reduction generally amounts to 70-85% peak flow attenuation of the 100-yr flow leaving the site in the Fourmile Creek watershed. All land use types of future development in the watershed should use this as a guideline for extreme flood protection. An example that shows how this detention requirement varies for different watershed size is provided in Table 5.14. Additionally, a map of watershed subbasins is provided in Figure 5.8. Note, this criterion equates to providing about 3 or more watershed inches of storage. The actual storage requirement would depend on future land use density, as well as what other stormwater practices are used (e.g., LID approaches) to meet multi-objective sustainable stormwater goals.

Table 5.14: Example detention requirement

Watershed	Area (Ac)	Pre-Development 5-yr (cfs)	Post-Development 100-yr (cfs)	Treated Future 100-yr (cfs)	Attenuation %	Storage Volume (Ac-Ft)	Storage Volume as Watershed Depth (in)
W6300	68	25	139	28	80%	17	2.94
W6060	95	18	113	19	83%	22	2.75
W1770	98	29	147	26	82%	25	3.01
W2130	116	75	245	68	72%	34	3.49
W3080	148	69	242	65	73%	38	3.07

Figure 5.8: Drainage areas used for hydrologic modeling



5.2.5 Opportunities for Stormwater Detention

Many stormwater detention options can be implemented though out the watershed, ranging from small farm or "development" ponds to larger reservoirs. This section focuses on exploring the opportunities for regional stormwater facilities to reduce flood risk. The type of detention can be designed based on objectives and site-specific conditions, which could include a wet pond (permanent water pool) or a dry pond.

5.2.5.1 Modeling of Large Reservoir

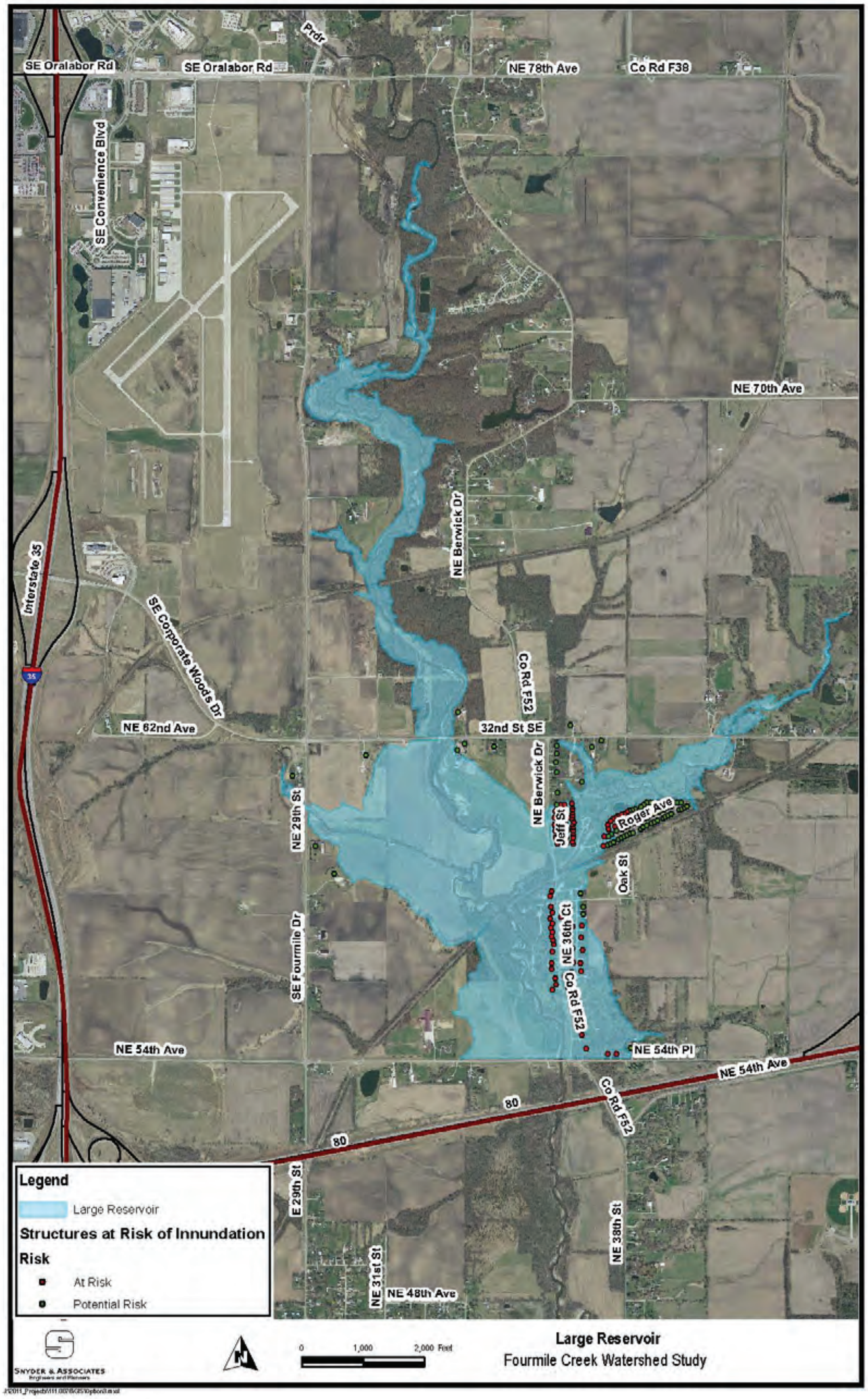
At previous public meetings, Snyder & Associates heard many citizens suggest they would like to see one of our stormwater management alternatives be a large reservoir located upstream of the City of Des Moines and the City of Pleasant Hill to provide flood protection. An investigation of this idea was completed to compare with the utilization of multiple smaller basins

This reservoir was sized to provide sufficient storage to attenuate the future 100-year flow rate of 12,300 cfs at Easton Boulevard to a level less than the current 10-year flow rate of 4,700 cfs. The simulated reservoir modeled met this goal by storing 5,700 Ac-Ft of water and reducing the 100-year peak flow rate to 4,375 cfs at Easton Boulevard.

In the hydrologic model of this option, the reservoir was located just north of NE 54th Avenue. This location enables the reservoir to provide a level of protection to the City of Des Moines, the City of Pleasant Hill, and the unincorporated area known as Norwoodville. If the reservoir were to be located farther north, it would not be able to collect and attenuate the flow of Muchikinock Creek. In order to achieve a desirable reduction of peak flow rate at Easton Boulevard with only one reservoir, the reservoir would need to be located to include the nearly 12 square mile Muchikinock Creek Watershed.

While this option would be successful in reducing flooding in the Cities of Des Moines and Pleasant Hill, it would flood a large amount of land near the unincorporated area known as Berwick as shown in Figure 5.9. Additionally, to accommodate the reservoir, at least 48 homes in the Berwick neighborhood and 120 homes in the Sunny Brook Mobile Home Park would need to be purchased. The number of homes that would need to be acquired to build a large reservoir, in addition to the environmental impacts of the reservoir itself, make the project unfeasible.

Figure 5.9: Large reservoir



One large basin upstream of Des Moines can reduce the 100-yr peak flow rate from 12,300 cfs with the "do nothing" future conditions model to 4,400 cfs at Easton Boulevard. This results in a flow ratio with respect to the future model of 0.39 at Easton Boulevard. Results for this option are summarized in Table 5.15.

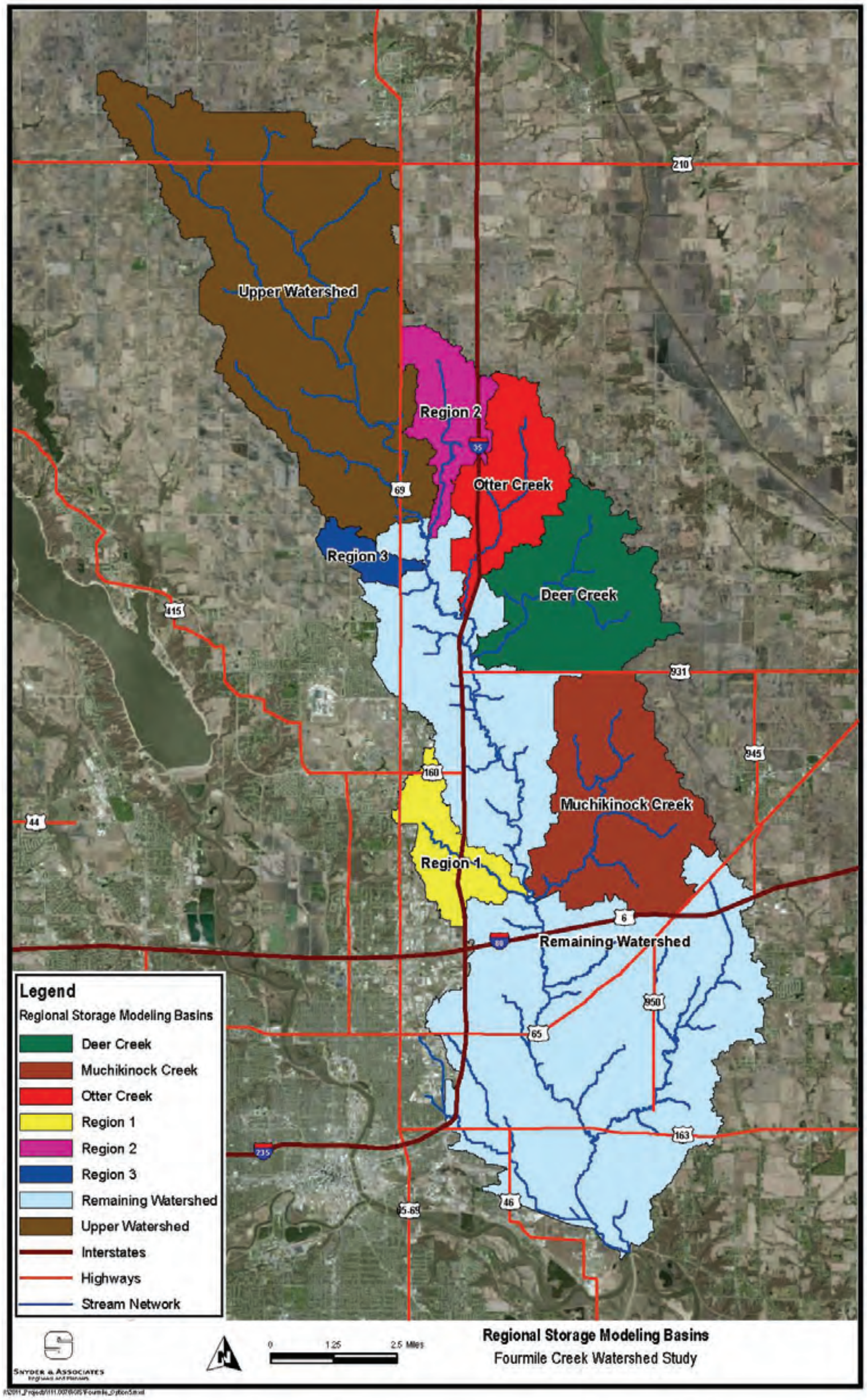
Table 5.15: Large reservoir modeling results

		100-yr Peak Flowrates (cfs)		Flow Ratio with respect to current model	
Landuse	**Model**	**NE 86th Ave.**	**Easton Blvd.**	**NE 86th Ave.**	**Easton Blvd.**
Current	Current Model	6,100	11,300	1.00	1.00
Future	Future Model	6,300	12,300	1.03	1.09
Future	Large Reservoir	6,300	4,400	1.03	0.39

5.2.5.2 Modeling of Regional Detention

The alternative to one large basin is having multiple regional stormwater detention basins throughout the watershed. Basins were placed in the hydrologic model at key locations where regional tributaries enter Fourmile Creek. Seven separate watersheds were identified as places for potential stormwater detention in this analysis. These seven watersheds were chosen in part because they are all areas in which development will occur within the planning period. The fact these seven watersheds are not fully developed allows for potential stormwater retention projects. A map of regional watersheds analyzed is shown in Figure 5.10.

Figure 5.10: Regional watersheds



The seven regions used in this analysis range in size from 1 to nearly 31 square miles. Table 5.16 includes the watershed size, current 100-yr, and future 100-yr peak flow rates for each region. These include both existing (2010) and future (2030) conditions.

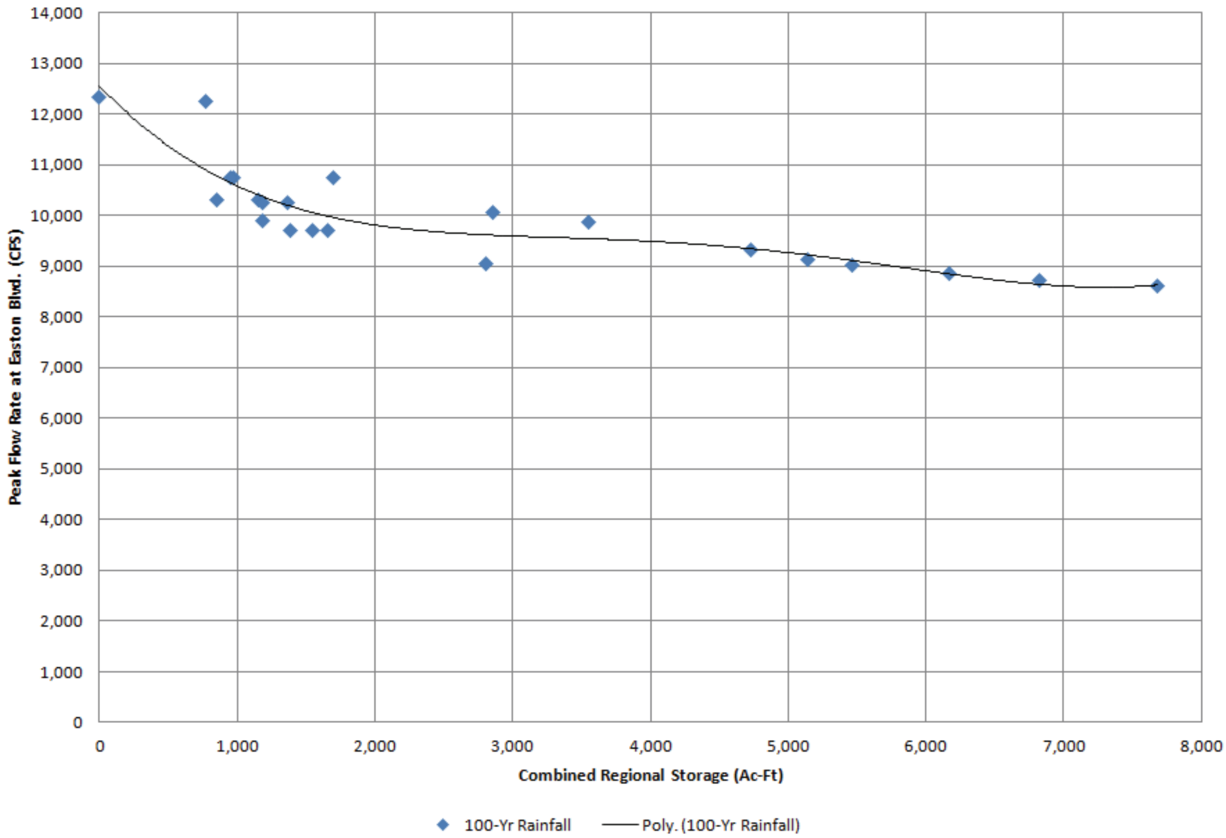
Table 5.16: Sub watershed flow data

		100-yr Peak Flowrates (cfs)		
Region	Region Area (Sq. Mi.)	Current	Future	With Regional Detention
Otter Creek	6.01	1,200	1,200	900
Muchikinock Creek	11.68	2,900	3,200	1,800
Deer Creek	9.53	700	900	500
Upper	30.97	3,300	3,300	3,000
1	3.69	1,600	1,600	800
2	4.03	800	800	700
3	1.27	600	800	200

A model was developed in order to estimate the generic stormwater storage in a region necessary to achieve varying degrees of peak flow reduction. Regional storage does not have to consist of one large basin but rather can be achieved in many ways. Examples of possible storage configurations include but are not limited to: one large basin, a few small basins combined with wetland restoration or the use of development ponds.

The regional storage reservoirs were modeled across a range of sizes in order to understand the relationship between peak flow rates at Easton Boulevard in Des Moines and the combined regional storage in the upstream watershed. The greatest reduction in peak flow rate was achieved with over 7,600 Ac-Ft of combined storage between the seven regional reservoirs. However, the combined regional storage volume began to produce diminishing returns in peak flow reduction after approximately 2,000 Ac-Ft. As shown on the graph in Figure 5.11, the amount of flow rate reduction gets smaller with additional detention provided beyond 2,000 cfs. (i.e. the graphed line gets flatter).

Figure 5.11: Easton Boulevard peak flow rate relationship to detention storage provided



Results of the regional storage model under a moderate storage configuration (1,200 Ac-Ft) are summarized in Table 5.17. The regional storage model reduces the 100-yr peak flow rate from 12,300 cfs with the "do nothing" future conditions model to 10,300 cfs at Easton Boulevard. The regional storage model results in a flow ratio with respect to the current model of 0.91 at Easton Boulevard.

Table 5.17: Regional storage modeling results

		100-yr Peak Flowrates (cfs)		Flow Ratio with respect to current model	
Landuse	**Model**	**NE 86th Ave.**	**Easton Blvd.**	**NE 86th Ave.**	**Easton Blvd.**
Current	Current Model	6,100	11,300	1.00	1.00
Future	Future Model	6,300	12,300	1.03	1.09
Future	Regional Storage	5,600	10,300	0.92	0.91

5.2.6 Integrating Stormwater Management Opportunities

No "silver bullet solution" was identified during this study to address the stormwater issues of the Fourmile Creek Watershed, particularly to reduce the risk of flooding. Based on the stormwater management assessment, an integrated approach that includes multiple practices throughout the watershed is needed. Urban and rural lands need to be managed sustainably as part of one integrating unit—the watershed. As small as it may seem, the multiplying effect of numerous small improvements is an opportunity to manage stormwater more sustainably and contribute to the health of the watershed and safety and quality of the human and natural environment. Another benefit is that more people can be educated about stormwater impacts and control methods, and become champions/stewards, when the facilities are encountered in their neighborhood.

6 STORMWATER MASTER PLAN

This chapter includes elements developed as part of the Fourmile Creek Watershed Study to foster a comprehensive and collaborative approach to sustainable stormwater management in this watershed. Summarized are the vision, guiding principles, goals, and institutional framework. In addition, to facilitate implementation and to enhance existing programs, the plan is organized into five core components and includes recommendations for implementation.

6.1 Vision

Through input received at public meetings and close communications with the technical advisory and steering committee, the following vision statement was developed.

> ***To foster land stewardship and sustainable watershed management that reduces flood risk, improves water quality, and supports socioeconomic and environmental functions.***

6.2 Guiding Principles

This stormwater master plan relies on these key and overarching guiding principles:

- **Healthy watershed stewardship approach—**encourages the use of watersheds as the practical management unit to integrate ecological functions and uses of the landscape so as to protect or improve the quality of the natural and human environment. This includes, for example, recognizing the ecological functions of the floodplain to protect water quality and aquatic habitat, as well as to reduce downstream flood impacts.
- **Sustainable land stewardship—**land is a precious resource and the sustainable use of each rural field and urban parcel are important to the health of the watershed, as well as preserving the quality of the land for generations to come. For example, good stewards of the land that preserve and enhance soil quality (good soil structure, organic matter, and biology) to serve productive and ecological functions, including water retention and reducing runoff that would otherwise exacerbate downstream flooding.
- **Stakeholder and multi-jurisdictional cooperation—**watershed issues and opportunities present a major challenge, particularly with our limited economic and financing resources, that require cooperative action between watershed stakeholders: property owners, cities, counties, and soil and water conservation districts. Cooperation is essential, particularly in stormwater management, to leverage limited resources and invest where the benefit is greater. For example, establishing and managing upstream vegetation in floodplain corridors can help reduce the need for more expensive measures downstream.

6.3 Goals

A watershed framework for setting and supporting goals is crucial because everyone in the watershed has a role and responsibility in stormwater management through sustainable land stewardship. For example, ponding water a few inches in backyard rain gardens can help reduce runoff peak flows and flooding of downstream homes.
Key stormwater management goals for the Fourmile Creek Watershed include:

Managing stormwater through sustainable land use stewardship is important to increasing safety and protecting infrastructure. Management should particularly aim at restoring healthy pre-settlement hydrology, while supporting the socioeconomic and environmental functions of the land.

6.4 Institutional Framework

An effective and sustainable institutional framework to support Fourmile Creek Watershed goals needs to:

- Strengthen the existing institutions (counties, cities, Soil and Water Conservation Districts, and others) to enhance and expand existing programs and services, such as:
  - stormwater outreach, education, and incentives.
  - planning and permitting for new developments or redevelopment.
  - implementation of stormwater practices as individual projects or as part of other public projects (street improvements; road crossings of streams; recreational areas, and others).

- Facilitate inter-institutional cooperation to promote, fund, and implement sustainable stormwater practices.

To meet these needs the Fourmile Creek Watershed Management Authority (FCWMA) was formed in September 2012 and is made up of the jurisdictions of Polk County, Story County, Boone County, City of Ankeny, City of Des Moines, City of Sheldahl, City of Slater, City of Alleman, City of Elkhart, City of Altoona, City of Bondurant, City of Pleasant Hill, Story County Soil and Water Conservation District, Boone County Soil and Water Conservation District, and Polk County Soil and Water Conservation District. The FCWMA has several charges as outlined by the Iowa Code including:

1. Assess the flood risks in the watershed.
2. Assess the water quality in the watershed.
3. Assess options for reducing flood risk and improving water quality in the watershed.
4. Monitor federal flood risk planning and activities.
5. Educate residents of the watershed area regarding water quality and flood risks.
6. Seek and allocate moneys made available to the Authority for purposes of water quality and flood mitigation.
7. Make and enter into contracts and agreements and execute all instruments necessary or incidental to the performance of the duties of the Authority. The Authority shall not acquire property by eminent domain.

As noted previously, the best way to develop and implement improvements to improve water quality and reduce flooding is on a watershed basis. The FCWMA will be the conduit for the recommendations from this report to be further evaluated, prioritized, and implemented. This is not to say the FCWMA is the regulatory body for stormwater items within the watershed. The 28E agreement between the members retains those powers for each individual jurisdiction. However, through additional education, working together, and implementation by the larger body of jurisdictions, the improvements in flood reduction and water quality will come to fruition much more quickly than with each jurisdiction working separately on these items.

6.5 Five Components

The stormwater management plan has been organized into five components:

While these organizational components seek to facilitate implementation, they need to also be integrated, such as where rural and urban land uses are intertwined and dynamic in time. The essence is to foster a programmatic approach to be practical and support existing institutional framework and programs.

6.5.1 Sustainable Rural Land Management

6.5.1.1 Description

Nearly 60% of the Fourmile Creek watershed is agricultural land. For this reason, it is important that a portion of the stormwater management plan address impacts from agricultural runoff. Producers and rural landowners within the watershed control the decisions made on the majority of the land within the watershed. Therefore, a critical component of this section of the plan is providing watershed education. By providing information to the landowners and explaining the challenges facing the watershed, we will be able to help make producers and landowners educated decision makers. Providing education will also introduce landowners to BMPs and conservation practices that may benefit their land as well as the watershed.

Conservation practices such as soil and wetland restoration also play a big part in this section of the stormwater management plan. Wetlands reduce flood risk and improve water quality by storing and treating water before it enters the creek. By identifying and restoring key wetlands, we may be able to make significant improvements to the health of Fourmile Creek. Additionally, healthy soil can store large amounts of water before becoming saturated and running off to a waterway. Restoring soil health is also important in reducing flood risk.

The strategies and recommendations outlined herein factor in the current regulatory environment in the State of Iowa and focus on voluntary improvements versus regulated improvements.

6.5.1.2 Strategies

The strategies noted below would assist in bringing the existing rural hydrology closer to the pre-settlement hydrology.

- **Provide watershed education.** Meet with homeowners, producers, and landowners to explain watershed issues and demonstrate best management practices.
- **Support existing programs for conservation farming practices.** A multitude of federal and state conservation programs are available to producers and landowners.
- **Enhance, restore, and create wetlands.** Wetlands are natural sponges that capture and store stormwater. They can help recharge groundwater supplies and remove pollutants from stormwater.
- **Maintain and enhance the hydrologic function of prairie potholes.** Prairie potholes in the upper reaches of the watershed are capable of storing tremendous amounts of water. These areas should be identified and maintained in order to prevent future increases in flood risk due to their removal.
- **Restore soil quality.** Soil rich in organic material is able to hold more water than soil that has been deteriorated. This reduces the amount of runoff reaching waterways after rainfall events and can be a valuable tool in reducing flood risk.
- **Establish multi-objective conservation areas with integrated environmental and recreational amenities.** Conservation areas such as lakes and wetlands can provide valuable stormwater storage in times of flooding while also being an environmental and recreational amenity to residents throughout the year.
- **Establish stream and environmental corridors.** In rural areas, these stream corridors would provide a buffer between row crops and the creek. Creating a corridor of native vegetation along Fourmile Creek and its tributaries will benefit the overall health and water quality of the creek as well as provide a designated floodplain during extreme flood events. These buffers can also provide some peakflow attenuation benefit, such as reducing water velocities in the floodplain.
- **Establish regional basins to achieve stormwater management goals.** Regional stormwater detention basins in rural areas can be created to reduce peak runoff from intensely farmed areas.

6.5.1.3 Tools

Promote implementation of practices that contribute to watershed goals, such as sustainably managing the land as stewards of water quality and water quantity.

Institutions that support the rural community with technical assistance and funding are shown in Table 6.1. Some of the potential agricultural programs, funding sources, and best management practices are listed in Table 6.2 and Table 6.3; some of the data and terms vary in time, so current program information should be used, particularly cost that is updated yearly.

Table 6.1: Institutional resources

Resource	Description
Natural Resource Conservation Service – Iowa **http://www.nrcs.usda.gov/wps/portal/nrcs/site/ia/home/**	The Iowa NRCS is an agency within the United States Department of Agriculture. The NRCS works with landowners through conservation planning and assistance designed to benefit the soil, water, air, plants, and animals that result in productive lands and healthy ecosystems.
Iowa Department of Agriculture and Land Stewardship (IDALS) **www.iowaagriculture.gov**	IDALS provides farmers with expertise and funds to help them install practices that preserve our highly productive soil, prevent erosion and protect our critical waterways.
Iowa State University Extension and Outreach – Agriculture **www.extension.iastate.edu/topic/agriculture**	Iowa State University Extension and Outreach works to serve the citizens of Iowa by applying research throughout the state.

Table 6.2: Potential agricultural programs and funding sources

Environmental Quality Incentives Program (EQIP)

- **Purpose:** A voluntary program provides financial and technical assistance to agricultural producers to help plan and implement conservation practices that address natural resource concerns.
- **Practices:** Cover Crops, No-till and Strip-till, Grade Stabilization Structures, Grassed Waterways, Terraces, Water and Sediment Control Basins, Drainage Water Management, Pasture Management, and other conservation practices.
- **Eligibility:** Owners and/or producers who are engaged in livestock, agricultural or forest production on private agricultural land with a natural resource concern.
- **Contract:** 1-3 year contracts with financial incentive payments based on a payment schedule.
- **Contact:** USDA-Natural Resources Conservation Service (NRCS), Polk Soil and Water Conservation District (SWCD)

Conservation Stewardship Program (CSP)

- **Purpose:** A voluntary program that encourages producers to address resource concerns by implementing additional conservation activities and maintaining existing conservation systems. It provides financial and technical assistance to conserve and enhance natural resources on the land.
- **Practices:** Annual payment based on conservation performance of existing system and new activities. Maximum annual payment is $40,000.
- **Eligibility:** Producers who are the operator of record in the USDA farm records management system and have control of the land for the contract period. Eligible land is cropland, pastureland, and nonindustrial forest land.
- **Contract:** 5 year contracts with annual stewardship payments.
- **Contact:** USDA-Natural Resources Conservation Service (NRCS), Polk Soil and Water Conservation District (SWCD)

Conservation Reserve Program (CRP)

- **Purpose:** A voluntary program to convert cropland to grass and/or trees to reduce erosion, increase wildlife habitat, improve water quality, and increase forestland.
- **Practices:** Filter Strips, Riparian Buffers, Farmable Wetlands and Buffers, Shallow Water Areas, Grassed Waterways, and other practices.
- **Eligibility:** Owners and/or producers on private agricultural land with a natural resource concern.

- **Contract:** 10 or 15 year contracts with financial incentive payments to establish cover. Annual rental payments based on soil types.
- **Contact:** USDA-Farm Service Agency (FSA), USDA-Natural Resources Conservation Service (NRCS), Polk Soil and Water Conservation District (SWCD)

Conservation Reserve Enhancement Program (CREP)

- **Purpose:** A voluntary program to develop wetlands which are strategically located and designed to remove nitrate from tile drainage water.
- **Practices:** Wetland restoration and conservation cover.
- **Eligibility:** Private landowners.
- **Contract:** Annual rental payment for up to 15 years plus an easement required for a minimum of 30 years with permanent easements offered as well. Also receive reimbursement for wetland and buffer establishment.
- **Contact:** USDA-Farm Service Agency (FSA), USDA-Natural Resources Conservation Service (NRCS), Polk Soil and Water Conservation District (SWCD)

Wetland Reserve Program (WRP)

- **Purpose:** A voluntary easement program to protect, restore, and enhance wetland functions and provide wildlife habitat.
- **Practices:** Wetland restoration and wildlife habitat establishment.
- **Eligibility:** Land which has been owned for seven years and can be restored to wetland conditions.
- **Contract:** Permanent easements, 30 year easements, or 10 year contracts
- **Contact:** USDA-Natural Resources Conservation Service (NRCS), Polk Soil and Water Conservation District (SWCD)

Table 6.3: Potential agricultural programs and best management practices

- Environmental Quality Incentive Program (EQIP) – a federal program that pays incentives to implement conservation practices.
    - Cover Crops - $24 -34/ac – increases soil organic matter which increases water infiltration and water holding capacity in the soil profile.
    - No-till and Strip-till - $18/ac - increases soil organic matter which increases water infiltration and water holding capacity in the soil profile.

- Drainage Water Management - $44-82/water control structure – manages the flow of water in subsurface drainage tile systems. Holds water in the soil profile.
- Grade Stabilization Structures-Earthen Embankment Dam- $1.36-1.97/cu yd – control gully erosion and provide temporary water storage.
- Water and Sediment Control Basins- $1.27-1.41/cu yd – traps sediment and provides temporary water storage.
- Terraces - $1.65-1.86/ foot – traps sediment and provides temporary water storage.
- Grassed Waterways - $1,560 – 2,540/acre – erosion control and filters runoff.

NOTE: Incentive payment rates are updated annually (2013 data).

- Iowa Financial Incentive Program – a state program that pays 50% cost share to implement conservation practices listed above.
- Conservation Reserve Program (CRP) – pays a rental rate based on the soil type to convert cropland to managed grass habitat for 10 or 15 years, and pays 50%-90% of practice implementation.
    - CP 27 and CP 28 – Farmable Wetland and Buffer – restore pothole wetlands that store water.
    - CP 9 – Shallow Water Areas – excavate shallow wetlands to store water.
    - CP 8A - Grassed Waterway - erosion control and filters runoff.
    - CP 21 and CP 22 – Filter Strips and Riparian Buffers – erosion control, filters runoff, and stabilizes streambanks.
- Conservation Reserve Enhancement Program (CREP) – constructed wetland below a large subsurface drainage system to treat the water. Stores water in the wetland. CREP includes a CRP payment and a 30-yr or permanent easement payment.
- Wetland Reserve Program (WRP) – a federal program to purchase permanent easements on land to restore wetlands that provide water storage areas.

6.5.1.4 Recommendations

Create a Fourmile Creek WMA technical and stakeholder committees on sustainable rural land management.

The membership of the technical committee for this study should continue to work on sustainable rural land management issues. This includes 12-15 members from local jurisdictions, state and federal agencies such as IDNR, IDALS, IDOT, USGS, and NRCS as well as representatives from the Iowa Flood Center and Iowa State University. Others can be added as desired. Their purpose would be to assist the FCWMA in the formulation of technical ideas into mutually agreeable education and prioritization of recommended improvements.

A stakeholder committee made up of property owners, agriculture groups, FCWMA members, and others as desired would be formed to further understand the impacts on Fourmile Creek and provide input to develop mutually agreeable recommendations. Part of this process would be to perform a social assessment to provide a background to set achievable goals. One thing to consider would be to provide additional funding to supplement existing conservation programs as an incentive to make them more economically competitive. These programs could then be reintroduced to area landowners and producers.

Annually measure the amount of conservation practices within the watershed.

A critical element of any initiative is having good data. The last time a detailed investigation of the level of participation in conservation practices in the Fourmile Creek Watershed was 2006. In 2013, there were approximately 500 acres of conservation practices in the watershed and one bioreactor for tile drainage nitrogen removal. These conservation acres include 300 acres of cover crops, 150 acres of strip till, and 32 acres of rotational grazing. Better data on types and amounts is needed. This could include tillage practices (i.e., no-till), conservation practices (i.e., buffer strips), and drainage tile. This will allow a baseline condition to be determined as well as a measure of the impact of educational material provided to property owners and producers.

Complete an assessment of prairie potholes and wetland areas and target highest priority areas for acquisition.

Prairie potholes and wetlands should be protected. An assessment of the existing resources would allow for the prioritization of key properties to be acquired for protection. This could be either by easement or fee title acquisition. These acquisitions could be sized and located to ultimately become a part of the Polk County Conservation Board park system. This would both protect critical water resources infrastructure while at the same time providing a multi-objective conservation area.

Provide staff to coordinate rural efforts.

Effort will be needed to complete the conservation measurements and educational elements. This could possibly be provided through a joint agreement with the NRCS.

6.5.2 Sustainable Urban Land Management

6.5.2.1 Description

In 2010, over 36% of the Fourmile Creek Watershed existed as urban area including industrial, commercial, residential, and institutional land uses. These developments vary from recently built businesses and subdivisions to 60-70 year old neighborhoods. The older of these areas were developed during a time period that lacked stormwater regulations and requirements. The more recently built areas may have been designed to meet some stormwater requirements, but the requirements vary depending on the jurisdictional area and the land use. What all of these areas share in common are impervious surfaces and an opportunity for improvement. This section of the stormwater management master plan describes practices that can be used to target improving stormwater management in urban areas. Small drainage network, vegetation, and soil retrofits can have a large impact on the overall health of the watershed.

6.5.2.2 Strategies

- **Promote sustainable landscaping.** Vegetation plays a large role in the hydrologic performance of a watershed. By incorporating native trees, shrubs, and grasses into a property you can increase rainfall interception and uptake which reduces runoff. The following are practices commonly used in sustainable landscaping:
  - Rain gardens, bioretention systems, bioswales
  - Tree and shrub plantings
  - Native plantings and ecologically-friendly systems
- **Restore soil quality.** Soil rich in organic material and nutrients is better able to store moisture and thereby reduces runoff.
- **Support existing institutional framework, programs, and capacities.** Analyze and implement voluntary stormwater retrofits. Some local municipalities and soil and water conservation districts already have programs in place.

6.5.2.3 Tools

Many stormwater best management practices are available for the sustainable land stewardship of urban environments. The practices can range from simple landscaping projects (e.g., aerating lawns, planting trees, installing a rain garden) to structural practices (e.g., water harvesting cisterns, bioretention units with drainage systems, ponds).

Table 5.10 includes a list of selected resources for stormwater best management practices, covering types, performance data, and implementation guidance and criteria.

Table 6.4 includes potential funding sources for urban BMPs. However, funding sources can be very diverse and change in time. Cities, SWCDs, and other institutions may also have incentive programs to support sustainable stormwater practices.

Table 6.4: Potential funding sources for urban BMPs

Program	Description
IDALS-Stormwater Best Management Practices Loans	Low interest loans for developers, landowners, watershed organizations, non-ms4 cities and others. Qualifying practices include: Infiltration practices, soil quality restoration, native landscaping; Detention basins; Pond / wetland system; Grassed waterways; Pervious concrete or asphalt, modular paving systems. For funding details see: http://www.iowaagriculture.gov/FieldServices/stormwaterBMPloans.asp or http://www.iowasrf.com/program/other_water_quality_programs/storm_water_management_best_practices.cfm
Iowa's Clean Water State Revolving Fund (CWSRF)	Low-interest loans to finance publicly owned wastewater treatment, sewer rehabilitation, replacement, and construction, and stormwater quality improvements. http://www.iowasrf.com/program/clean_water_loan_program/
Water Resource Restoration Sponsored Projects (via CWSRF)	"Water Resource Restoration Sponsored Projects" will help cities, watershed organizations, landowners and others address local water quality problems. Funded in conjunction with a SRF Loan for watershed protection practices such as stream buffers, wetland restoration and green infrastructure.
Local programs and incentives	Some jurisdictions and soil and water conservation districts offer local incentives. For example, Ankeny, Des Moines, and the Polk County Soil and Water Conservation District have grant opportunities for property owners to install BMPs.

6.5.2.4 Recommendations

Investigate locations for possible retrofits of existing infrastructure to optimize stormwater management.
Each jurisdiction should complete a review of their existing stormwater system, as time permits, to determine if there are any existing detention basins or other infrastructure that would be candidates for redesign to include management of the water quality volume. The inspection and analysis of existing infrastructure may yield simple retrofits that would optimize the performance of existing systems. It may be possible due to the configuration of the basin to construct modifications to the outlet structure of the basin to hold the 1.25” water quality volume. Also, there may be some older developments without detention that may have opportunities to install an improvement. Any modifications would need to be voluntary from the property owner unless city ordinances were changed to require these changes.

Work with property owners to implement the priority local matching grants or other incentives.
Ankeny, Des Moines, and the Polk County Soil and Water Conservation District have grant opportunities for property owners to install BMPs. These jurisdictions should continue to work with property owners to facilitate these improvements. Those jurisdictions without a program should consider implementing one. Other incentives can also be explored.

Continue to work with the Iowa Stormwater Education Program and local jurisdictions for educational opportunities.
Ankeny, Des Moines, Altoona, Pleasant Hill, and the Polk Soil and Water Conservation District are members of the Iowa Stormwater Education Program which provides quarterly programming, several certification programs, technical services, and workshop facilitation.

6.5.3 Sustainable Land Development

6.5.3.1 Description

The population of Fourmile Creek Watershed is increasing and nearly all the cities and towns within the watershed are experiencing growth. As described in section 4.2.3.1, as impervious area within a watershed increases, the watershed becomes “peaky” and flood risk and water quality concerns typically increase. As the population and urban area within the Fourmile Creek watershed grows, it will become increasingly important to utilize innovative and sustainable land development practices. Techniques for sustainable land development include minimizing impervious area, emulating natural hydrologic processes, and protecting sensitive resources. This section of the stormwater management master plan outlines strategies and tools for implementing sustainable land development in the Fourmile Creek Watershed.

6.5.3.2 Strategies

- **Consider stormwater quality and management early in the design process.** Oftentimes, by the time stormwater is considered in the design of a site or development, the costs to modify the site to meet the desired requirements are substantial. A proactive approach will allow a full range of options to be considered early on in the process and ultimately provide a better solution. As a part of this process, identify and create a plan to protect sensitive resources such as water supply sources, erodible soils, floodplain areas, and aquatic and terrestrial ecosystems.
- **Utilize Low Impact Development Strategies.** Low Impact Development (LID) was discussed in Section 5.2.4.1. The principle is that it is less expensive to control runoff and pollution at the source (where rain falls), than at the end of the pipe. Working with developers to implement LID strategies will ultimately reduce the overall cost of handling stormwater when the cost for downstream conveyance systems is considered.
- **Maintain and enhance the hydrologic function of prairie potholes.** As annexation extends into agricultural areas, the existing prairie potholes are typically graded to drain as part of the new development. The stormwater storage and water quality benefits of these areas are lost. As part of the development process, these areas should be identified and maintained. Their continued function will assist in regulating downstream flow to minimize impacts on the downstream stormwater system. Depending upon the size of the pothole, this could be a regional strategy as well.
- **Establish stormwater requirements that meet the unified stormwater sizing criteria.** While this study is focused on Fourmile Creek, the use of the unified stormwater sizing criteria will assist in the protection of tributaries within the watershed and ultimately benefit Fourmile Creek. Table 6.5 shows the elements of these criteria. Detention storage should be provided for a pre-settlement condition (meadow in good condition).
- **Reserve a safe path of conveyance for the extreme flood event.** In the event there is not enough detention within the site, a safe conveyance path for the extreme flood event should be provided.
- **Integrate access and maintenance considerations into the development.** All stormwater infrastructure will require maintenance. Design the system appropriately with those considerations in mind. An understanding of property ownership and maintenance responsibilities should be a part of the process.

6.5.3.3 Tools

Table 6.5 includes the unified stormwater sizing criteria. Table 6.6 some of the many resources available to promote sustainable land development.

Table 6.5: Unified stormwater sizing criteria

Criteria	Goal
Water Quality Protection	Treat the runoff from 90% of the storms that occurs in an average year (1.25 inches of rainfall) providing water quality volume for detention with permanent pool or as volume to be filtered/infiltrated (e.g., bioretention, dry ponds)
Channel Protection	Provide 24 hours of extended detention of the runoff from the 1 year 24 hour rainfall
Overbank Flood Protection	Provide peak discharge control of the 5 year to not exceed downstream conveyance capacity and not to increase downstream flood risk.
Extreme Flood Protection	Reduce post-development 100 year peak flow to pre-development 5 year peak flow level or provide conveyance to a regional detention facility.

Table 6.6: Resources for land development

Resource	Description
US Green Building Council www.usgbc.org	The US Green Building Council is a non-profit organization that promotes buildings that are sustainably designed, built and operated. The USGBC website offers numerous resources for those who want to learn more.
Low Impact Development Center www.lowimpactdevelopment.org	The Low Impact Development Center is a non-profit organization dedicated to the advancement of low impact development technology. Their website contains many useful case studies of low impact development projects.
Low Impact Development Urban Design Tools Website www.lid-stormwater.net	This resource was developed by the US EPA Office of Water and contains many great tools and design examples for Low Impact Development.

In many cases, a low impact development approach using practices like vegetated swales and rain gardens can be less expensive than installing a separate stormwater sewer system, since it reduces the need for the construction of street gutters, grates, street catchment basins and sewer pipes (USEPA, 2007). These practices contribute to runoff volume reduction by allowing infiltration and slowing runoff flows, which can also contribute to flood reduction goals.

6.5.3.4 Recommendations

Create a FCWMA committee to establish consistent development standards relating to stormwater for all jurisdictions.
Stormwater requirements need to be consistent and support watershed goals, which require cooperation between the jurisdictions responsible for guiding and enforcing future development conditions. Jurisdictions within the watershed should adopt similar development standards including the unified stormwater sizing criteria of the Iowa Stormwater Management Manual. This will help make sure the impacts on Fourmile Creek are as consistent as possible throughout the watershed while maintaining a level playing field for economic development. A FCWMA

committee should develop a draft resolution and a sample development standard for consideration by members.

Complete analyses of subwatersheds in developing areas to determine concepts of regional stormwater improvements.
The Fourmile Creek Watershed Study will provide the framework of hydrology, hydraulics, and recommendations for future improvements within the entire watershed. The next step will be to develop a more refined regional stormwater concept within each subwatershed in the context of upcoming development. This should factor in proposed land uses, property owners, and the detention volume and stream corridor elements required to meet the requirements of the unified sizing criteria on a regional basis. This should also include methodologies to connect the site level strategies with the regional stormwater plan.

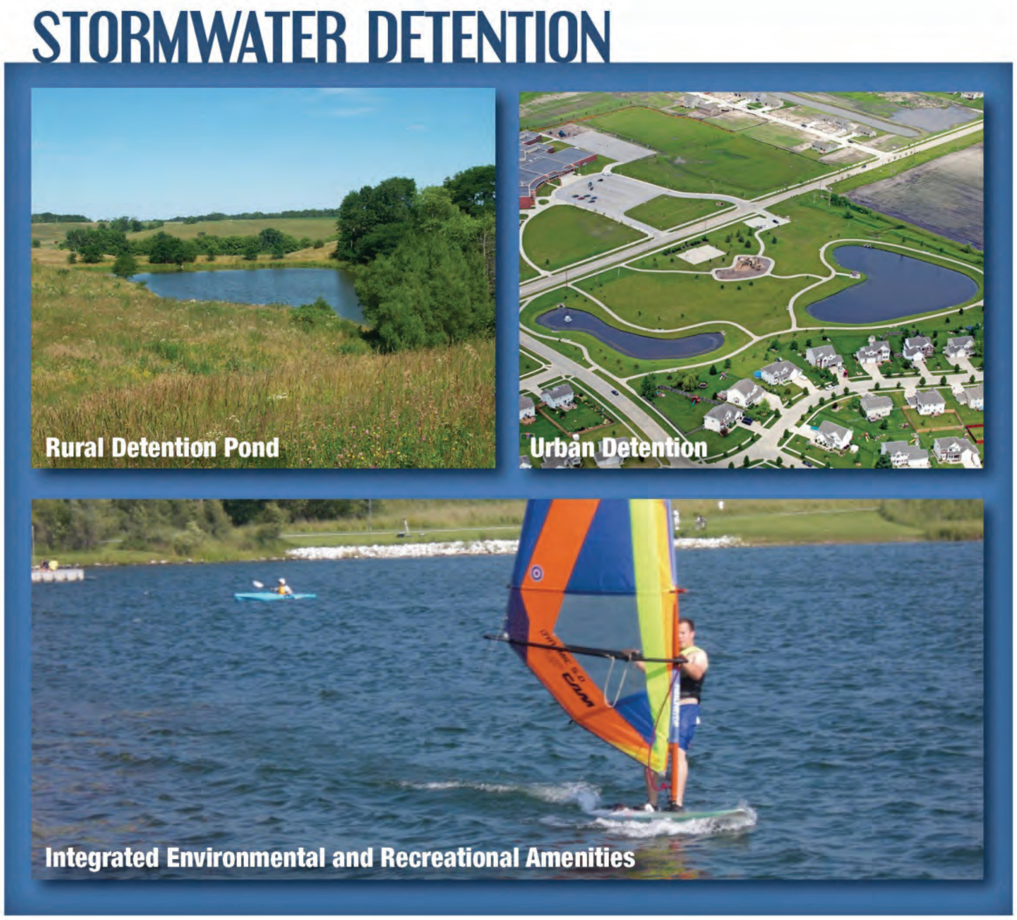
Acquire property so that regional strategies can be implemented on public lands.
Whether it is an existing prairie pothole/wetland ground or the stream corridor for Fourmile Creek, jurisdictions in the Fourmile Creek watershed should, to the maximum extent practicable, acquire property to establish and enhance the regional stormwater conveyance system. This property would also include the extreme flood conveyance area (greater than 100-year flood event) for Fourmile Creek and subwatersheds. Regional stormwater improvements are typically more extensive than individual site improvements and they convey stormwater from numerous upstream property owners. In addition, the acquisition will help assure additional development does not occur in the stream corridor area. Public ownership of the improvements helps assure they can be designed with access and maintenance in mind.

Develop a maintenance program for the regional improvements.
In order to function as intended, all BMPs will eventually require maintenance. They should have a routine maintenance schedule where they are inspected for proper performance and captured sediments and other items are removed and disposed of properly. This should also include the management of vegetation along the stream corridors. Uncontrolled growth of trees and brush can limit sunlight to the ground, causing erosion resistant ground cover to be lost. A program of seasonal mowing or burning can limit the growth of undesired species. During the initial phases of the corridor development, selective clearing may be necessary where trees and brush have become overgrown.

6.5.4 Stormwater Detention

6.5.4.1 Description

Stormwater detention is a necessary component of the stormwater management master plan. During extreme rainfall events, detention areas attenuate peak flow rates downstream and reduce flooding. These detention sites are versatile and may take the form of native or constructed wetlands, farm ponds, urban detention basins or multi-purpose regional detention facilities. This section of the stormwater plan identifies types of detention to target, desired quantity of detention, and priority locations.



6.5.4.2 Strategies

- **Establish multi-purpose stormwater detention facilities ranging from dry to wet basins.** Effective stormwater detention facilities can function as dry or wet bottom basins. In order to determine the preferred basin, careful consideration should be given to the site and water quantity/quality goals for the particular location. These facilities would be programmed by completion of a subwatershed concept plan and coordination with adjacent property owners.

- **Integrate environmental and recreational amenities.** Conservation areas such as lakes and wetlands can provide valuable stormwater storage in times of flooding while also being an environmental and recreational amenity to residents throughout the year.
- **Establish stormwater facilities that:**
  - Support water quality to flood protection objectives
  - Reduce vulnerability to climate variability
  - Are maintainable/sustainable
- **Land for establishing stormwater detention facilities can be provided in several ways:**
  - Maintaining current private land ownership
  - Acquiring land for public ownership
  - Using existing public land
  - Using existing easements
- **When defining if private land ownership is to be maintained, consideration should be given to important factors, such as:**
  - Establishing appropriate easements (e.g., floodplain/drainage easements)
  - Defining monitoring, operation, and maintenance responsibilities (e.g., sediment removal)

6.5.4.3 Tools

Based on the opportunities evaluated in this study, high priority should be given to providing a minimum of 1,200 Ac-Ft of regional stormwater detention storage to reduce flood risk. On-going efforts need to continue to plan, fund, and implement detention storage facilities of many types (e.g., dry and wet ponds, wetlands). Site-specific assessments are needed to optimize flood risk reduction based on site constraints and drainage area characteristics.

6.5.4.4 Recommendations

As previously discussed in section 0, modeling results of regional storage indicate that 1,200 Ac-Ft of stormwater detention in the upper watershed would provide significant reductions in peak flow. Table 6.7 includes a recommendation for distributing 1,200 Ac-Ft of detention storage in the watersheds analyzed in the regional storage model. The intent is to optimize downstream flood risk reduction.

Table 6.7: Recommended storage

Region	Recommended Storage (Ac-Ft)
Otter Creek	120
Muchikinock Creek	370
Deer Creek	190
Upper	180
1	170
2	60
3	110
Total	**1,200**

Seven locations have been identified as potential locations for regional stormwater detention facilities in Figure 6.1 and Figure 6.2. The intention in providing these general locations is to identify sections of the creek that could provide the noted downstream benefits. Additional site investigation engineering will be necessary to understand optimum locations based on topography, land ownership, and future development.

Figure 6.1: Potential detention locations 1

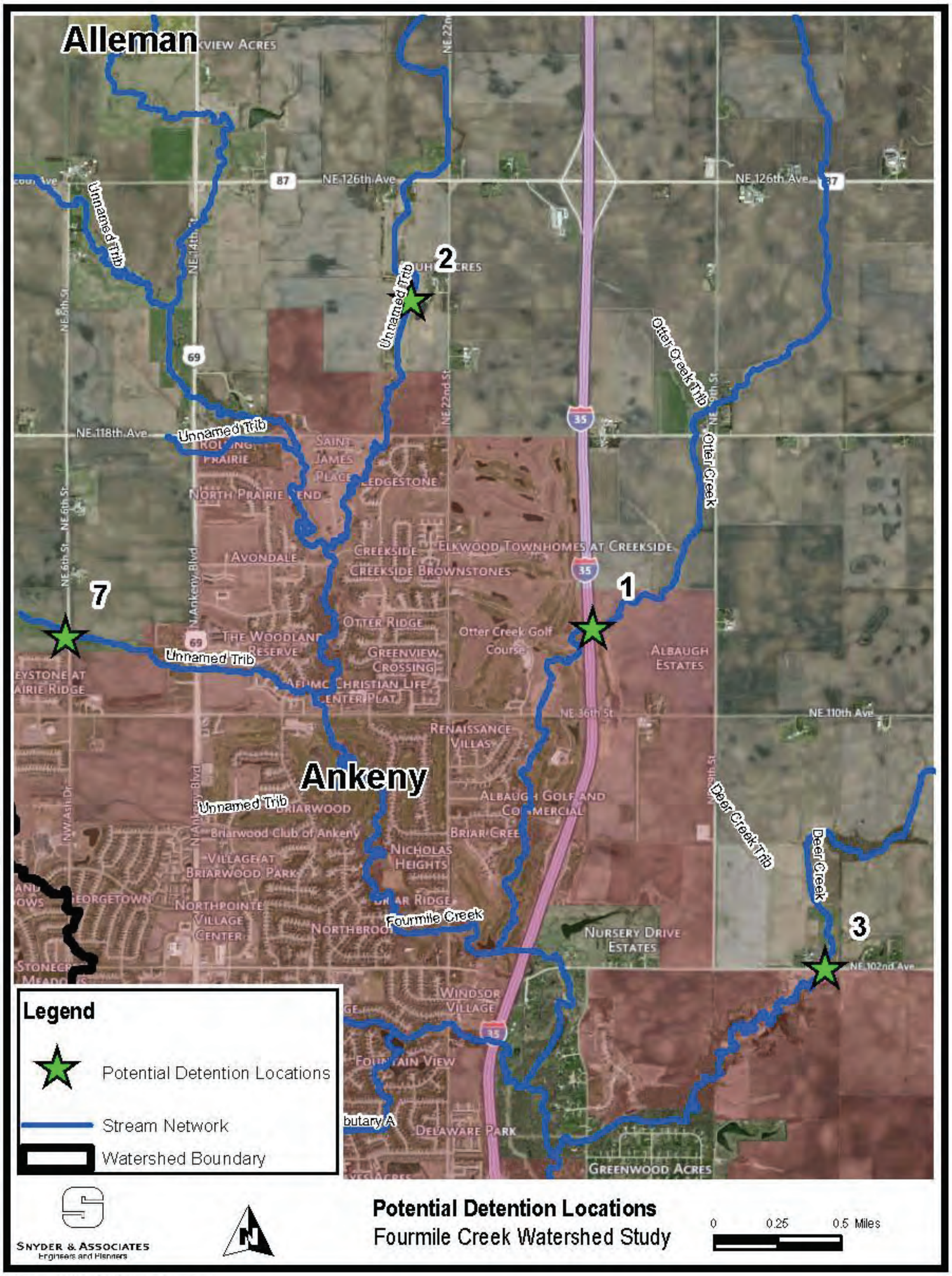


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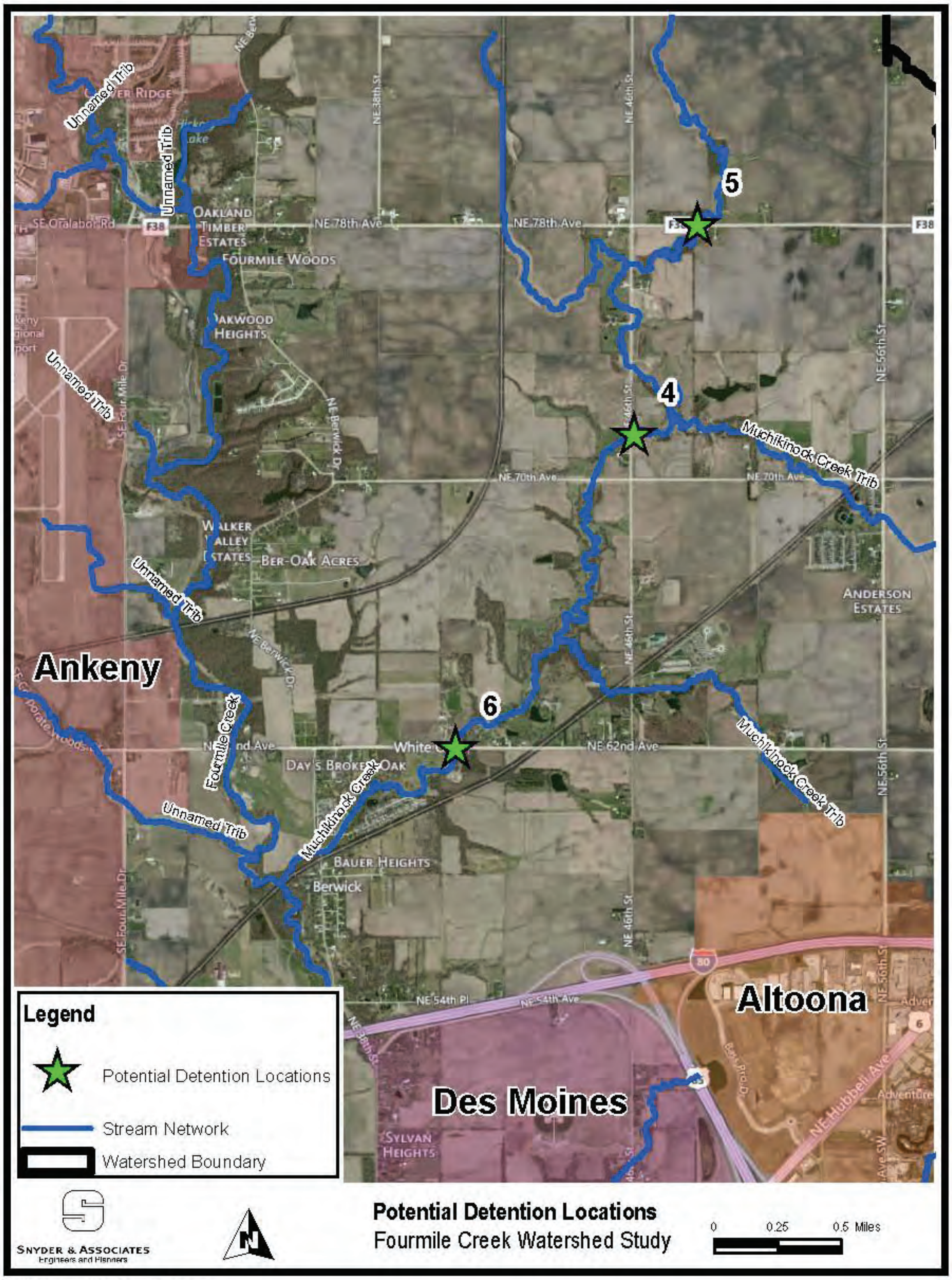
Figure 6.2: Potential detention locations 2



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6.5.5 Stream Corridors

6.5.5.1 Description

Stream corridors are ecosystems consisting of a stream channel, a floodplain, and a transitional upland fringe—that function as dynamic and valued crossroads in the landscape (FISRWG, 1998, pg.1-1). The management of stream corridors needs to include sustainable strategies that support the diverse functions of the corridor, such as:

- Reducing flood risk
- Cycling nutrients
- Filtering and treating runoff contaminants (e.g., sediment and nutrients)
- Improving water quality and other conditions (e.g., aeration, nutrient removal)
- Absorbing and gradually releasing floodwaters
- Slowing runoff velocities and increasing runoff travel times
- Attenuating peak flows with floodplain storage
- Maintaining and improving aquatic and terrestrial habitats (e.g., fish, wildlife)
- Recharging ground water

Restoring healthy stream conditions includes all sustainable stream restoration strategies and techniques that support watershed goals and stream corridor functions. Stream restoration can contribute to improving water quality and stream habitat, as well as to reducing flood risk. The strategy of establishing healthy streams is not limited to just Fourmile Creek but includes all streams in the watershed, such as:

- Ephemeral, intermittent, or perennial streams—during, right-after, in-between precipitation events (rain or snow)
- Small swales and ditches in urban and rural lands
- Large tributaries and main creeks

6.5.5.2 Strategies

- **Acquire properties, particularly those with existing structures, at risk for flooding.** The biggest concerns expressed by the public were flood related. In fact, 200 structures would flood from the updated 10-year flood and 381 structures would flood from the updated 100-year flood. Due to the elevation of many of these structures compared to the calculated flood elevations, there is not an economical way to lower the flood elevation to protect them from flooding which leaves acquisition of the property as the best alternative. Also, as new developments occur adjacent to waterways within the watershed, stream corridors should be acquired as part of the development process.
- **Stabilize streambanks.**
  As stated previously, streambank erosion was identified as a top concern of many residents attending the public meetings. The floods of 2008 and 2010 created prolonged periods of erosive velocities in the creek. In many locations, property owners along the creek observed the creek channel widening and deepening. It is important to begin stabilizing these banks before the problem worsens leaving the channel more degraded and property along the creek at risk. Banks can be stabilized using bioengineering techniques that enhance habitat while adequately preventing future erosion, which can include live stakes and other planting techniques. Streambank protection measures should also include appropriate integrated stream restoration techniques, such as grade control measures that reduce stream channel degradation and reduce flow velocities at the streambanks.
- **Creation of a multipurpose stream corridor.**
  While flood plain functions may be the most critical for stream corridors, they do serve multiple purposes. A public stream corridor allows for the protection and establishment of adjacent aquatic and terrestrial habitat. Sensitive wetland areas can be protected and enhanced. Passive and active recreation facilities are possible within this corridor. The entire system can serve as an excellent educational tool.

Implementation strategies need to consider an upstream-to-downstream watershed approach, so upstream improvements also benefit downstream efforts. For example, slowing runoff velocities with low-cost techniques in small swales and ditches can reduce impacts and more expensive stream mitigation efforts downstream.

Stream restoration strategies should seek to establish sustainable stream channel dimensions, patterns, and profiles. Strategies should particularly aim to:

- Restore and stabilize stream channel profile/grade
- Stabilize streambanks
- Reconnect floodplain to channel or establish "floodplain benches"
- Restore meanders or establish longer channel lengths
- Establish perennial vegetation buffers
- Establish in-stream water quality treatment features (e.g., two-stage ditches to foster nutrient uptake and treatment of tile drainage having a lower "floodplain" that is connected to the stream)

6.5.5.3 Tools

Property Acquisition
Available LiDAR and aerial mapping were utilized to determine the flood risk for homes along Fourmile Creek. A tabulation was created of existing properties along Fourmile Creek, the approximate LiDAR elevation of the first floor of the structure, and the 100-year flood elevation. With this information, an understanding of which structures would be impacted by the 100-year flood was determined. As noted previously, this includes 274 existing structures in the floodplain. The City of Des Moines has completed 153 voluntary buyouts with FEMA disaster assistance from the 2008 and 2010 flood events.

Stream Assessments
The Polk County Soil and Water Conservation District in association with Polk County Conservation Board is completing a stream assessment to determine locations where streambank improvements would be warranted along Fourmile Creek. Upon the completion of this assessment, the information can but utilized to prioritize areas and search for funding sources.

6.5.5.4 Recommendations

Continue a voluntary buyout program to remove vulnerable structures and establish a stream corridor through Des Moines and Pleasant Hill.
Establishing a continuous stream corridor through the cities of Des Moines and Pleasant Hill is a priority. Previous voluntary property buyouts conducted by the City of Des Moines have proven effective in reducing flood damage. Properties to be acquired should be prioritized according to their flood risk and stream corridor continuity. A map showing a key section of this stream corridor is provided in Figure 6.3. The map identifies publicly owned land and the boundary of the 100-yr flood. This information can be used to identify properties to offer a voluntary buyout.

For planning purposes, Table 6.8 shows an estimate of the potential range of residential structures within the 100-year floodplain that could be acquired.

Table 6.8: Recommended range of structures for voluntary buyout

Location	Minimum *	Maximum **
Interstate 80 - Hubbell Avenue	0	9
Hubbell Avenue - Easton Boulevard	24	80
Easton Boulevard - University Avenue	7	44
University Avenue - Des Moines River	0	6
Pleasant Valley Mobile Home Court Pleasant Hill	0	138
Total	**31**	**277**

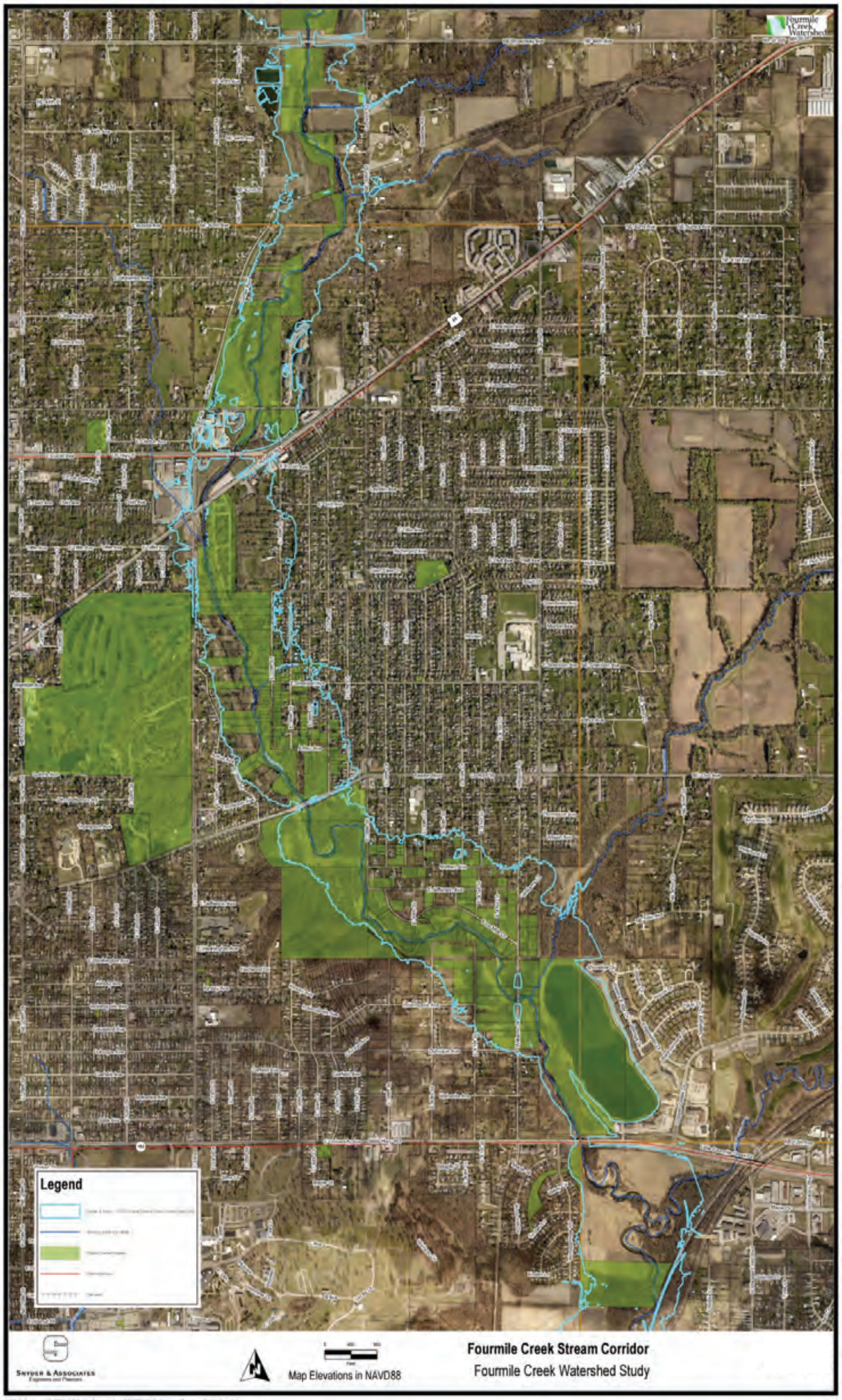
* Establish stream corridor continuity

** Structures at risk from 100-yr flood

Delineate and protect existing stream corridors as development occurs.
As new developments occur, protect undeveloped stream corridors to prevent structures being built in the floodplain corridor or other impacts that can adversely affect the floodplain functions of riparian lands.

Plan and implement sustainable stream restoration.
Develop a master plan for each stream corridor area in order to address elements such as streambank erosion and aquatic habitat enhancement. Streambank restoration needs should be investigated and opportunities to protect and enhance sensitive areas should be considered.

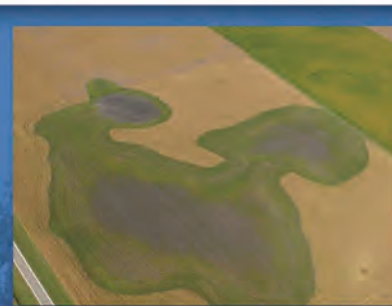
Figure 6.3: Fourmile Creek stream corridor



6.6 Summary of Recommendations

SUMMARY OF RECOMMENDATIONS

Sustainable Rural Land Management



- Create Fourmile Creek Watershed Management Authority technical and stakeholder committees on sustainable rural land management.
- Annually measure the amount of conservation practices within the watershed.
- Complete an assessment of prairie potholes and wetland areas and target highest priority areas for acquisition.
- Provide staff to coordinate rural efforts.

Sustainable Urban Land Management

- Investigate locations for stormwater retrofits.
- Work with property owners to implement matching grants.
- Work with Iowa Stormwater Education Program and local jurisdictions on educational opportunities.

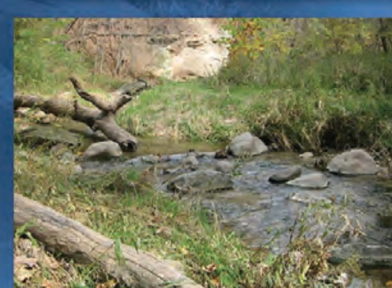
Sustainable Land Development

- Create a Fourmile Creek Watershed Managament Autority committee to establish consistent development standards for all jurisdictions.
- Analyze subwatersheds in developing areas to determine concepts of regional stormwater improvements.
- Acquire property so that regional improvements can be constructed on public lands.
- Develop a maintenance program for regional improvements.

Stormwater Detention

- Provide at least 1,200 Ac-Ft of stormwater detention in the upper watershed.

Stream Corridors



- Continue voluntary buyout program to remove vulnerable structures and establish stream corridor in Des Moines and Pleasant Hill.
- Protect existing stream corridors as development occurs.
- Plan and implement sustainable stream restoration projects.

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MAPS

APPENDIX A: PUBLIC INPUT

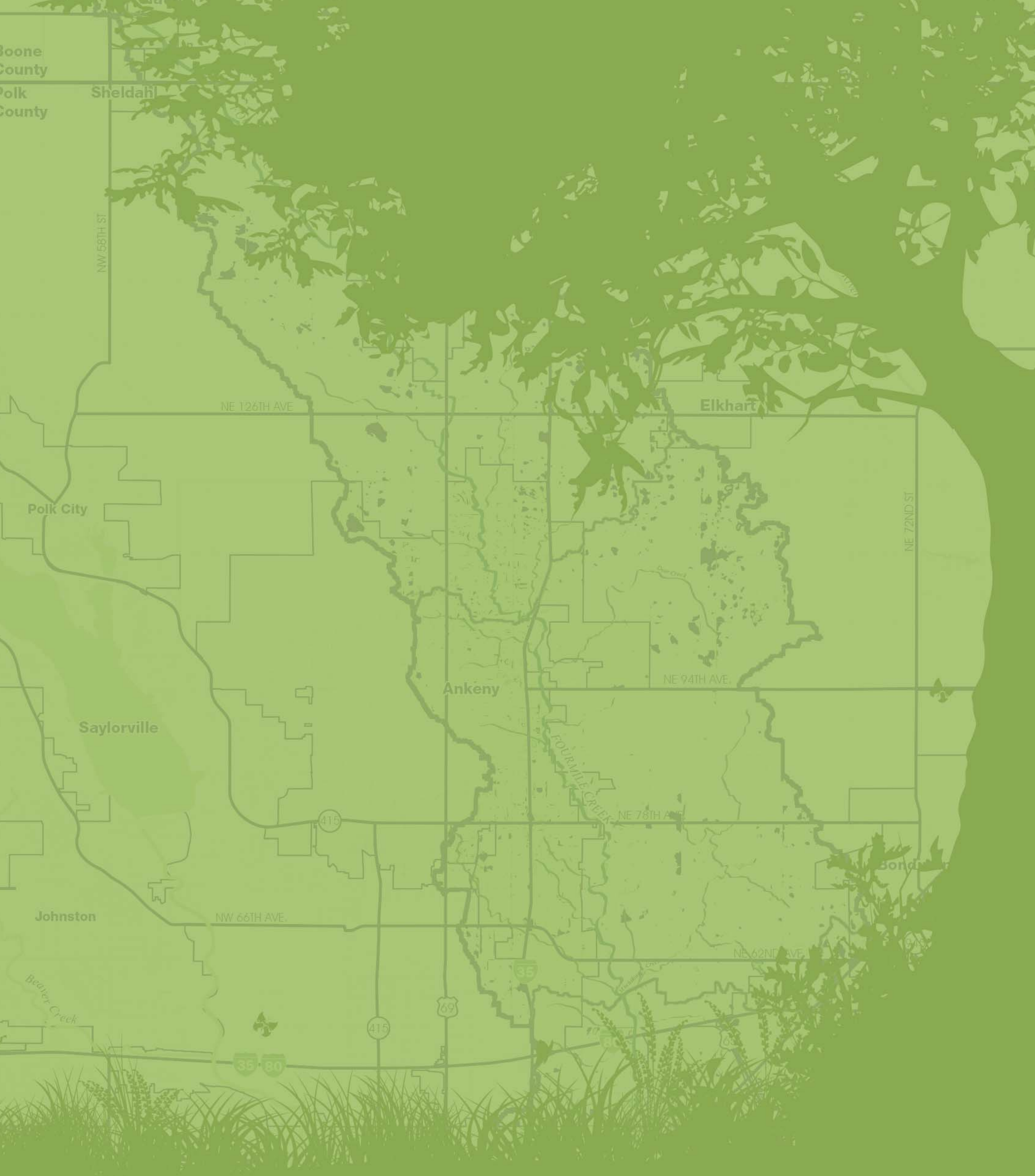
- Summary of public input
- Questionnaire

APPENDIX B: HYDROLOGIC DATA

- Rainfall data
- USGS annual peak flow frequency analysis – Fourmile Creek at Easton Boulevard (Sta.05485640): Graph and Program PeakFq output
- Hydrologic Input
  - Map: Drainage areas for hydrologic modeling
  - Hydrologic Input Summary: 2010 Land Use Conditions
  - Peak Flow Rates: 2010 Land Use Conditions
  - Hydrologic Input Summary: 2030 Land Use Conditions
  - Peak Flow Rates: 2030 Land Use Conditions

APPENDIX C: HYDRAULIC DATA

- Plan: Fourmile Creek – 2010 (cross-sections plan view)
- HEC-RAS Table 1 Results – Snyder 2010 Conditions
- Hydraulic Profiles – Snyder 2010 Conditions
- Cross Section graphs– Snyder 2010 Conditions
- Plan: Fourmile Creek – 2030 (cross-sections plan view)
- HEC-RAS Table 1 Results – Snyder 2030 Conditions



Prepared by Snyder & Associates, Inc.

Fourmile Creek Watershed