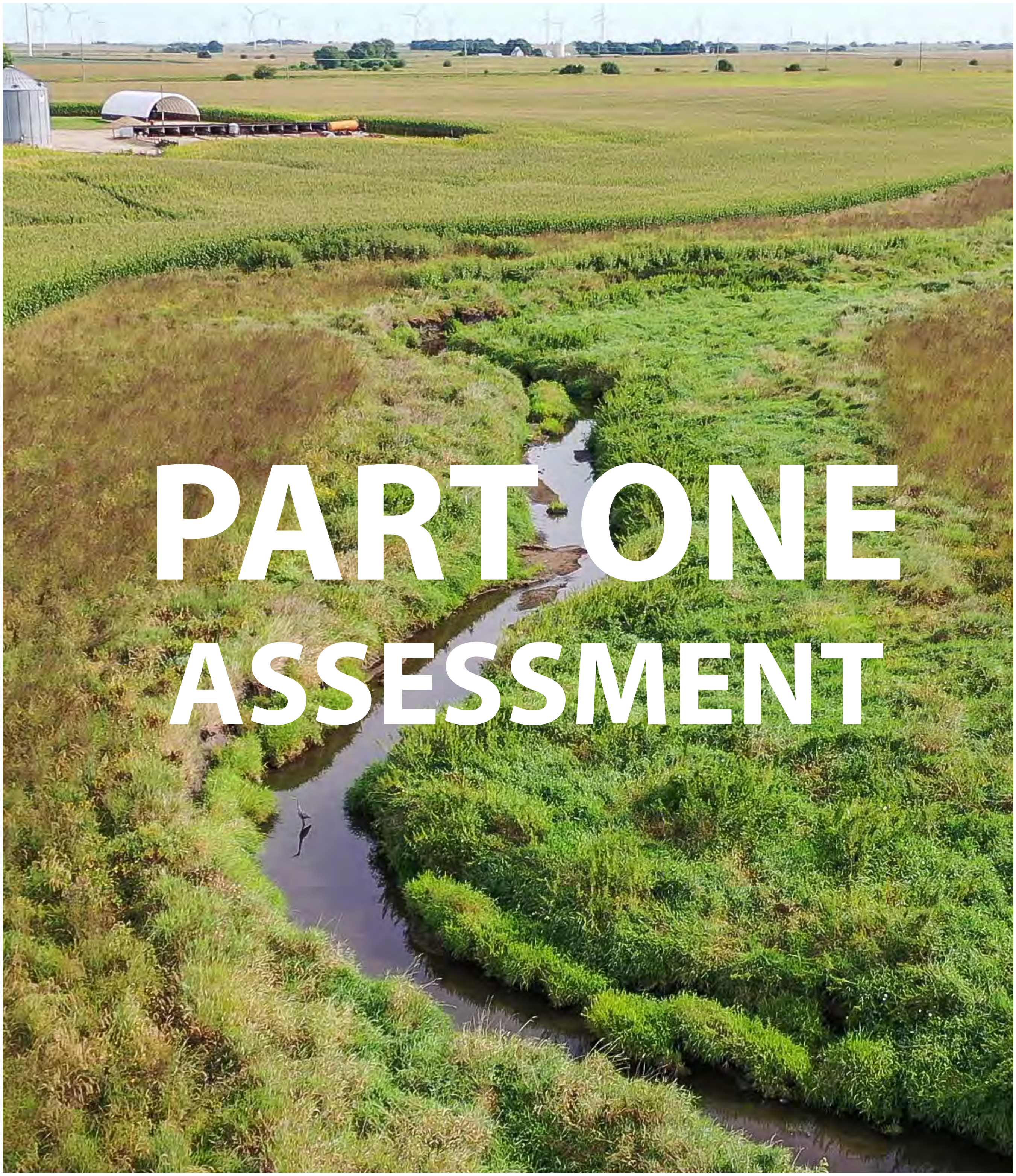
PART ONE
ASSESSMENT



JANUARY 2020

BEAVER CREEK
watershed plan

RDG PLANNING • DESIGN

EOR water ecology community

SNYDER & ASSOCIATES

This watershed plan was commissioned by the members of the

BEAVER CREEK
watershed management authority

With contributions of its Board and Watershed Plan Steering Committee,
in partnership with the consultant team led by RDG Planning & Design.

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CONTENTS

WHERE DO I FIND EPA'S NINE MINIMUM ELEMENTS FOR WATERSHED PLANS?

Although many different components may be included in a watershed plan, EPA has identified nine key elements that are critical for achieving improvements in water quality. EPA requires that these nine elements be addressed in watershed plans funded with Clean Water Act section 319 funds and strongly recommends that they be included in all other watershed plans intended to address water quality impairments. In general, state water quality or natural resource agencies and EPA will review watershed plans that provide the basis for section 319-funded projects. Although there is no formal requirement for EPA to approve watershed plans, the plans must address these nine elements if they are developed in support of a section 319-funded project.

- Adapted from "Handbook for Developing Watershed Plans to Restore and Protect Our Waters", USEPA Office of Water – Nonpoint Source Control Branch, March 2008.

#1 - Identification of causes of impairment and pollutant sources or groups of similar sources that need to be controlled to achieve needed load reductions and any goals identified in the watershed plan. Sources that need to be controlled should be identified at the significant subcategory level along with estimates of the extent to which they are present in the watershed.

CHAPTER 2

Factors related to hydrology and potential pollution sources such as terrain, soils, and land use changes.

CHAPTER 3

A review of known impairments of designated uses for water resources within this watershed.

CHAPTER 4

Current and historic climate data is reviewed, along with an analysis of historic streamflow patterns and flood risk.

CHAPTER 5

A review of related studies that were previously completed that influence this plan.

CHAPTER 6

Identification of the key pollutants of concern identified by this plan and the potential impacts of these pollutants. Existing available monitoring data is reviewed. Pollutant load and sources are projected by subwatershed and land use type.

CHAPTER 7

Details regarding stream characteristics, stability and buffering.

CHAPTER 8

Pollutant load and sources are projected by subwatershed and land use type.

#2 - An estimate of the load reductions expected from management measures.

CHAPTER 11

For each of the eleven HUC-12 subwatershed a specific 3-0year implementation plan has been developed which includes projected load reductions.

CHAPTER 14

Rates of implementation and reduction are included in this chapter.

#3 - A description of the non-point source management measures that will need to be implemented to achieve load reductions and a description of the critical areas in which those measures will be needed to implement this plan.

CHAPTER 10

Proposed policy changes are non-structural management measures. The urban and rural policies outlined in this plan are those that are recommended for adoption to achieve the goals of this plan.

CHAPTER 11

For each of HUC-12 subwatersheds the 30-year plan details the type and potential locations of management practices needed to meet the projected load reduction targets.

CHAPTER 12

Measures to address future flood risk are noted.

CHAPTER 14

A list of first steps and adoption rates are included here.

CHAPTER 15

Cost associated with implementation of strategies outlined in this plan are included in this chapter.

#4 - Estimate of the amounts of technical and financial assistance needed, associated costs and/or the sources and authorities that will be relied upon to implement this plan.

CHAPTER 10

Reviews some of the technical assistance needed to implement policy changes.

CHAPTER 11

Evaluates the cost of implementation strategies at the subwatershed scale.

CHAPTER 15

Summarizes costs for watershed scale implementation and monitoring.

#5 - An information and education component used to enhance public understanding of the project and encourage their early and continued participation in selecting, designing and implementing the non-point source management measures that will be implemented.

CHAPTER 13

This is the education and collaboration plan.

#6 - Schedule for implementing the non-point source management measures identified in this plan that is reasonably expeditious.

CHAPTERS 11 AND 12

Include the strategies for addressing water quality and flood risk

CHAPTER 14

The schedule for implementation of the practices listed in Chapters 11 and 12 can be found here.

#7 - A description of interim measurable milestones for determining whether non-point source management measures or other control actions are being implemented.

SEE CHAPTER 14

#8 - A set of criteria that can be used to determine whether loading reductions are being achieved over time and substantial progress is being made toward attaining water quality standards.

SEE CHAPTER 14

#9 - A monitoring component to evaluate the effectiveness of the implementation efforts over time, measured against the criteria established under item #8.

CHAPTER 14

The monitoring program is outlined here.

CHAPTER 15

The costs and schedule for implementing the monitoring program is included in this chapter.

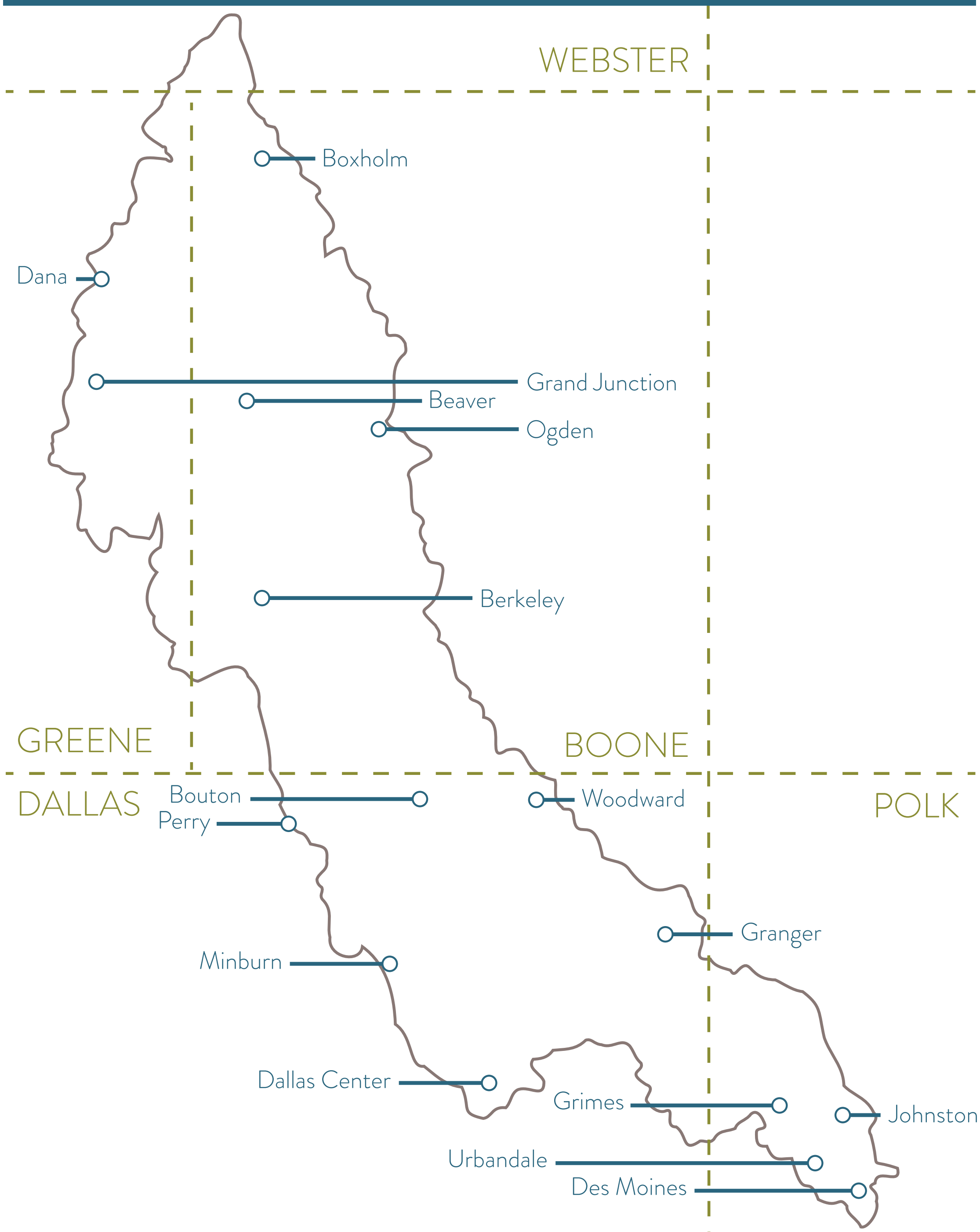
01

THE PROCESS & THIS PLAN

This chapter gives a brief overview of the Beaver Creek Watershed Plan and the process used to interact with key stakeholders throughout to its creation. It also provides guidance on how to use this plan and where to find key pieces of information.

01

Jurisdictions within the watershed.



INTRODUCTION

In 2010, the State of Iowa passed legislation to allow local governments to form Watershed Management Authorities (WMA). The "Authority" in this name is a term the legislature often uses when referencing a convening body. In truth, each WMA has no actual authority. They cannot levy taxes, acquire property or enforce any types of rules on their own. Instead, **each one is an alliance of jurisdictions within a given watershed, coming together to focus on water quality and quantity issues through collaboration and education.** By law, WMAs cannot be formed without inviting all of the Soil and Water Conservation Districts, communities and counties within the designated watershed to the table. It only takes two such jurisdictions, joining together (by mutual adoption of a 28E agreement) to actually form the WMA.

The "authority," however, continues to rest with the local governments within each watershed. **For all practical purposes, a WMA can only recommend that its member-governments take action – it cannot force that action.**

The Beaver Creek WMA in Central Iowa was formed based on this legislation, with the process of building this alliance being spearheaded by the government of Polk County. A grant from the Iowa Department of Natural Resources was secured to pay for consulting services to development of this plan. As of the date of this plan, all but one (Dallas County) of the eligible jurisdictions originally invited to join the WMA have done so.

In 2018, the Beaver Creek WMA selected the consultant team of RDG Planning & Design (Des Moines), Emmons and Olivier Resources (Oakdale, MN / Boone) and Snyder and Associates (Ankeny) to guide the development of the watershed plan. The consultant roles could be generally described as follows:

- **RDG Planning and Design:**

  Project lead and project management, leading stakeholder engagement and public outreach and creating the master plan document, based on technical information provided by their partner firms.
- **Emmons and Olivier Resources:**

  Perform water quality resource assessments and development of related plan elements.
- **Snyder and Associates:**

  Perform water quantity (flood impact) assessments and development of related plan elements.

Stakeholder workshop held in Ogden.

PROCESS

PUBLIC INTERACTIONS

Public involvement and input from key stakeholders were central to plan development. **This approach to stakeholder and public engagement was used to identify issues and build connections among stakeholders.** It allows for the exchange of ideas and builds greater understanding of the watershed. The list of participants involved in developing the plan was enlarged, expanding input and branding ownership.

WMA Meetings and Organization

STEERING COMMITTEE

Monthly meetings with a smaller workgroup dedicated to guiding plan development and providing more detailed review of technical information related to assessments and proposed implementation.

Meeting dates:

October 15, 2018
RDG led discussion about the process and schedule and preliminary assessment data collected.

November 5, 2018
The consultant team led discussion to determine the process for upcoming stakeholder workshops.

February 7, 2019
The consultant team reviewed the plan for Small Group meeting #2.

April 1, 2019
The consultant team led discussion about feedback gathered at Small Group meeting #2 and discussed approaches for developing implementation plan based on that feedback.

May 6, 2019
The consultant team discussed progress and approach for modeling and development of implementation plan.

June 25, 2019
The consultant team reviewed draft version of implementation plan.

August 22, 2019
RDG reviewed draft version of the education and outreach plan.

September 18, 2019
The consultant team reviewed draft plan chapters and comments on previously published report elements.

December 2018, January 2018, March 2019 were not held to accommodate other stakeholder workshops.

QUARTERLY MEETINGS

Scheduled meetings with the full WMA board to review progress and validate decisions made by the steering committee.

Meeting dates:

July 15, 2018:
Consultant team introductions were made to the board.

October 18, 2018
RDG and the consultant team provided update of process, schedule and assessment data collection.

January 17, 2019
RDG and the consultant team provided update of process, output from December and January stakeholder events. Summarized assessment material provided to IDNR.

April 18, 2019
RDG and the consultant team summarized information from prioritization workshops and validated direction on implementation plan that was discussed at the April 1 steering committee meeting.

July 18, 2019
RDG and the consultant team reviewed technical chapters of the HUC-12 water quality plans and approaches to address flooding.

October 18, 2019
Board review of completed watershed plan.

Stakeholder Events

TOPIC-BASED SMALL-GROUP MEETINGS

Description: **Two workshops that engaged small groups with local knowledge of specific watershed issues** (e.g., flooding, producer groups, channel stability) to use watershed data collection to validate assumptions and expand the consultant team's knowledge of local issues the plan should address. One workshop occurred during the assessment phase, the other during development of the implementation plan. When they occurred, they supplanted the steering committee meeting scheduled for that month.

First meeting: December 3, 2018 (assessment) – This meeting was used to review maps to validate assessment information gathered about the watershed related to natural resources, agricultural practices and flooding. Policies were a fourth topic discussed within small groups.

Second meeting: March 14, 2019 (implementation) – This meeting was used to review ACPF output and discuss strategies on how to prioritize work efforts to be described in the implementation plan.

Participants: Pre-identified list of jurisdictional staff, public works, crop service providers, landowners, producers, trade group representatives, women and legacy landowners, early implementors and other local advocates.

Outcome: A better definition of the specific, local issues that the watershed plan needs to address. Validated data collected from assessment reports, consultant analysis and project partners.

VISIONING - GOAL-SETTING WORKSHOP

Description: **A workshop to define the vision, goals and objectives to be addressed** as the plan moves from the assessment phase into implementation.

Meeting date: January 14, 2019 – A facilitated discussion was used to discuss the vision, mission, goals and objectives of the Beaver Creek Watershed plan. Groups offered feedback on "trial balloon mission statements", offering up their own versions of these statements. Refined lists of goals and objectives were also developed related to agricultural practices, flooding, natural resources and policy.

Participants: Pre-identified list of jurisdictional staff, public works, crop service providers, landowners, producers, early implementors and other local advocates.

Outcome: Finalized issues to be addressed by creation of an implementation plan. Described the vision, mission and objectives that the plan will seek to achieve.

NUMERIC DATA COLLECTION AND ANALYSIS

To complete this plan, numeric data was collected and analyzed for several key factors:

- Climate data from the Des Moines Airport Natural Weather Service Station, including temperature, precipitation and length of growing season. This information was used to determine recent and historic trends for these factors.
- Stream gage flow data from a USGS station located along Beaver Creek at NW 70th Avenue in Johnston, including daily average flow rates and gage height (measure of stream depth). This was used to look at seasonal and historic trends and patterns of runoff, stream flow and flood events.
- Water quality monitoring data from available sources. Although available data was limited, it was important in validating the key pollutants of concern, how their levels compare to state water quality standards and their potential sources within the watershed.

Desktop Analysis

Geographic Information System (GIS) data was reviewed to identify important conditions throughout the watershed. Aerial photographs (past and present), topographic information, soils data and other available information was analyzed. Surface information was used to more precisely identify the overall boundary of the Beaver Creek Watershed and subdivide it into smaller subwatershed areas. Output from the Agricultural Conservation Planning Framework tool from Iowa Department of Natural Resources was also integrated into the desktop analysis.

Field Assessments

Conditions noted in desktop assessments were verified by observations in the field. These included:

- Windshield surveys – following along roadways and trails to photograph and note conditions across the watershed.
- Information and photographs from local Soil and Water Conservation Districts, based on their interactions with land owners and producers throughout the watershed.

Drone footage taken from the upper Beaver Creek watershed.

DETAILING THE PLAN

Information gathered through public interaction and data analysis has been developed into this plan. The plan is generally divided into two separate parts:

Part I – Assessment

- **Chapter 1:** The Process and The Plan
- **Chapters 2 - 8:** What did we learn about the watershed?

Part II – Actions and Implementation

ACTIONS

- **Chapters 9 - 12: What strategies, projects and policies are necessary to address the key concerns identified in the assessment?**

IMPLEMENTATION

- **Chapters 13 - 16:**
  - How do we educate key stakeholders on what actions are necessary?
  - What is the timetable to complete improvements, adopt policies and monitor results?
  - What resources are needed to carry out the plan?
  - How should the plan be evaluated and adjusted to stay on track to meet project goals?

HOW TO USE THIS PLAN

This Watershed Plan can be viewed is a comprehensive effort, addressing a wide variety of issues. The discoveries of this plan need to be relayed to a variety of stakeholders with very different levels of awareness. Some findings are larger concepts and more general ideas. Other parts of the plan need to be more technical and detailed, to provide decision-makers with the level of information they need to support the findings of this plan, propose new policies and dedicate or acquire the financial resources to carry them out.

For this reason, each chapter features headers that highlight the most important concepts, both in outline and graphical forms. The content that follows in each chapter features graphs and sidebar discussions which highlight these key ideas. Each chapter also includes a more detailed explanation of these concepts, which is valuable to all, but may be more useful to implementers of the plan.

THE GRAND OVERVIEW

Part 1 – Assessment

Chapter 2 -Watershed Geography

Information about the overall character of the watershed, including soils, terrain, slopes and changes in land use.

Chapter 3 - Designated Uses & Impairments

A closer look at the uses that major streams within the watershed should be expected to support and how which of those uses may not be fully realized based on known pollutants or impairments.

Chapter 4 - Climate, Streamflow & Flood Risk

Analysis of trends in temperature, precipitation, stream flow and flooding. These conditions have a direct impact on the challenges facing this watershed and the measures necessary to address them.

Chapter 5 - Related Studies

This plan isn't the first study related to the Beaver Creek Watershed. A few past studies that influenced the development of this plan are reviewed here. These studies demonstrate what issues have already been identified within this watershed and how this area relates to other areas downstream.

Chapter 6 - Water Quality Assessment

A review and analysis of the available water quality sampling data from the watershed.

Chapter 7 - Streambank Assessment

A desktop review of stream conditions related to stream stability, character and buffer conditions.

Chapter 8 - Pollutant Source Assessment

The key pollutants of concern are identified. The results of computer water quality simulations are listed, including their suspected source (by location and land use).

Part 2 – Actions and Implementation

ACTIONS

Chapter 9 - Strategic Framework

The vision, mission and goals of this plan are outlined here.

Chapter 10 - Policy Recommendations

This chapter outlines policy initiatives and approaches that will be needed to widely adopt recommendations set forth in this plan.

Chapter 11 - Water Quality Improvement Strategies

A key chapter for implementors. Potential conservation practice locations are mapped for each of the 11 HUC-12 subwatersheds of Beaver Creek. For each subwatershed, the most cost effective approach to reaching desired reduction goals is included.

Chapter 12 - Flood Risk Reduction Strategies
This chapter reviews how flood risks could be impacted by increasing precipitation and strategies needed to reduce risk and prevent expansion of areas exposed to impacts from flooding.

IMPLEMENTATION

Chapter 13 - Education and Collaboration Plan
Educating the public, stakeholders and decision makers is essential to the success of this plan. This chapter reviews how to get these groups to understand this plan and how they can work together to carry it out.

Chapter 14 - Measures and Milestones

This chapter addresses these questions:

What is the proposed timeline to implement projects and policy changes? How is progress evaluated?

How do we monitor for improvements in water quality and share data with other groups?

How is progress to be reported back to the board and the public at large?

Chapter 15 - Resource Requirements

Resources are required to execute this plan. This chapter outlines the financial commitments required for coordination, project construction, maintenance and monitoring. It also details some potential methods to fund these needs.

Chapter 16 - Evaluation and Amendments
To be effective, this plan needs to be a "living document," adapted based on lessons learned and changing conditions as the plan is implemented. These conditions need to be regularly evaluated so that regular corrections can be made to the plan to keep it on course.

THE NEXT STEPS

Since watershed management authorities are "authorities without authority," this plan is dependent on a variety of local communities, stakeholders and property owners to carry it out. Upon approval of the plan by the WMA Board, each community will need to take action to adopt the plan. Each jurisdiction will need to review their ordinances and policies to determine what changes are needed to carry out the recommendations of this plan. Projects will need to be incorporated into local budgets or alternative sources of funding (grants, etc.) pursued. Ongoing resources and staff will need to be committed to carrying out water quality monitoring and the education and collaboration plan. Most of all, this plan needs champions – devoted local advocates that are committed to making sure that it is carried to its conclusion.

This plan outlines a long-term process to initiate progress to improving water quality and watershed health. Land uses and other conditions within the certain parts of the watershed are rapidly changing. For this reason, it is difficult to accurately predict conditions that will need to be addressed for a longer period of time. Annual progress toward meeting the objectives of this plan should be monitored by the members of the WMA. At the end of a ten-year period, this planning effort should be re-visited in greater detail by the WMA Board in some fashion, to evaluate results, lessons learned and changed conditions. At that time the path forward for the next ten or twenty years should be set.

The conditions detailed in this plan have developed over a period of more than 150 years. It may take several decades to make enough improvements to meet water quality goals for the entire watershed. The commitment of resources set forth in the plan may be daunting. However, a decision to not commit to these efforts will result in further deterioration in water quality, streambank instability and a potential for greater flood impacts in the future. Not addressing these issues will assuredly lead to greater costs in the future. These aren't just financial costs, but impacts to health, habitat, recreation and our natural resources.

Monarch butterfly caterpillar in a bioretention planter in Johnston.

02

WATERSHED CHARACTERISTICS

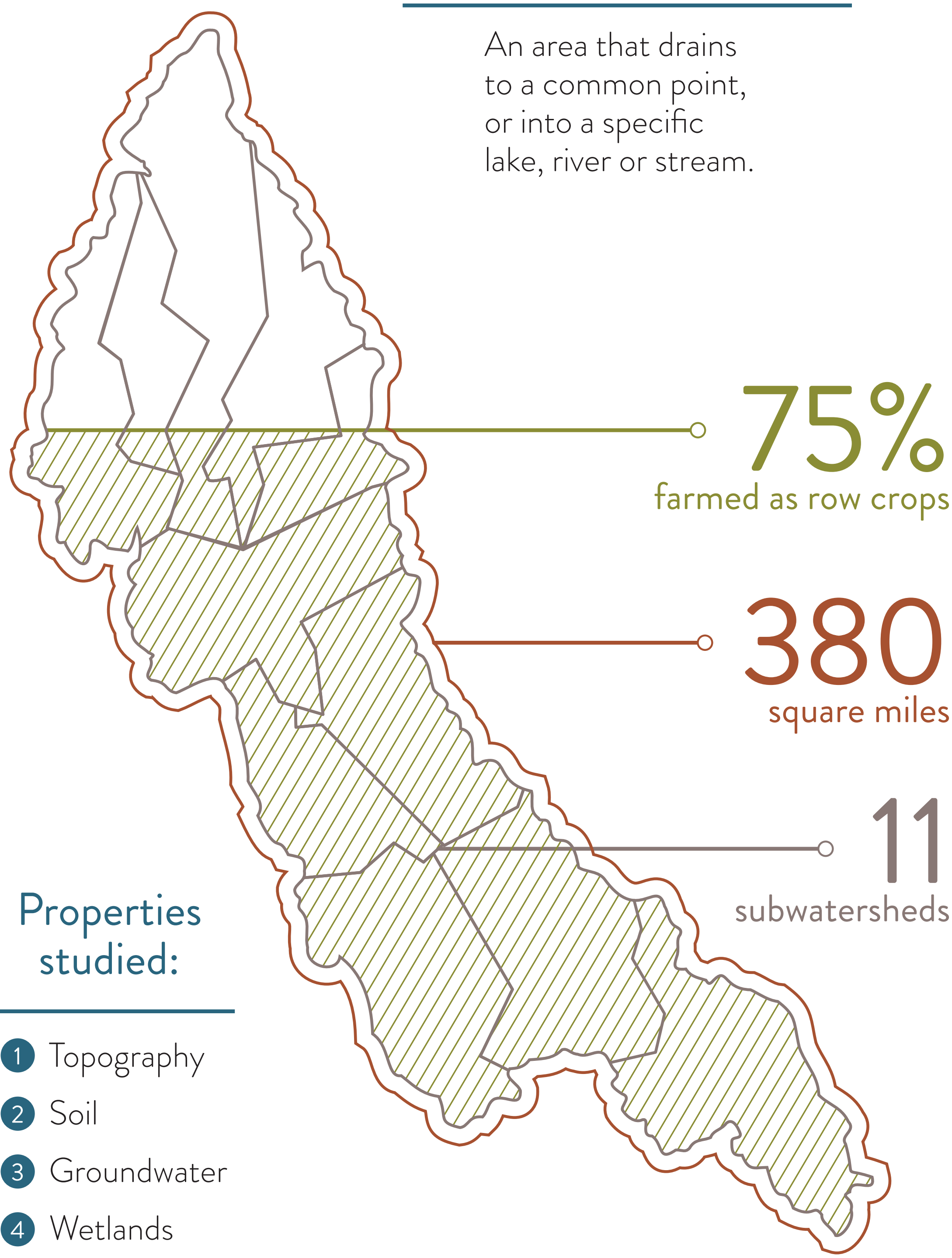
A watershed is an area of land that drains to a common point. The Beaver Creek watershed covers approximately 380 square miles across parts of Boone, Dallas, Greene, Polk and Webster Counties in Central Iowa. The footprint of its watershed includes fifteen communities and unincorporated areas within each county. Beaver Creek generally drains from north to south, to its confluence with the Des Moines River just north of Interstate 80 along the boundary between Des Moines and Johnston.

The Des Moines River flows generally southeast, first through Red Rock Lake in Marion County. Then, into the Mississippi River near Keokuk at the far southeastern corner of the state. The Mississippi River flows south, ultimately reaching the Gulf of Mexico in Louisiana.

02

What is a watershed?

An area that drains
to a common point,
or into a specific
lake, river or stream.



Properties studied:

1. Topography
2. Soil
3. Groundwater
4. Wetlands

WATERSHED NETWORK

The United States Geological Survey (USGS) created a hierarchical system of watershed areas represented by a unique Hydrologic Unit Code (HUC) number. There are six levels in the hierarchy, represented by hydrologic unit codes from 2 to 12 digits long, called regions, subregions, basins, subbasins, watersheds, and subwatersheds. **Table 2.1 describes the USGS system's hydrologic unit levels and their characteristics.** In this hierarchy, Beaver Creek is a HUC-10 Watershed within the Middle Des Moines Subbasin (HUC-8)

Table 2.1: USGS Watershed Hierarchical System

USGS WATERSHED HIERARCHICAL SYSTEM				
NAME	HUC LEVEL	AVERAGE SIZE	EXAMPLE NAME FROM BEAVER CREEK WATERSHED	EXAMPLE CODE (HUC)
Region	2	177,560 sq-miles	Upper Mississippi River	07
Subregion	4	16,800 sq-miles	Des Moines	0710
Basin	6	10,596 sq-miles	Des Moines	071000
Subbasin	8	700 sq-miles	Middle Des Moines	07100004
Watershed	10	40,000–250,000 acres	Beaver Creek	0710000409
Subwatershed	12	10,000–40,000 acres	Headwaters Beaver Creek	071000040905

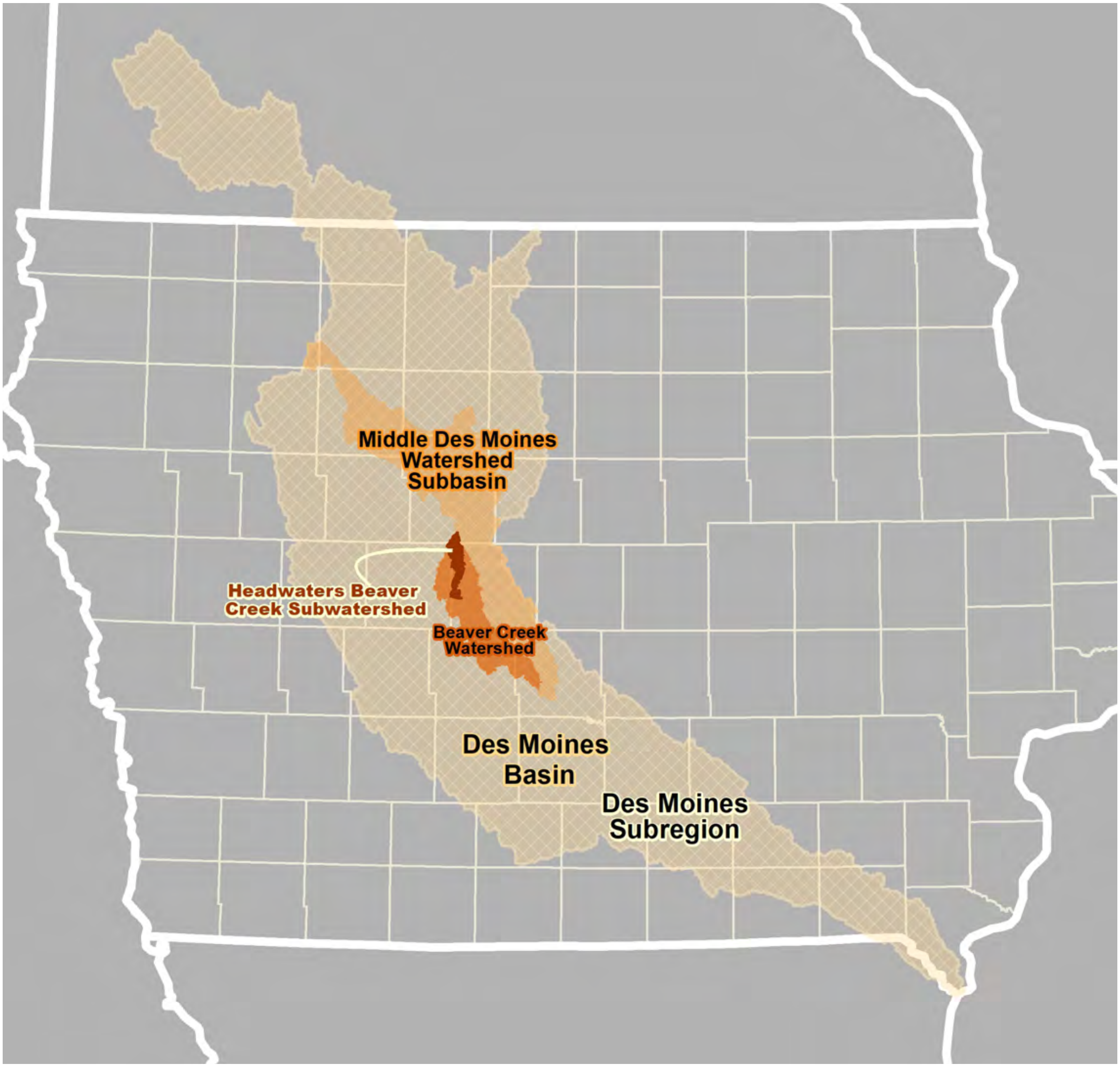
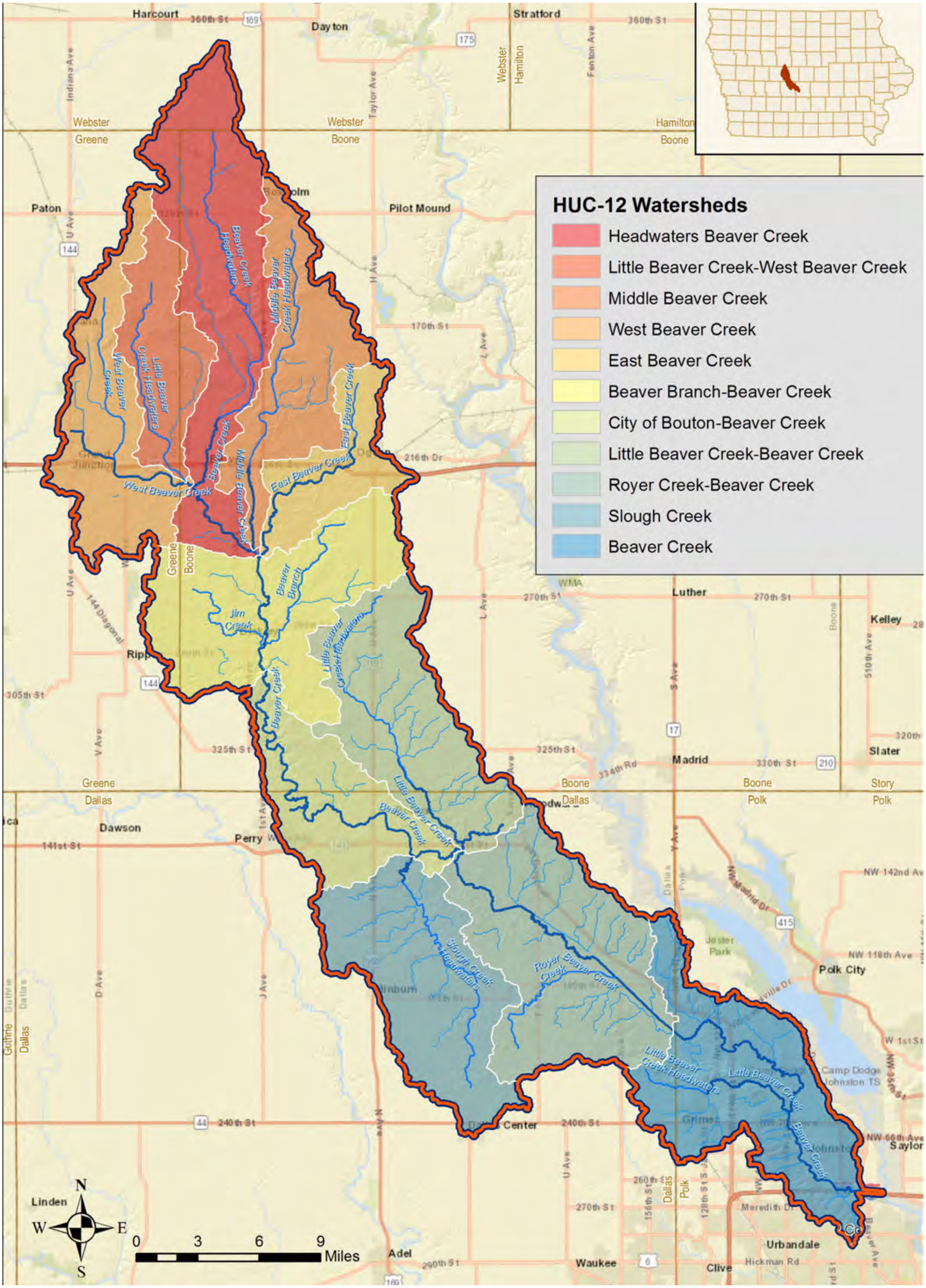


Figure 2.1. USGS Hydrologic Hierarchy System: Beaver Creek Illustration

Figure 2.2. HUC-12 Watersheds of the Beaver Creek Watershed



Subwatersheds (HUC-12)

Subwatersheds are the smallest unit within the USGS system although many times these are further subdivided for a variety of purposes, particularly when developing hydrologic and water quality models. **The Beaver Creek Watershed includes eleven Subwatersheds (HUC-12)** as shown in Table 2-2 and Figure 2.2. Subwatersheds are the hydrologic scale that is commonly used for implementation efforts. At this scale landowners are likely to have established personal relationships and a small, dedicated group can have a meaningful role in improving the health of a subwatershed.

Table 2.2: Watersheds and subwatersheds of Beaver Creek Watershed

WATERSHEDS AND SUBWATERSHEDS OF BEAVER CREEK WATERSHED		
SUBWATERSHED NAME	HUC-12 CODE	ACRES
Beaver Branch-Beaver Creek	71000040906	27,747
Beaver Creek	71000040911	28,205
City of Bouton-Beaver Creek	71000040909	16,892
East Beaver Creek	71000040904	10,559
Headwaters Beaver Creek	71000040905	30,156
Little Beaver Creek - Beaver Creek	71000040908	23,627
Little Beaver Creek-West Beaver Creek	71000040901	12,170
Middle Beaver Creek	71000040903	18,537
Royer Creek-Beaver Creek	71000040910	31,767
Slough Creek	71000040907	25,381
West Beaver Creek	71000040902	19,306

LAND COVER

Land cover and use, both natural and human influenced, are the main factors driving the quality and character of water resources in the Beaver Creek Watershed. **Land use within the Beaver Creek Watershed is predominately (>75%) agricultural,** with urban development largely limited to the larger communities surrounding the Des Moines metropolitan area in the southern third of the watershed (Table 2.3 and Figure 2.3). The distribution of land cover in the Beaver Creek Watershed was determined using Iowa's High \Resolution Land Cover Dataset, with a spatial resolution of one square meter. **Figure 2.4 maps the location of the high resolution land cover dataset for all of the Beaver Creek Watershed.** This dataset illustrates that the forested/grassland riparian areas are primarily located along the portion of Beaver Creek that is south of Berkley. Land cover is varied within the developed portions of the watershed.

The impact various land cover has on water quality is further described in the discussion within this report.

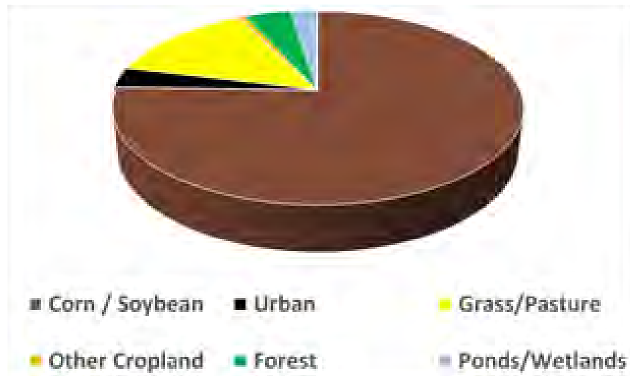
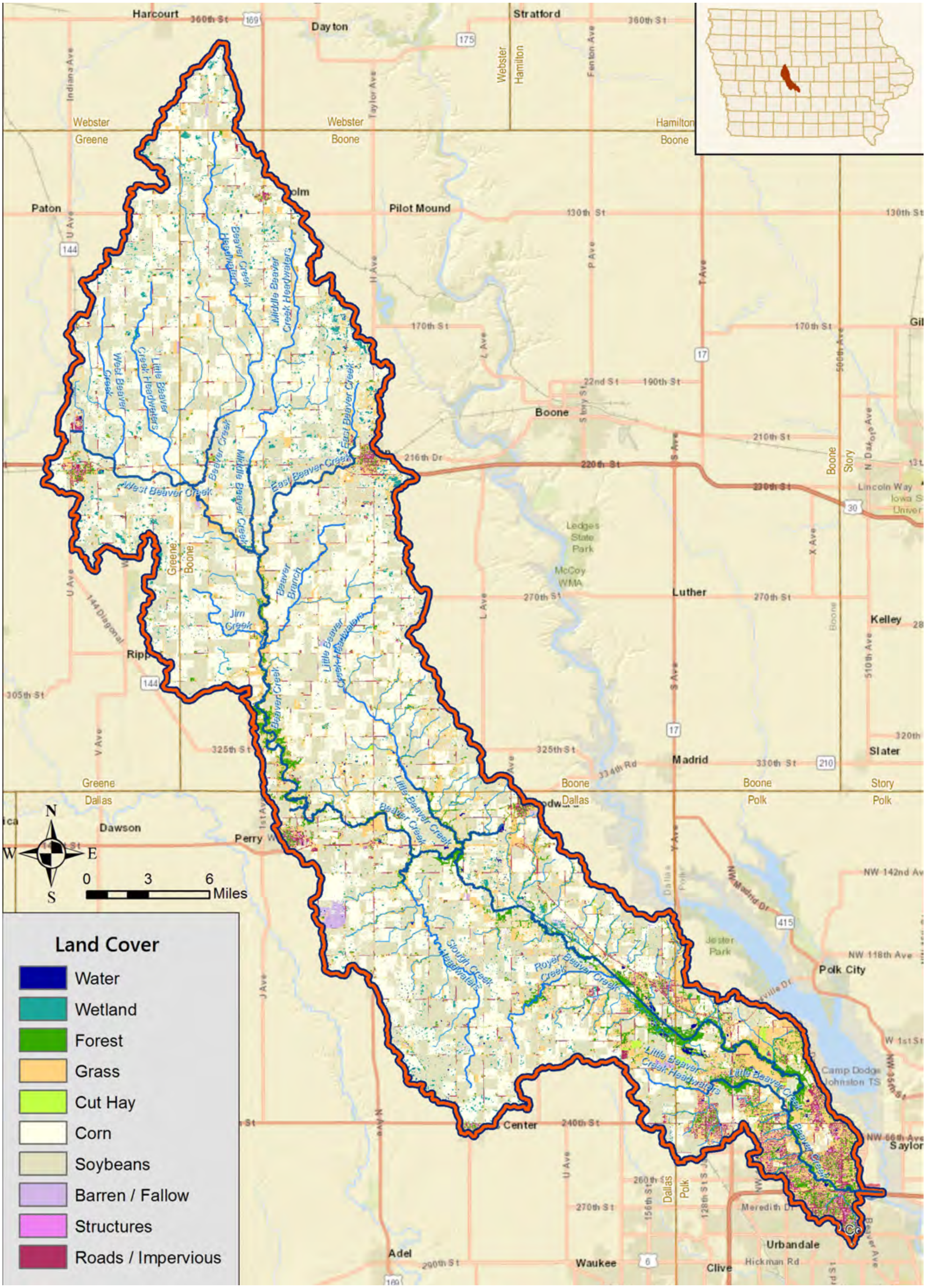


Figure 2.3. HUC-12 Watersheds of the Beaver Creek Watershed

Table 2.3: Creek Watershed - Land Cover

HUC-12 NAMES	% FORESTED	% GRASSLAND	% WATER/ WETLAND	% ROW CROP	% DEVELOPED
City of Bouton	9.4%	9.4%	1.6%	68.5%	3.5%
West Beaver Creek	1.1%	1.1%	3.2%	84.6%	2.8%
Middle Beaver Creek	0.5%	0.5%	4.2%	83.1%	1.4%
Little Beaver Creek	0.5%	0.5%	2.1%	88.2%	1.2%
Beaver Creek	15.0%	15.0%	1.6%	37.8%	12.6%
Slough Creek	1.9%	1.9%	2.4%	84.0%	1.4%
Royer Creek	7.6%	7.6%	2.6%	69.5%	2.5%
Little Beaver Creek	3.0%	3.0%	1.1%	81.2%	1.9%
Beaver Branch	1.3%	1.3%	1.8%	86.4%	1.1%
East Beaver Creek	1.7%	1.7%	3.9%	72.7%	3.8%
Headwaters Beaver Creek	0.7%	0.7%	2.8%	84.7%	1.6%
Watershed Totals	**3.9%**	**3.9%**	**2.5%**	**76.4%**	**3.1%**

Figure 2.4. Beaver Creek Watershed - High Resolution Land Cover



TOPOGRAPHY

Figure 2.5 depicts the topographical relief and varying slopes found within the watershed. It was derived using LIDAR data. LIDAR (Light Detection and Ranging) is a remote sensing method that uses light in the form of a pulsed laser to measure variable distances to the ground. **The vast majority (77.1%) of the watershed has gentle, rolling slopes of less than 5%.** The northern most ten miles of the Beaver Creek are so flat that they have been described as a system of slough and ponds without a defined channel. Steeply sloped areas identified include those areas adjacent to Beaver Creek south of Berkley, areas adjacent to the headwaters of Royer Creek, and areas adjacent to Little Beaver Creek just north of Grimes.

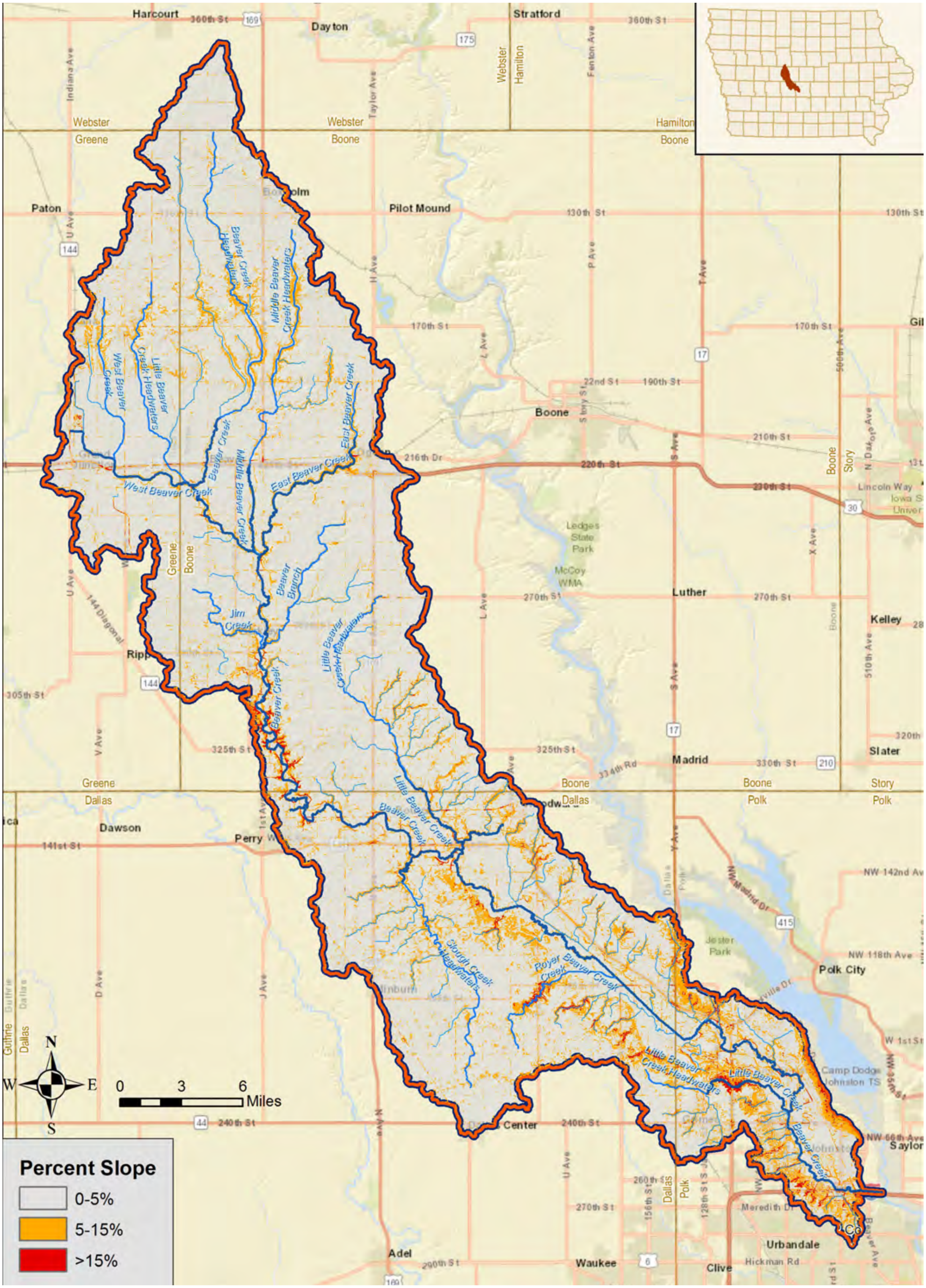
Steeply sloped areas are exceeding 15% which represents less than 3% of the total watershed area.

The topography of the watershed was used as factor in developing recommendations for areas within the watershed to protect. It also provided one of the key indicators in locating streambank erosion areas. Note that the streambank erosion areas identified were not ground-truthed but based on topography and stream stratigraphy and therefore may not reflect reality in the stream. **Further field review is recommended prior to advancing and restoration efforts. Refer to Chapter 7 for more information about stream conditions.**

Did you know?

The highest point in the watershed is located within the Gary moraine, a remnant ridge from the Wisconsin Glaciation located in the northern part of the Webster County with an altitude of 1,184 feet. The lowest elevation is on the flood plain of Beaver Creek where the stream leaves the watershed, at 812 feet.

Figure 2.5: Beaver Creek Watershed – Percent Slope



SOILS

The Soil Survey Geographic (SSURGO) soils GIS layer available from the United States Department of Agriculture (USDA) were clipped to the watershed boundary. This tabular data includes hydrologic soil group classification. Each Map Unit Symbol corresponds to a soil series description, which describes the major characteristics of the soil profile for the given Map Unit.

The Natural Resource Conservation Service (NRCS) has classified soil series into Hydrologic Soils Groups (HGS) based on the soil's runoff potential. There are four major HSGs (A, B, C, and D) and 3 dual HSG groups (A/D, B/D, and C/D). **HSG A soils have the lowest runoff potential whereas HSG D soils have the greatest**. Dual soil series include those soils that have an upper soil profile which is conducive to allowing water to infiltrate similar to a type A, B, or C soil and an underlying confining layer within 60 inches of the soil surface that restricts the downward movement of water. The first letter applies to the drained condition, if undrained, the soil will act more like a D soil with a higher runoff potential and lower infiltration rates. Dual soil series were grouped into one category for mapping purposes.

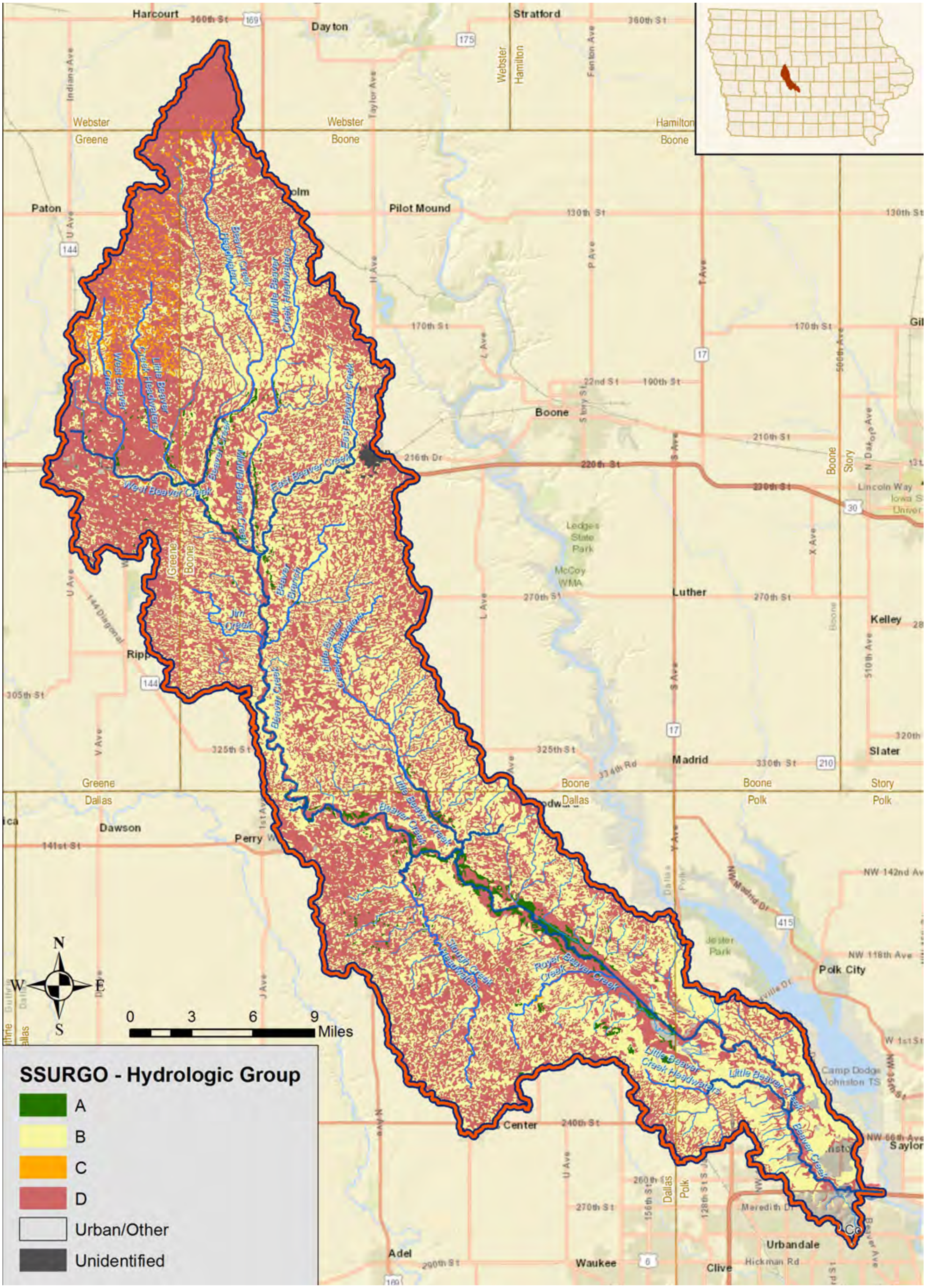
Group A soils consist of sand, loamy sand, or sandy loam soil types. These soils have very low runoff potential and high infiltration rates.

Group B soils consist of silty loams or loams. These soils have moderately high infiltration rates and low runoff potential.
Group C soils consist of sandy clay loam. The have low infiltration rates and consist of soils with a layer that impedes the downward movement of water and soils. These soils have moderately high runoff potential.

Group D soils consist of clay loam, silty clay loam, sandy clay, silty clay, or clay soils with the highest runoff potential. These soils have very low infiltration rates and a high water table.

The hydrologic soil groups in Beaver Creek Watershed are illustrated in Figure 2.6. **The primary soil hydrologic groups are moderately well drained (B) and moderately well drained with a high water table (B/D).** Mapped soil series in the uplands include primarily hydrologic soil group B soils including Clarion, Nicollet, Sparta, and Spillville soil series. These soil series are comprised of deep, moderately drained loams, silty loams and clay loams. Soil series located within the many concave depressions associated with former prairie-pothole wetlands include Knoke, Biscay, Canisteo, Webster, and Zook. These soils series are deep, poorly drained, silty, clay-loams. Areas containing row crop (Corn/Soybean) land cover with B/D or C/D soils represent likely locations for subsurface tile drainage. The installation of subsurface tile drainage in areas with B/D and C/D soils has allowed for row crops to thrive in areas that were historically wetland.

Figure 2.6: Beaver Creek Watershed – Hydraulic Soil Group



GEOLOGY AND GROUNDWATER RESOURCES

The following is a summary of the groundwater resources and underlying geology of the Beaver Creek Watershed, based on available data included in a review of Geology of Boone County, a report compiled by Samuel Walker Beyer; Geology of Dallas County, a report compiled by A.G. Leonard; Geology of Polk County, a report compiled by H.F. Bain; and data collected by the Iowa DNR.

Approximately 80% of Iowa residents in both urban and rural settings rely on groundwater as their primary source of drinking water. Protecting groundwater quality and quantity is extremely important to Beaver Creek Watershed residents as groundwater availability is limited in certain areas of the watershed either due to poor water quality (high mineral content), distribution (distance to areas where it is needed), or yield (adequacy of overall available supply). **In general, the portions of the watershed in Boone County, which includes the northeastern third of the watershed, have limited groundwater availability;** fortunately these areas are outside of large population centers so the amount of water is sufficient for local domestic uses. The westernmost portion of the watershed that falls within **Greene County obtains groundwater from buried sand and gravel aquifers** which vary widely in their capacity to produce high-quality water. The southernmost portions of the watershed that fall in **Dallas County and Polk County contain a greater abundance of groundwater with several artesian wells** located less than 100 feet from the surface that supply a sufficient quantity of water to meet local demand.

Surficial Hydrogeology

The Beaver Creek Watershed is covered by glacial drift commonly associated with two periods of glaciation, the Late Wisconsin Episode (Des Moines Lobe) and the earlier Hudson Episode. Since the glacial period, the surface has been worked and re-worked by rivers and streams, eroding valleys, leaving significant alluvial deposits.

The Cambrian-Ordovician aquifer covers nearly the entire state of Iowa. The Cambro-Ordovician aquifer is the major deep aquifer in the watershed, and includes the St. Peter Sandstone, the Prairie du Chien dolomite, and the Jordan Sandstone, the last being the major water producer (Thompson, 1982). The Cambrian-Ordovician aquifer is confined by a series of geologic units comprised of shale, dolomite and limestone that control downward groundwater transport to the aquifer. **Generalized hydrogeological cross-sections for Iowa including the Des Moines River are shown in (Figure 2.7).** In the Beaver Creek Watershed, the Cambrian-Ordovician aquifer is covered by the Mississippian Aquifer which overlays a series of confining layers consisting of limestone, dolomite, and shale.

These confining layers include the Dakota, Windrow series, the Pella and St. Louis Formation, the Lower and Upper Cherokee Groups, and the Marmaton Group (Figure2.8).

Recharge to the Mississippian aquifer is from: 1) precipitation where the bedrock is at or near the surface, 2) leakage to the aquifer from Beaver Creek and its tributaries, and 3) groundwater inflow from areas outside of the Beaver Creek watershed. The Mississippian Aquifer is heavily used as a drinking and industrial water supply. The Devonian-Silurian Aquifer (Middle Bedrock Aquifer) is also used by several communities and rural residents. The main water-producing units in the Devonian-Silurian are a series of limestones and dolostones. There are also more than 80 shallow, quaternary, and alluvial wells that are heavily used as both a drinking water source and industrial water supply.

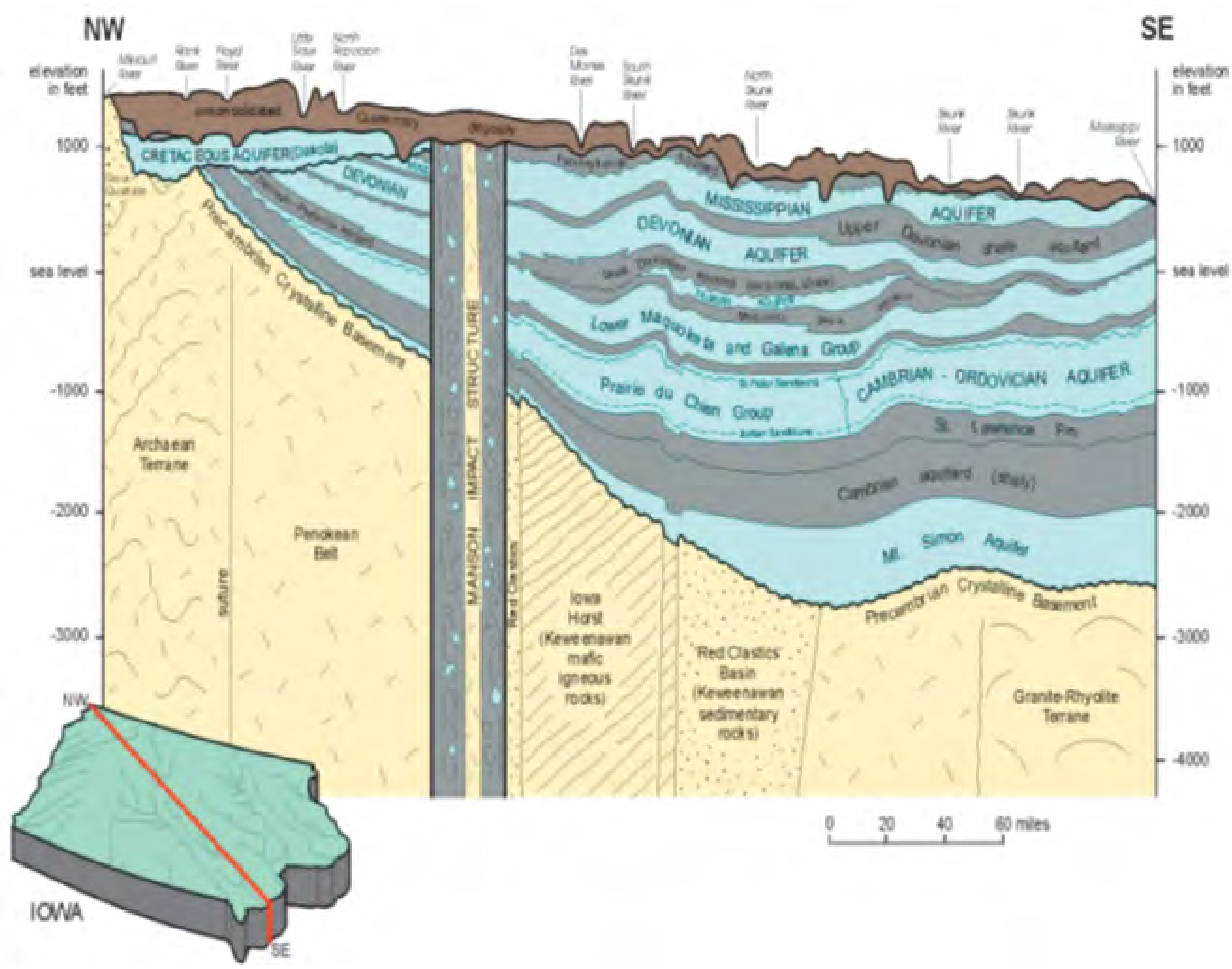
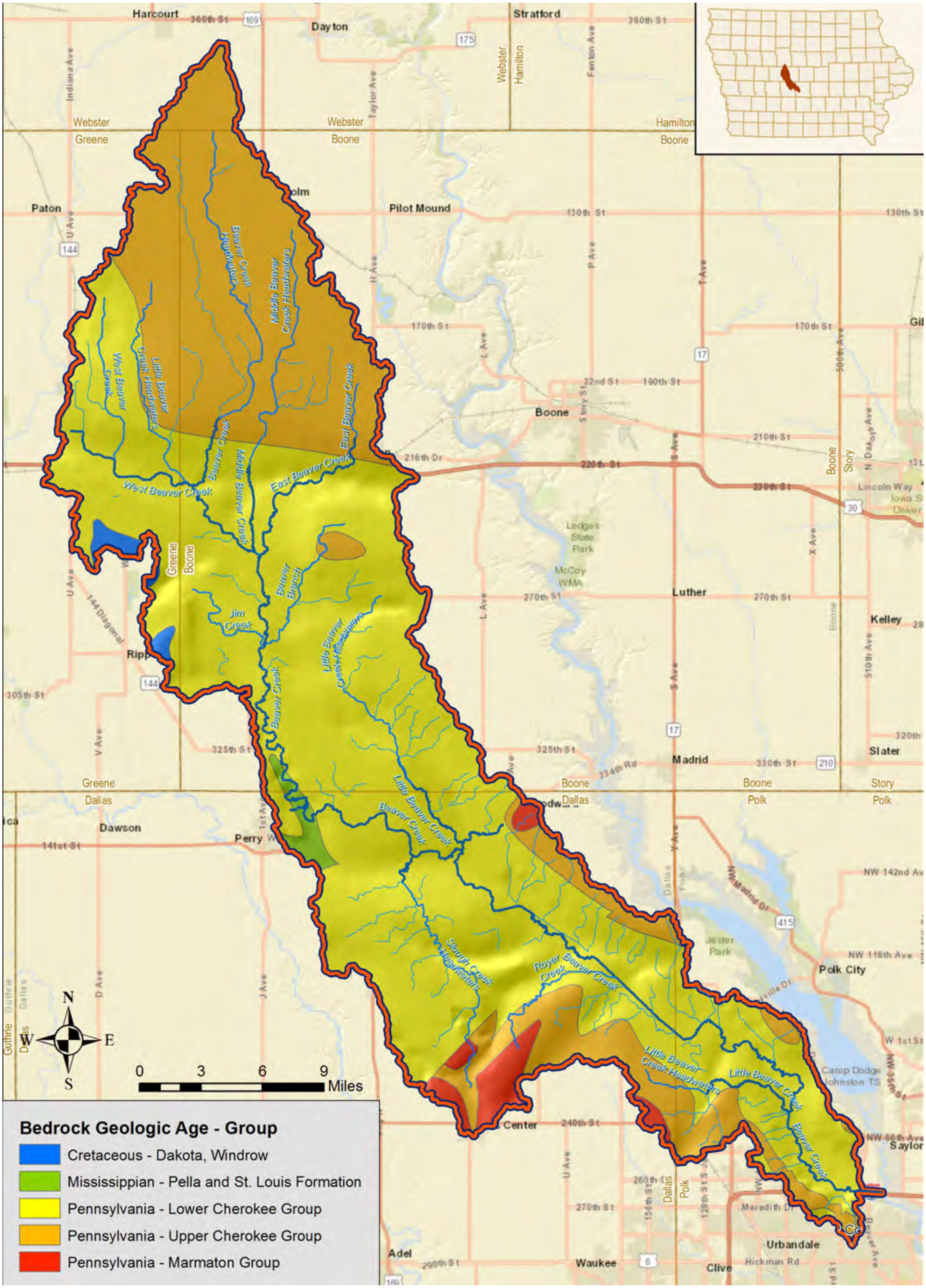


Figure 2.7: Generalized hydrogeological cross-section from northwestern to southeastern Iowa (modified from Prior and others, 2003).

Figure 2.8: Bedrock Geologic Age and Group



Groundwater Vulnerability

In 1991, the Iowa DNR identified regions of Iowa with similar hydrogeological characteristics and classified these characteristics into 10 unique groups (map units) based on their relative vulnerability to groundwater contamination. **Reviewing these classifications for Beaver Creek Watershed makes it possible to see where groundwater protection issues are most relevant.** Within the Beaver Creek Watershed, there are four map unit classifications (Figure 2.9); groundwater quality, yield, and susceptibility to contamination are described below for each map unit:

Alluvial Aquifers: Areas underlain by sand and gravel aquifers situated beneath floodplains along stream valleys, alluvial deposits are associated with stream terraces and benches, and glacial outwash deposits. Natural water quality is generally excellent (less than 500 mg/L total dissolved solids [TDS]) and yields vary with texture and thickness of alluvium (commonly greater than 100 gallons/minute [GPM] in larger valleys, less in smaller valleys). Most wells are very shallow; high potential for aquifer contamination; high potential for well contamination.

Variable Bedrock Aquifers: Area underlain by regional bedrock aquifers, including carbonate and sandstone units; aquifers vary considerably in natural water quality (500-2000 mg/L TDS) and yields (although generally above 20 GPM).

Moderate Drift Confinement: 100 to 300 feet of glacial drift overlie regional aquifers; most wells aredeep and completed in the bedrock aquifer. Low potential for aquifer contamination; low potential for well contamination.

Shale Drift Confinement: Cherokee shales or Upper Cretaceous shales overlie Mississippian carbonate or Dakota Sandstone aquifers respectively. Most wells are shallow and developed in the drift, some wells are deep and completed in the bedrock aquifer. Low potential for aquifer contamination; high potential for contamination of drift wells; moderate potential for contamination of bedrock wells.

Drift Groundwater Source: Bedrock aquifers are absent or overlain by greater than 300 feet of glacial drift; wells are completed in thin, discontinuous deposits of sand and gravel within the till or at the interface between overlying loess and rill: natural water quality is highly variable (250-2500 mg/L TDS) and yields are generally low (less than 10 GPM). Most wells are shallow and completed in the drift; low potential for bedrock aquifer contamination; high potential for well contamination.

Two highly susceptible wells have been identified in 2 communities (Grimes and Woodward) within the Beaver Creek Watershed (Figure 2.9). Communities can coordinate with the IDNR to conduct a site investigation to determine if the contaminant is from a point or non-point source.

Source Water Protection Areas and Highly Vulnerable Groundwater Wells

The Iowa DNR has also developed a GIS layer depicting Groundwater capture zones – the land surface area that has been determined to provide water to a public water supply well based on available geologic and hydrogeologic information. **Groundwater capture zones located in areas with high vulnerability for aquifer and well contamination and/or areas with high-observed pollutant concentrations (i.e., nitrate-nitrite concentrations exceeding 10 mg/L) should be prioritized as source water protection areas** (Figure 2.10). The Iowa DNR operates a Source Water Protection Program, which requires a Phase 1 Assessment that defines the source water area and susceptibility to contamination.

Wetland in the Beaver Creek watershed.

Figure 2.9: Beaver Creek Watershed Highly Susceptible Wells and Groundwater Vulnerability

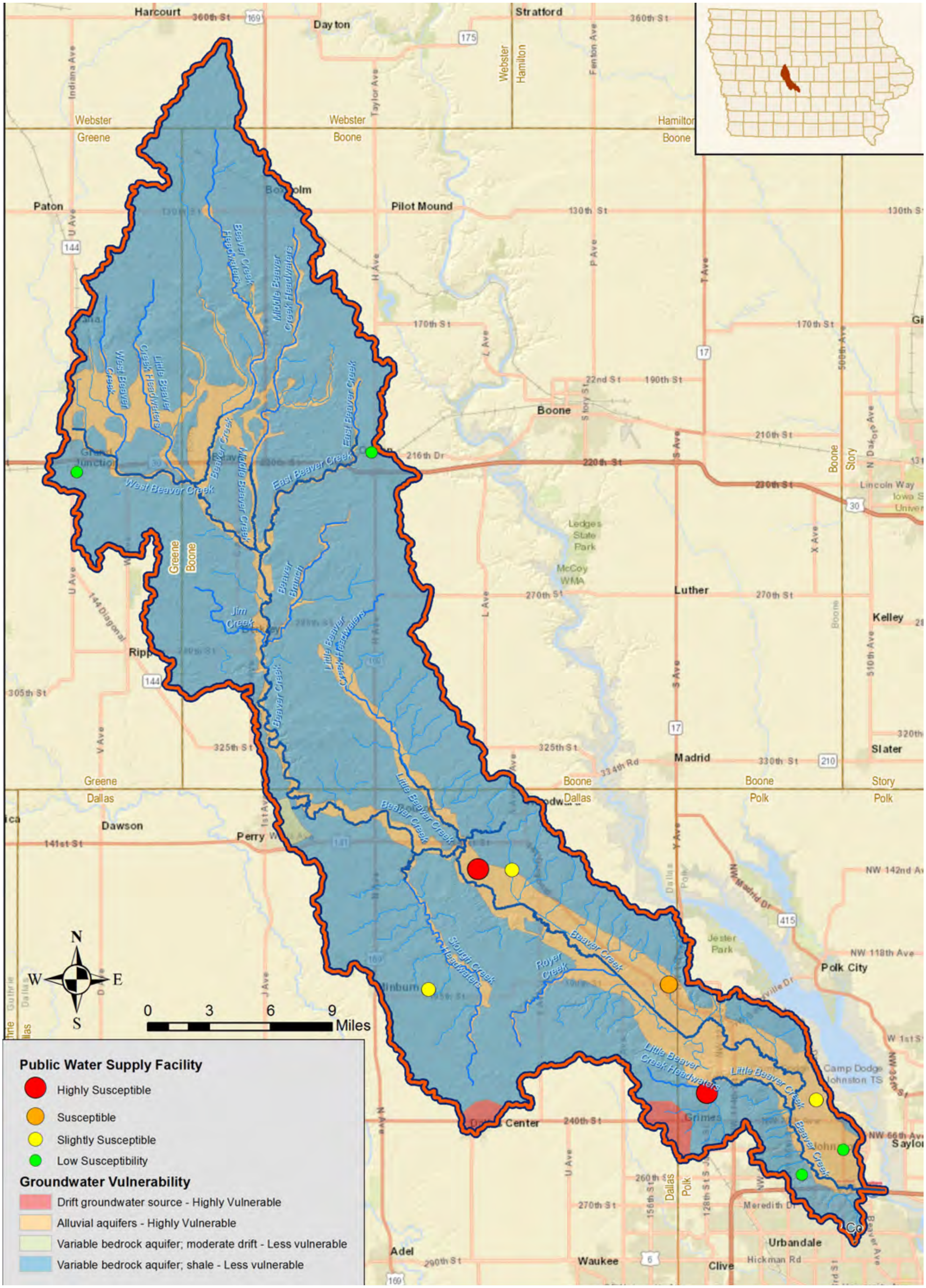
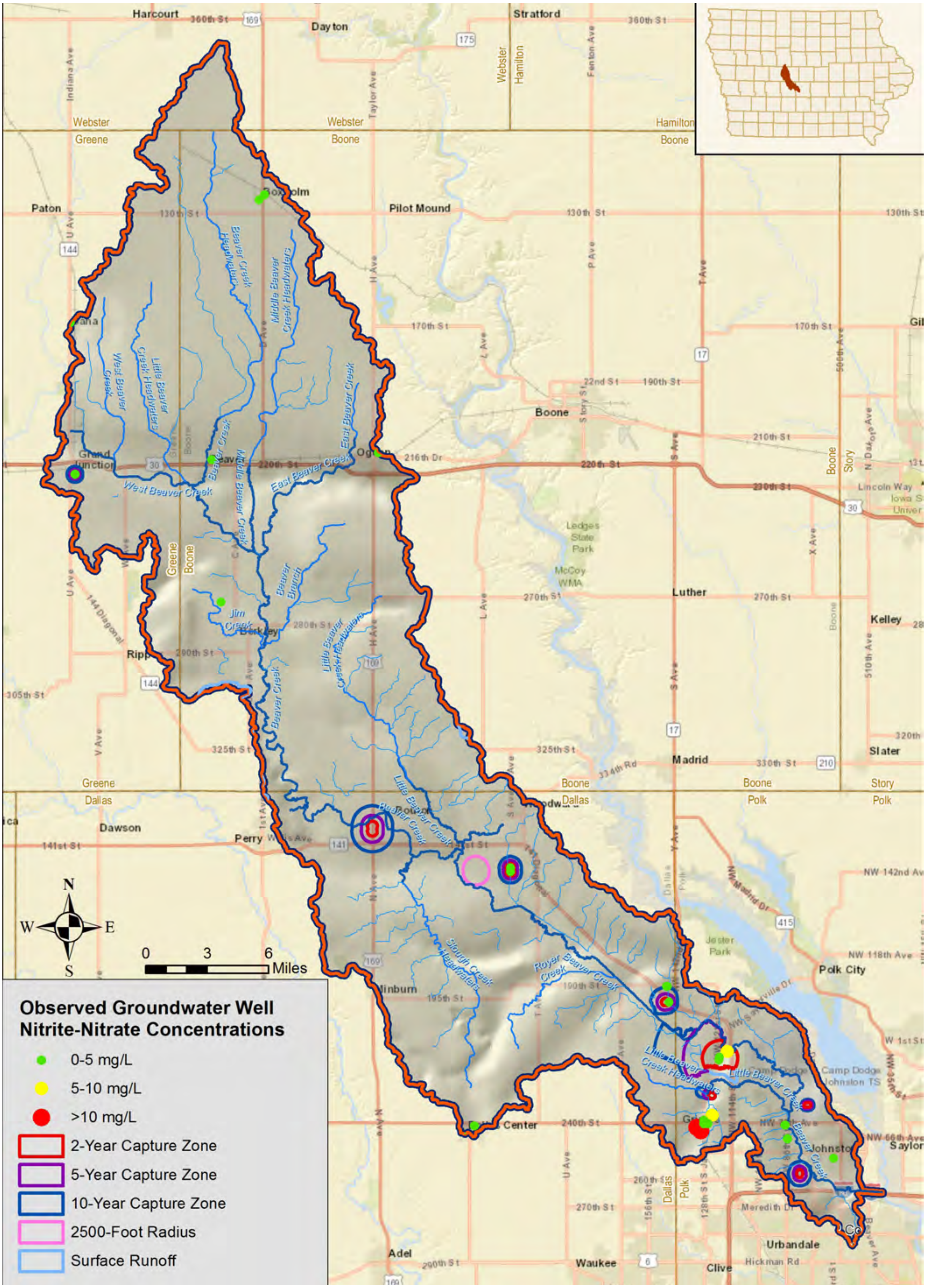


Figure 2.10: Groundwater Capture Zones (SourceWater Protection Areas) and Observed Nitrate-Nitrite Concentrations



STREAM RIPARIAN AREAS

Riparian areas are the areas immediately adjacent to a stream. These areas can provide significant benefits to the stream if they are in a healthy state, adequately vegetated with a natural plant community. **An evaluation of riparian health was conducted by looking at the land cover within the areas immediately adjacent (within 150 feet) to the streams of Beaver Creek Watershed** using the Iowa DNR's High Resolution (1 square meter) Land Cover dataset. Areas where the stream riparian area consisted of natural land (Forests, Grasslands) were mapped as 'natural' areas.

These are riparian areas that should be protected in the future. Table 2.4 provides a breakdown of the riparian landcover distribution for the primary streams in the watershed. **Areas where the exiting landcover within the riparian zone is currently cropland represent restoration opportunities as described later in the report.** There are several examples of where remaining tracts of natural land cover intersect the stream riparian area, such as the largely forested buffers adjacent to Beaver Creek near Berkley (Figure 2.11).

STREAM NAME	% FORESTED	% GRASSLAND	% WETLAND	% ROW CROPS	% DEVELOPED
Beaver Creek (Mouth of Beaver Creek to Boone/Dallas county line)	64%	11%	13%	10%	3%
Beaver Creek (Mouth of Beaver Creek to Boone/Dallas county line)	32%	45%	14%	7%	4%
East Beaver Creek	6%	57%	5%	31%	2%
Little Beaver Creek (Mouth to confluence with an unnamed tributary in Polk County)	55%	21%	3%	16%	5%
Little Beaver Creek (Mouth to confluence with an unnamed trib. in Boone County)	54%	24%	5%	15%	3%
Middle Beaver Creek	1%	68%	11%	18%	1%
Slough Creek	61%	19%	7%	13%	8%
Unnamed Creek (Little Beaver Creek)	53%	21%	1%	24%	2%
Unnamed Creek (City of Bouton)	14%	33%	8%	43%	3%
Unnamed Creek (West Beaver Creek)	0%	21%	3%	51%	27%
Unnamed Creek (West Beaver Creek)	1%	17%	1%	81%	0%
West Beaver Creek	79%	49%	5%	37%	2%

Table 2.4: Riparian Landcover Distribution within 150 feet of Primary Streams in the Beaver Creek Watershed.

** Green shading indicates areas within 150' of a stream where more than 40% of the riparian landcover is mapped as a 'natural' land cover. Red shading indicates areas where more than 40% of the riparian landcover is mapped as cropland or more then 25% mapped as developed (impervious).*

LAKES AND WETLANDS

There are 36 conservation and recreation lands with public accesses located within the Beaver Creek Watershed. Many of these parks contains wetlands, ponds, or lakes that provide valuable fish and wildlife habitat as well as recreational opportunities for area residents and visitors (Figures 2.11a and 2.11b).

Terra Lake

Terra Lake is an 8 acre lake located within a 200 acre park within the City of Johnston. The park provides amenities for large gatherings including a newly-constructed amphitheater for outdoor concerts, hiking/ cross-country skiing trails, a fishing pier, a playground, and numerous native plantings. In 2017, the 8-acre lake was stocked with breeding-size largemouth bass, channel catfish, and bluegills which will provide the start of a healthy fish population.

Figure 2.11a: Terra Lake

Brenton Slough

Brenton Slough is a 53-acre backwater wetland complex located north of Grimes. Brenton Slough is located in Polk County's Northwest Planning Area. Polk County has designated the Brenton Slough Wetland Complex as protected open space. Brenton Slough is a well-known location for bird watchers as it provides critical habitat for rare bird species such as Marsh Wrens. Brenton Slough is also frequently visited by anglers seeking to catch largemouth bass, bluegill, and channel catfish.

Figure 2.11b: Brenton Slough

Figure 2.13: Beaver Creek Watershed Lakes and Wetlands

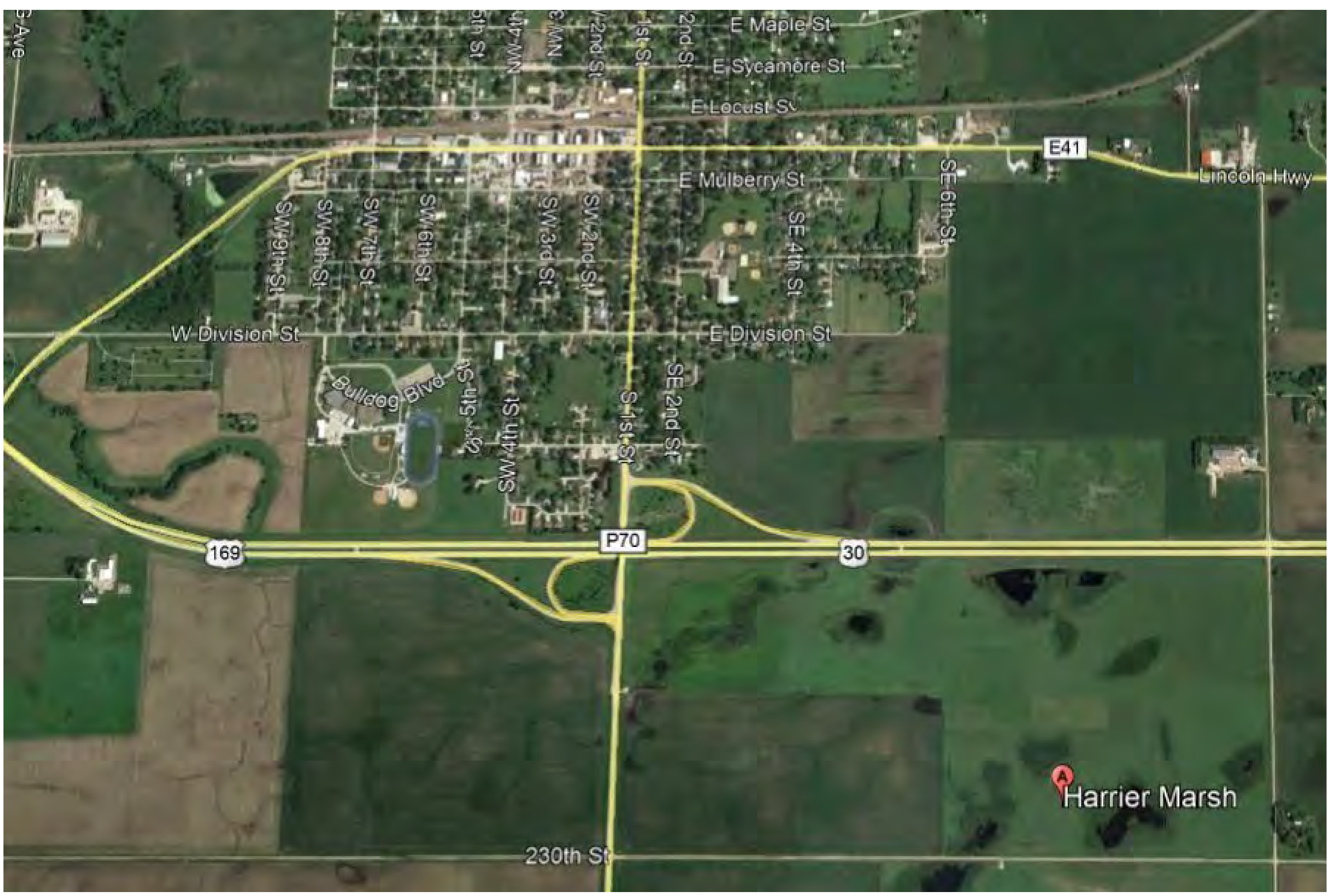
Wetlands

Many of the historic wetlands in the Beaver Creek Watershed were drained for agricultural purposes; however, some wetland areas persist, primarily within floodplains and riparian areas. The remnant wetlands contribute to the watershed through the functions they perform and the value they provide. Wetland functions are the natural processes that occur in the wetlands, and can include hydrologic flux and storage, increased biological productivity, biochemical cycling and storage, increased decomposition, and improved wildlife habitat and diversity. Actual wetland functions vary depending on the type of wetland, position on the landscape, season of the year, and how the surrounding land use impacts the area hydrologically and ecologically.

Wetlands have values that benefit both people and the environment. These values can be based on the functions the wetland carries out, like improving water quality, carbon sequestration, water retention, and habitat; the aesthetic value of the wetland, or the ability of the wetland to provide opportunities for recreation and education.

One wetland in the Beaver Creek Watershed that has been recognized, for not only its wetland functions but its value to the watershed, is Harrier Marsh, located within the 420 acre Harrier Marsh Wildlife Management Area, one mile south of Odgen, near Highway 169.

Aerial photo of Harrier Marsh near Ogden (from Google Earth).



Sign at Harrier Marsh.

Wetland in the Beaver Creek Watershed

03

DESIGNATED USES & IDENTIFIED IMPAIRMENTS

The following sections describe the current state of lakes and streams within the Beaver Creek Watershed. The sections begin with a general summary of the stream network within the watershed followed by a discussion of the water quality conditions of each stream.

03

Support uses

12 segments of Beaver Creek and it's tributaries facilitate recreational uses and wildlife habitat.

Impaired uses

High-levels of nutrients and other biological factors impair recreational uses along Beaver Creek and Little Beaver Creek.

IOWA WATER CLASSIFICATION

Iowa's surface water classifications are described in IAC 61.3(1) as two main categories, **Designated Uses and General Uses.**

Designated use segments are water bodies, which maintain flow throughout the year or contain sufficient pooled areas during intermittent flow periods to maintain a viable aquatic community. **Streams in the Beaver Creek watershed with designated use classifications are described below in Table 3.1.**

General use segments are intermittent watercourses and those watercourses that typically flow only for short periods of time following precipitation and whose channels are normally above the water table. These waters do not support a viable aquatic community during low flow and do not maintain pooled conditions during periods of no flow.

IOWA WATERS DESIGNATED USES

Primary contact recreational use:

Class A1 - Waters in which recreational or other uses may result in prolonged and direct contact with the water, involving considerable risk of ingesting water in quantities sufficient to pose a health hazard. **Such activities would include, but not be limited to, swimming, diving, water skiing, canoeing and kayaking.**

Secondary contact recreational use:

Class A2 - Waters in which recreational or other uses may result in contact with the water that is either incidental or accidental. During the recreational use, the probability of ingesting appreciable quantities of water is minimal. **Class A2 uses include fishing, commercial and recreational boating, any limited contact incidental to shoreline activities,** and activities in which users do not swim or float in the water body while on a boating activity.

Children's recreational use:

Class A3 - Waters in which recreational uses by children are common.

Class A3 waters are water bodies having definite banks and bed with visible evidence of the flow or occurrence of water. **This type of use would primarily occur in urban or residential areas** where children may come in contact with the water resource through such activities as playing/splashing in the stream or attempting to sein for minnows, catch tadpoles, etc.

Warm water Type 1:

Class BWW-1 - Waters in which temperature, flow, and other habitat characteristics are **suitable to maintain warm water game fish populations,** along with a resident aquatic community that includes a variety of native nongame fish and invertebrate species. These waters generally include border rivers, large interior rivers, and the lower segments of medium-size tributary streams.

Warm water Type 2:

Class BWW-2 - Waters in which flow or other physical characteristics are capable of supporting a resident aquatic community that includes a variety of native nongame fish and invertebrate species. The flow and other physical characteristics limit the maintenance of warm water game fish populations. These waters generally consist of small perennially flowing streams.

Human health:

Class HH - Waters in which fish are routinely harvested for human consumption, or waters both designated as a drinking water supply.

Paddlers on Beaver Creek during an event opening a water trails access in Johnston (City of Johnston).

Table 3.1: Surface Water Designated Use Classifications for Beaver Creek Watershed Streams

STREAM	REACH DESCRIPTION	A1	A2	A3	BWW-1	BWW-2	HH
Beaver Creek	Mouth of Beaver Creek (S17, T79N, R24W, Polk Co.) to Boone/Dallas county line (NW 1/4, NW 1/4 S2, T81N, R28W)	✓				✓	
	Boone/Dallas county line (NW 1/4, NW 1/4 S2, T81N, R28W) to the confluence with Unnamed Creek (S29, T84N, R28W, Boone Co.).		✓			✓	
East Beaver Creek	Mouth (NE 1/4 S21, T83N, R28W, Boone Co.) to 210th Street (North Line S31, T84N, R27W, Boone Co.).		✓			✓	
Little Beaver Creek (Beaver Creek)	Mouth (S35, T80N, R25W, Polk Co.) to confluence with an unnamed tributary (SW1/4, SW1/4, S29, T80N, R25W, Polk Co.)		✓			✓	
Little Beaver Creek (Little Beaver Creek)	Mouth (S14, T81N, R27W, Dallas Co.) to confluence with an unnamed tributary (SE1/4, SE1/4, S29, T82N, R27W, Boone Co.)		✓			✓	
Middle Beaver Creek	Mouth (S21, T83N, R28W, Boone Co.) to Hwy. 30 (N. line, S4, T83N, R28W, Boone Co.)		✓			✓	
Slough Creek	Mouth (S16, T81N, R27W, Dallas Co.) to confluence with an unnamed tributary (NW1/4, S21, T81N, R27W, Dallas Co.)		✓			✓	
Unnamed Creek (Little Beaver Creek)	Mouth (S11, T81N, R27W, Dallas Co.) to S. Line SW 1/4, NE 1/4, S12, T81N, R27W, Dallas Co.)		✓			✓	
Unnamed Creek (City of Bouton)	Mouth (S2, T81N, R28W, Dallas Co.) to K Circle (W. Line S2, T81N, R28W, Dallas Co.)		✓			✓	
Unnamed Creek (West Beaver Creek)	Mouth (SE 1/4, SW 1/4, S28, T84N, R29W, Greene Co.) to the road crossing at U Avenue (West line S28, T84N, R29W, Greene Co.).		✓			✓	
Unnamed Creek (West Beaver Creek)	Mouth (SW 1/4, SE 1/4, S34, T84N, R29W, Greene Co.) to the confluence with Unnamed Creek #1 (SE 1/4, SW 1/4, S28, T84N, R29W, Greene Co.).		✓			✓	
West Beaver Creek	Mouth (SE 1/4, SW 1/4, S6, T83N, R28W, Boone Co.) to the confluence with Unnamed Creek #2 (SW 1/4, SE 1/4, S34, T84N, R29W, Greene Co.).		✓			✓	

** Stream designated use classifications are based upon Iowa's Surface Water Classification Document (SWC), which was approved by the EPA on June 17, 2015.*

*** The four Unnamed Creeks were assigned to their respective HUC-12 watersheds shown in parenthesis in an attempt to differentiate the streams and provide additional context as to the location of the stream within the Beaver Creek Watershed.*

Table 3.2: Surface Water Designated Use Summary for Primary Streams in the Beaver Creek Watershed Streams

DESIGNATION CLASS	DESCRIPTION	NUMBER OF DESIGNATED STREAM SEGMENTS
Class A1	Primary contact recreational use	1
Class A2	Secondary contact recreational use	11
Class BWW-2	Warm water Type 2	12

Buffalo Grove Wildlife Area in Boone County.

IMPAIRED WATERS

Stream impairments are described in relation to their surface water classification and designated uses in. The State of Iowa has developed water quality standards for lakes and streams so that these waters support recreational uses and aquatic life (fish and macroinvertebrates). **Two stream reaches within the Beaver Creek Watershed are listed on EPA's 303 D list of impaired waterbodies due to elevated bacteria levels and/or aquatic life impairments (Figure 3.1)**. Beaver Creek is a major tributary to the Des Moines River. The Des Moines River is impaired for excess nutrients (nitrates) and bacteria (E. coli). The Iowa DNR approved the Water Quality Improvement Plan for Des Moines River, Iowa: Total Maximum Daily Load for Nitrate in 2009.

Des Moines River Nitrate TMDL

A TMDL Study is a determination of the maximum load of pollutant a given water body can receive and continue to meet water quality standards for that particular pollutant. TMDLs are conducted on water bodies where pollutant levels have been found to be in excess of water quality standards resulting in the water body failing to meet a designated use. TMDL studies determine a pollutant reduction target and allocate a portion of the needed reductions to each source of pollutant. Pollutant sources are characterized as either point sources or nonpoint sources. **Point sources receive a wasteload allocation (WLA) and include all sources that are subject to regulation under the National Pollutant Discharge Elimination System (NPDES) program,** e.g. wastewater treatment facilities, stormwater discharges in Municipal Separate Storm Sewer System (MS4) Communities, and concentrated animal feeding operations (CAFOs). **Nonpoint sources receive a load allocation (LA) and include all remaining sources of the pollutant as well as natural background sources.**

The Des Moines River TMDL Study for Nitrates was developed by Keith E. Schilling and Calvin F. Wolter. The TMDL was developed to address a reach of the Des Moines River that had been identified as being impaired due to excessive nitrate concentrations. The impaired reach is defined as the Des Moines River from the Center Street dam in the City of Des Moines to the Interstate 80 Bridge (segment 04-UDM-0010_2). **For the impaired segment, the Class C (drinking water) uses were assessed as "not supporting" due to the level of nitrate that exceeds state water quality standards and USEPA maximum contaminant level (MCL).** The applicable water quality standard for nitrate is 10 milligrams per liter (mg/l). The Water Quality Improvement Plan calculated the maximum allowable nitrate load from the 6.245 square mile Des Moines River Watershed that will ensure the impaired segment of the Des Moines River meets water quality standards.

Key Findings of the Des Moines River TMDL

- ✓ During the 1995 to 2006 period, nitrate concentrations in the river ranged from 0.5 to 14.5 mg/l and averaged 6.3 mg/l. Nitrate concentrations exceeded 10 mg/l approximately 16.4 percent of the time from 1995 to 2006 (719 out of 4382 values).
- ✓ Nitrate concentrations exhibit clear seasonality, with higher concentrations occurring during April, May, and June; as well as November and December.
- ✓ Elevated nitrate loading rates were associated with the Beaver Creek watershed located in the southern extent of the Des Moines River basin.
- ✓ Point sources contribute to 6.4 percent of the total nitrate load and nonpoint sources contribute 93.6 percent of the total nitrate load in the watershed.
- ✓ Established a target in-stream Nitrate concentration of 9.5 mg/l
- ✓ Nonpoint source nitrate loads require a reduction of 34.4 percent for all daily nitrate loads to be less than the TMDL target (9.5 mg/l).

For the Des Moines River TMDL several nitrate load reduction scenarios were evaluated using a Soil and Water Assessment Tool (SWAT) Model and finding are presented in following table.

Did you know?

There is limited data on the water quality of streams throughout the state. There is not enough data on most streams to identify if they should be classified as impaired.

Most streams that have been classified as impared were studied in greater detail because of an incident or situation that indicated that an impairment was possible.

More streams might be identified as impaired if additional water quality data was available for review.

GLOBAL SCALE NITRATE LOAD REDUCTION SCENARIOS	
SCENARIO	ESTIMATED NITRATE LOAD REDUCTION AT WATERSHED OUTLET
Ammonia Fertilizer Application 100 Reduce the rate of ammonia fertilizer application in the watershed from 170 kg/ha (152 lb/ac) to 100 kg/ha (89 lb/ac)	25.18%
Ammonia Fertilizer Application 50 Reduce the rate of ammonia fertilizer application in the watershed from 170 kg/ha (152 lb/ac) to 50 kg/ha (45 lbs/ac)	38%
Manure Remove all manure generated from permitted or registered CAFOs and feedlots	7.25%
Human Waste Remove all human waste from the watershed	4.8%
Highest Yielding Subbasins Target major nitrate load reductions in all subbasins with annual average losses greater than 13 lb/ac (Ammonia Fert. 50 Scenario)	14.6%
Downstream-most Subbasins target major nitrate load reductions in subbasins located closest to the DMWW intake (Ammonia Fert. 50 Scenario)	5.4%
Boone River Watershed Target major nitrate load reductions in the Boone River Watershed (Ammonia Fert. 50 Scenario)	5.46%
Upstream-most Subbasins Target major nitrate load reductions in subbasins located furthest away from the DMWW intake / Minnesota subbasins (Ammonia Fert. 50 Scenario)	6.04%

Table 3.3: SWAT Nitrate Load Reduction Scenarios

The target load reductions in Table 3.3 are from the Des Moines River Nitrate TMDL report.

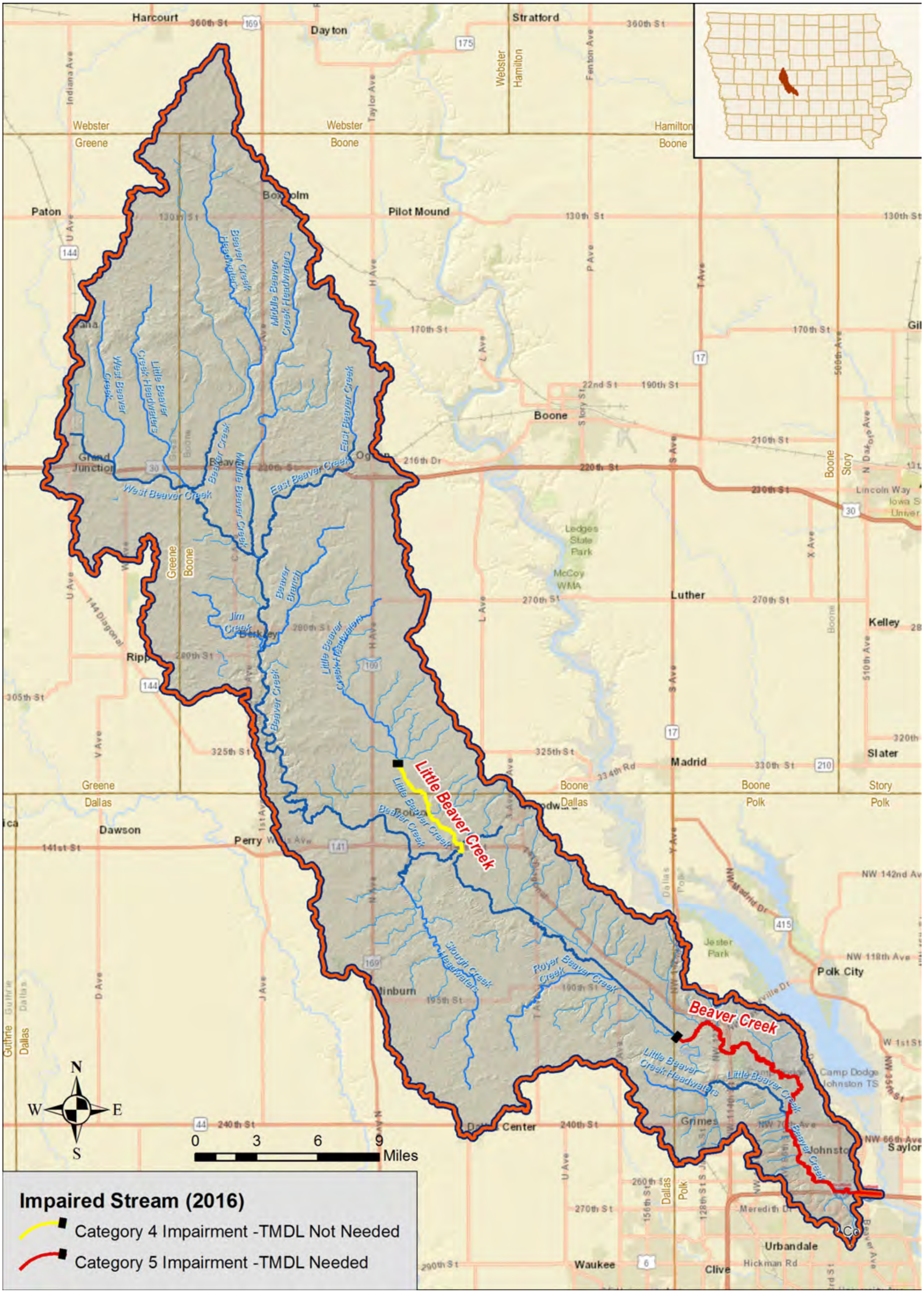


Figure 3.1: Impaired streams within the Beaver Creek Watershed.

Table 3.4: Beaver Creek Watershed Impaired Streams and Lakes

WATERBODY	CATEGORY	IMPAIRED USE	PRIMARY STRESSOR	USE SUPPORT	RATIONALE
Beaver Creek - Mouth (S17, T79N, R24W, Polk Co.) to Boone/ Dallas county line (NW 1/4, NW 1/4 S2, T81N, R28W)	5p 5b-v	Primary Contact Recreation, Aquatic Life	Indicator Bacteria, Biological (Flow, physical characteristics)	Partially* Supporting	Primary Contact: Geometric mean of E. coli is greater than the Class A1 criterion. Biological: Low aquatic macroinvertebrate IBI
Little Beaver Creek - Mouth (S14, T81N, R27W, Dallas Co.) to confluence with an unnamed tributary (SE1/4, SE1/4, S29, T82N, R27W, Boone Co.)	4c	Aquatic Life	Biological (Hydro-modification)	Partially* Supporting	Biological: low fish IBI
Des Moines River - Mouth (S14, T81N, R27W, Dallas Co.) to confluence with an unnamed tributary (SE1/4, SE1/4, S29, T82N, R27W, Boone Co.)	4a	Primary Contact Recreation, Drinking Water	Indicator Bacteria, Nutrients: Nitrates	Partially* Supporting	Primary Contact: Single-sample maximum criterion exceeded in significantly > 10% of bacteria samples Significantly > 10% of Nitrate samples fail to meet criterion

4a- TMDL has been completed but water quality standards have not yet been met

4c - Non-pollutant caused impairment. No TMDL needed

5p- Impairment occurs on a waterbody presumptively designated for Class A1 primary contact recreation use or Class B (WW1) aquatic life use.

5b-v- The aquatic life uses of a stream with a watershed size within the calibration range of IDNR biological assessment protocol (~10 to 500 square miles) are assessed as Section 303(d)-impaired based on results of the required two or more biological sampling events in multiple years within the previous five years needed to confirm the existence of a biological impairment.

*Because state water quality criteria are designed to be fully protective, slight to moderate impairment of a beneficial use do not necessarily preclude that use from being at least partially supported. There may be periods of the year in which these streams meet designated uses.

STREAMS

The streams within the Beaver Creek Watershed have been classified into the following management categories based on their designated uses.

PRIMARY STREAMS

Streams within the Beaver Creek Watershed with a DNR Designated Use are classified as "Primary streams" (Figure 3.2). Primary streams should be protected for their designated use classifications; **these streams represent the highest primary targets for protection and restoration measures.** Unnamed streams with water quality impairments are included within the primary streams. In some cases, the management category for a given stream differs from the upper portion to the lower reaches. A description of the named primary streams follows.

SECONDARY STREAMS

Named streams that maintain flow and/or pooled areas sufficient to maintain a viable aquatic community and support recreational uses that have not been assigned a designated use are classified as "Secondary streams" (Figure 3.2). Secondary streams represent the major tributaries to Beaver Creek Watershed's Primary streams. **Secondary streams represent the second highest primary targets for conservation** (protection and restoration) measures.

OTHER STREAMS

General use, unnamed streams within Beaver Creek Watershed are shown as "Other streams" in Figure 3.2. These **"Other" streams should be protected for livestock and wildlife watering, aquatic life, noncontact recreation, and industrial, agricultural, or domestic withdrawal uses** but do not represent the highest primary targets for implementation of conservation (protection and restoration) measures.

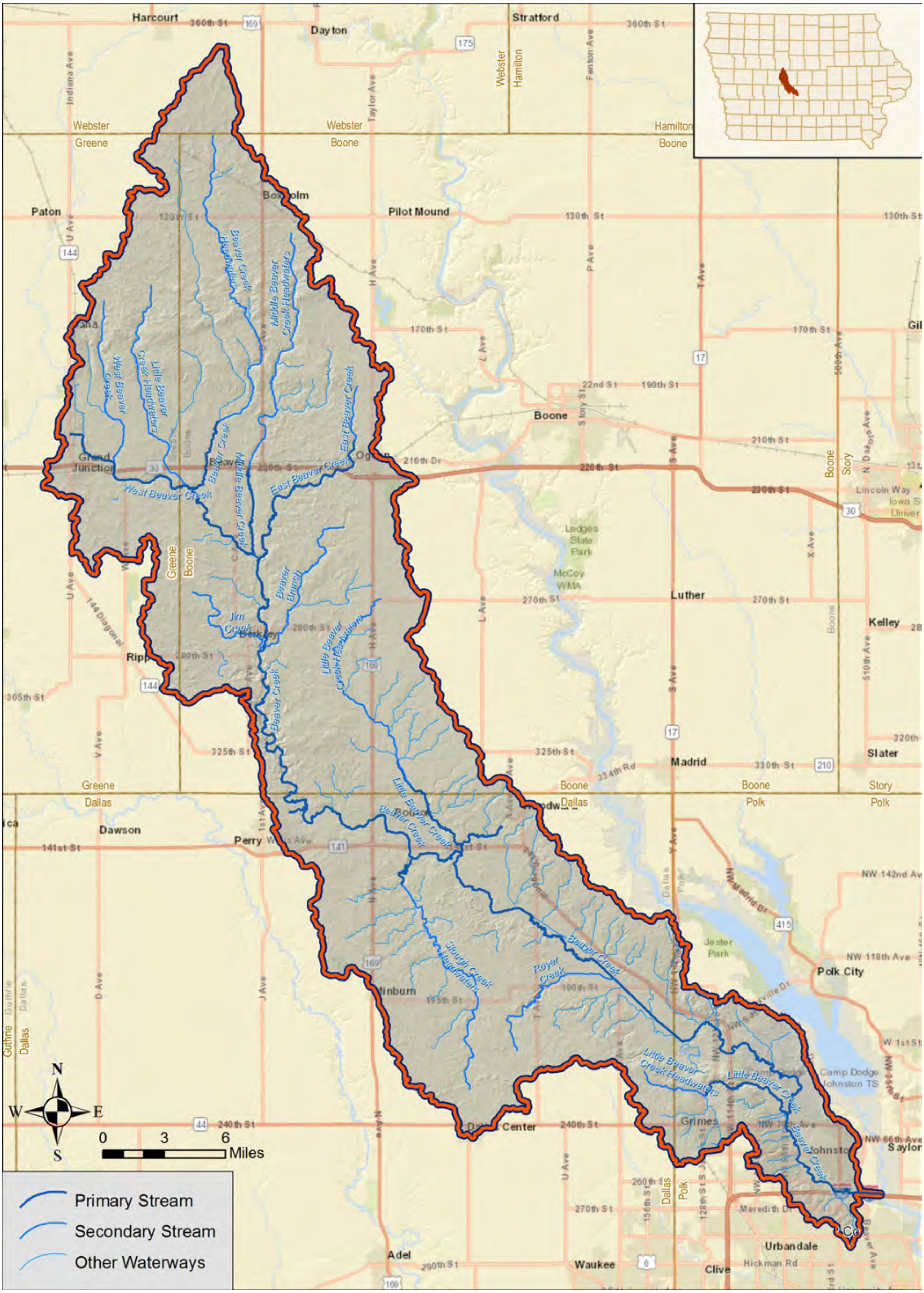
An example of a secondary stream in the Beaver Creek watershed.

Table 3.5: Beaver CreekWatershed Primary and Secondary Streams

STREAM CATEGORY	STREAM NAME
Primary	Beaver Creek
Primary	East Beaver Creek
Primary	Little Beaver Creek
Primary	Middle Beaver Creek
Primary	Slough Creek
Primary	Unnamed Creek (Little Beaver Creek)
Primary	Unnamed Creek (City of Bouton)
Primary	Unnamed Creek (West Beaver Creek)
Primary	Unnamed Creek (West Beaver Creek)
Primary	West Beaver Creek
Secondary	Beaver Branch
Secondary	* Beaver Creek Headwaters
Secondary	* East Beaver Creek Headwaters
Secondary	* Little Beaver Creek Headwaters
Secondary	* Middle Beaver Creek Headwaters
Secondary	Jim Creek
Secondary	Royer Creek
Secondary	* West Beaver Creek Headwaters

**The headwater reaches of these streams are considered a secondary primary because they have not been assigned a designated use and may not be capable of maintaining flow throughout the year or contain sufficient pooled areas during intermittent flow periods to maintain a viable aquatic community.*

Figure 3.2: Beaver Creek Watershed- Stream Classifications



MORE ABOUT THE PRIMARY STREAMS

Beaver Creek

Description

Beaver Creek, a fourth order stream at its mouth, is the most significant stream from a recreational usability perspective within the Beaver Creek Watershed. The Headwaters of Beaver Creek are located near the intersection of U.S. Highway 169 and State Highway 175, near the northern border of Boone County. The Headwaters portion of Beaver Creek has not been assigned a designated use. **The mainstem branch of Beaver Creek begins approximately 36 miles northwest of Des Moines,** northeast of the intersection of U.S. Highway 169 and U.S. Highway 30. The 64 mile long mainstem branch flows generally southeast towards the City of Des Moines, where it joins the Des Moines River, which ultimately drains to the Mississippi River south of Keokuk, Iowa.

Beaver Creek Greenbelt

The lower portion of Beaver Creek is located within the City of Johnston. **Several parks, trails, and greenspaces are located adjacent to the creek, these greenspaces provide natural refuge from the surrounding urbanized, metropolitan area.** Currently, the Creek is used by birders, anglers, and kayakers, however there are additional opportunities being proposed for Beaver Creek by the Iowa DNR, the City of Johnston and the City of Des Moines. These opportunities are largely focused on creating three non-motorized boat/canoe accesses, which would connect to local trail hubs near 70th Avenue, Terra Lake Park, and Merle Hay Road.

Designated Recreational Uses

The portion of Beaver Creek south of the Boone/Dallas County Line is listed as a Class A1 waterbody, indicating it is capable of supporting primary recreational uses such as swimming and kayaking. **The stretch of Beaver Creek north of the Boone/Dallas County Line is listed as a Class A2, BWW-2 waterbody,** indicating this reach is capable of supporting a warm water game fish population. The direct connection with the Des Moines River has allowed for a sustainable population of desirable gamefish species including smallmouth bass to become established within the creek.

Impaired Reaches

The stretch of **Beaver Creek south of the Polk/Dallas County Line** is impaired for biological life based on a low macroinvertebrate biotic index score. This stretch is also impaired for bacteria based on Geometric mean bacteria concentrations exceeding the Class A1 criterion.

For definition of stream order, see discussion on page 66.

East Beaver Creek

Description

East Beaver Creek, a first order stream at its mouth, originates north of the City of Ogden, north of U.S. Highway 30. The 11-mile long creek flows generally southwest around the City of Ogden before joining Beaver Creek. Based on the streambank assessment performed in Chapter 7, **stream banks of East Beaver Creek were identified as having a moderate potential for streambank failure to occur.** The riparian area within 150 feet of the East Beaver Creek channel is more than 50% grassland, these grasslands help to reduce this risk of streambank failure.

Designated Recreational Uses

East Beaver Creek is designated for secondary (canoeing) recreational uses. Gamefish production is limited in East Beaver Creek due to flow constraints and other physical characteristics.

Impaired Reaches

An insufficient amount of data has been collected on this stream to determine whether or not any stream reaches are impaired for their designated use.

Little Beaver Creek (Little Beaver Creek Subwatershed)

Description

Little Beaver Creek, a third order stream at its mouth, originates in central Boone County near U.S. Highway 169. The 15-mile long creek flows generally southeast before joining Beaver Creek west of Woodward. Based on the streambank assessment performed in Chapter 7, **stream banks of Little Beaver Creek were identified as having a moderate potential for streambank failure to occur.**

Designated Recreational Uses

Little Beaver Creek is designated for secondary (canoeing) recreational uses. Gamefish production is limited in Little Beaver Creek due to flow constraints and other physical characteristics.

Impaired Reaches

Results from biological monitoring conducted by the DNR in 2007 suggest the Class B (WW2) aquatic life uses should be considered partially supporting. Habitat alterations and lack of low flow stability associated with channelization and tiling in the watershed are the suspected causes of the impairment.

Little Beaver Creek (Beaver Creek)

Description

Little Beaver Creek, a third order stream at its mouth, originates west of the City of Grimes. The 8-mile long creek flows primarily east through the northern portion of the City of Grimes before joining the mainstem branch of Beaver Creek north of the intersection of NW 86th Street and NW 78th Avenue. Based on the streambank assessment performed in Chapter 7, **stream banks of Little Beaver Creek were identified as having a moderate potential for streambank failure to occur. Three high priority streambank instability sites were identified** in close proximity to the creek channel as described in Chapter 7.

Designated Recreational Uses

Little Beaver Creek is designated for secondary (canoeing) recreational uses. Gamefish production is limited in Little Beaver Creek due to flow constraints and other physical characteristics.

Impaired Reaches

An insufficient amount of data has been collected on this stream to determine whether or not any stream reaches are impaired for their designated use.

Middle Beaver Creek

Description

Middle Beaver Creek, a third order stream at its mouth, bisects the northern third of the Beaver Creek Watershed from North to South. The 15-mile long creek flows primarily south before joining the mainstem branch of Beaver Creek south of the intersection of U.S. Highway 30 and U.S. Highway 169. Based on the streambank assessment performed in Chapter 7, **stream banks of Middle Beaver Creek were generally identified as having a low potential for streambank failure to occur.** Furthermore, the riparian areas within 150 feet of the Middle Beaver Creek channel is more than 68% grassland, these grasslands help to reduce this risk of streambank failure.

Designated Recreational Uses

Middle Beaver Creek is designated for secondary (canoeing) recreational uses. Gamefish production is limited in Middle Beaver Creek due to flow constraints and other physical characteristics.

Impaired Reaches

An insufficient amount of data has been collected on this stream to determine whether or not any stream reaches are impaired for their designated use.

Slough Creek

Description

Slough Creek, a third order stream at its mouth, originates 6.5 southwest of the City of Minburn. The 13-mile long creek flows primarily north before joining the mainstem branch of Beaver Creek approximately 1.5 miles west of the town of Gardiner. Based on the streambank assessment performed in Chapter 7, **stream banks of Slough Creek were generally identified as having a low potential for streambank failure** with the exception of the most downstream reach near the confluence with Beaver Creek which was identified as having a high potential for streambank failure. **High priority streambank instability sites were identified on an unnamed tributary near the Slough Creek headwaters.** Slough Creek itself is well-buffered with 80% of the riparian area within 150 feet of the stream comprised of forest or grasslands.

Designated Recreational Uses

Slough Creek is designated for secondary (canoeing) recreational uses. Gamefish production is limited in Slough Creek due to flow constraints and other physical characteristics.

Impaired Reaches

An insufficient amount of data has been collected on this stream to determine whether or not any stream reaches are impaired for their designated use.

West Beaver Creek

Description

West Beaver Creek, a third order stream, originates in the northwestern third of the Beaver Creek watershed flowing south towards the City of Grand Junction. As the stream passes the City of Grand Junction, it turns to the east where it joins Beaver Creek south of the City of Beaver. **No priority streambank instability sites were identified in the streambank assessment described in Chapter 7.**

Designated Recreational Uses

West Beaver Creek is designated for secondary (canoeing) recreational uses. Gamefish production is limited in West Beaver Creek due to flow constraints and other physical characteristics.

Impaired Reaches

An insufficient amount of data has been collected on this stream to determine whether or not any stream reaches are impaired for their designated use.

Stream Ordering

Stream ordering is a method of assigning a numeric order or rank to each segment of a stream network. This order is a method for identifying and classifying types of streams based on their numbers of tributaries. Some characteristics of streams can be inferred by simply knowing their order. Stream orders provide a way to rank and identify relative sizes of channels in a drainage basin. First-order streams are dominated by overland flow of water; they have no upstream concentrated flow. Because of this, they are most susceptible to non-point source pollution problems and can derive more benefit from wide riparian buffers than other areas of the watershed. The Strahler method is the most commonly used method to describe stream order. In this method, all links without any tributaries are assigned an order of 1 and are referred to as first order. The stream order increases when streams of the same order intersect. Therefore, **the intersection of two first-order links will create a second-order link, the intersection of two second-order links will create a third-order link, and so on.**

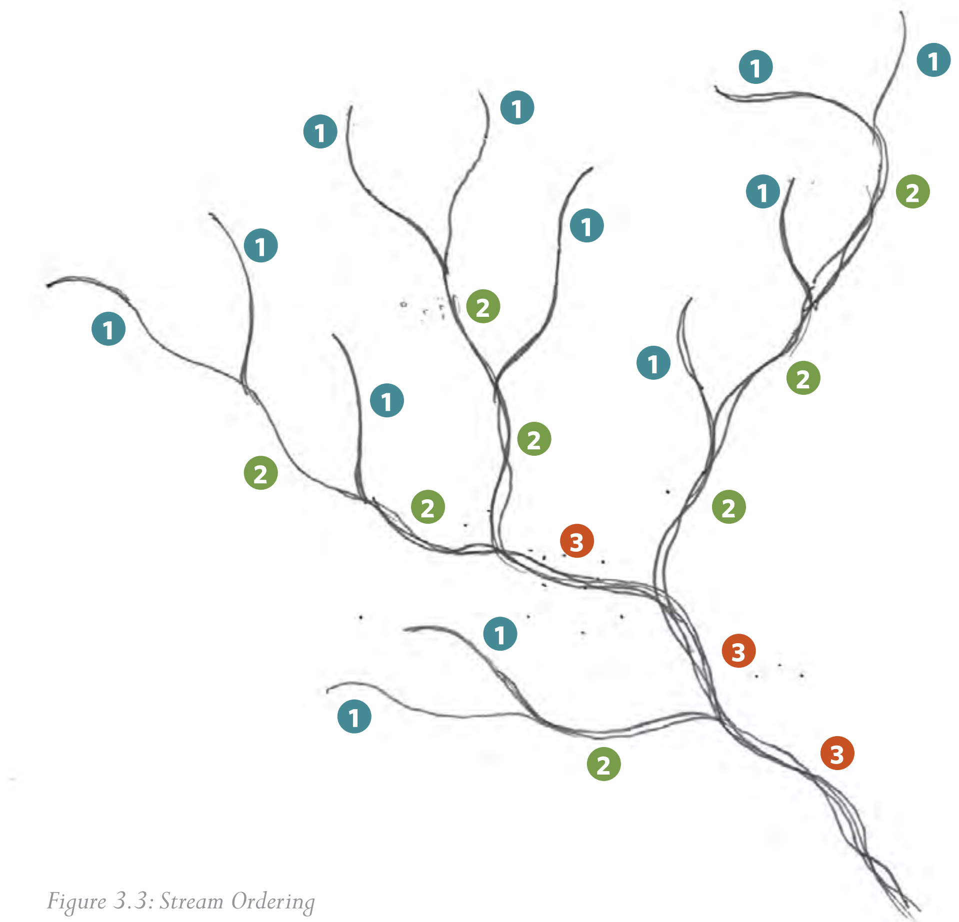


Figure 3.3: Stream Ordering

04

CLIMATE, STREAMFLOW & FLOOD RISK

Climate is the prevailing weather patterns for an area over an extended period of time. This section describes patterns of temperature, rainfall, storm intensities, growing season length, evaporation, and severe weather for Beaver Creek Watershed. Climate conditions are one of the primary factors that influence the volume and quality of runoff from the landscape.

04

Average annual temperature has increased 1.6° F*

1973 — 59.3° F

2019 — 60.9° F

Average annual precipitation has increased 19%*

1978 — 30.5 IN

2019 — 36.2 IN

* In Des Moines

Flow data

Recorded along Beaver Creek, at Johnston, since 1960.

Record flow

The peak annual flow of 21.7 billion cubic feet† would fill Saylorville Lake seven times over.

Streamflow

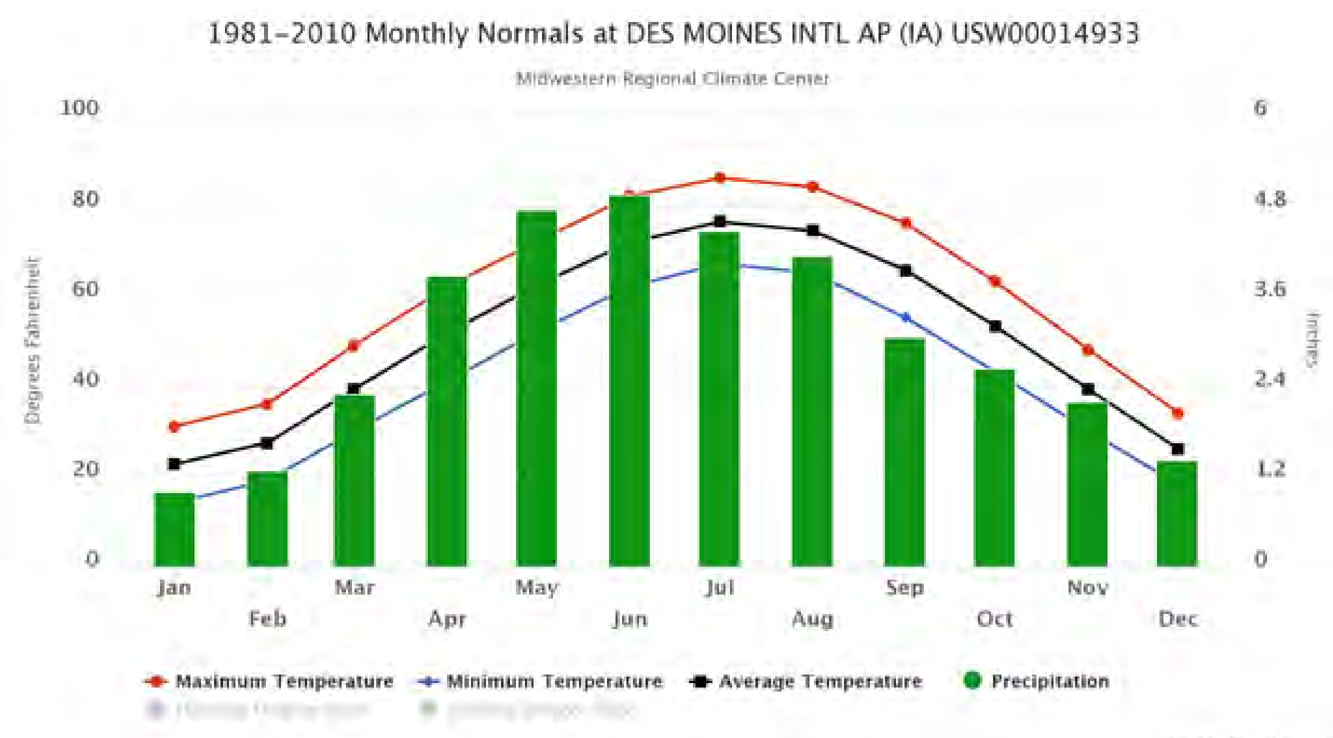
Volume has increased 2.3% on average annually since 1960.

† 2010

TEMPERATURE

National Oceanic and Atmospheric Administration (NOAA) climate data from Des Moines, IA were summarized with corresponding average, maximum, and minimum monthly temperatures plotted by month (Figure 4.1). There are multiple weather stations either within or in close proximity to the City of Des Moines. The Des Moines International Airport weather station was chosen because the City of Des Moines is located within the watershed and because this station contains climatic data dating back to the 1870's or earlier with 100% data coverage (no missing values). The average annual temperature is about 50° F, with hot and humid summers often near or exceeding 90° F. Peak average daily summer temperatures (about 85° F) are typically observed in July with slightly lower averages noted for June and August. Winters can have temperatures dropping well below freezing in December, January and February. The remaining 'cold' months of November, March and April typically have average daily maximum temperatures above freezing (32°F). Broadly speaking, daily average minimum and maximum temperatures

Figure 3-6. Average monthly climate data for Des Moines, IA. NOAA's Midwestern Regional Climate Center



It has been noted that average regional temperatures have increased over time. To evaluate this pattern, observed average annual minimum and maximum temperatures at the Des Moines International Airport weather station were plotted for the time period 1970 to 2017 in Figure 4.2. While there can be seen a slight increase in average annual maximum temperatures, the increasing pattern is more pronounced for the average annual minimum temperatures. Annual minimum temperature values have increased about 2-3 degrees F from 1970 to 2018. Other studies have noted that since 1970: (1) the nighttime temperatures have increased more than the daytime temperatures; (2) daily minimum temperatures have increased in the summer and winter; (3) daily maximum temperatures have risen in winter but declined substantially in the summer (Report to the Governor and Iowa General Assembly, 2011.)

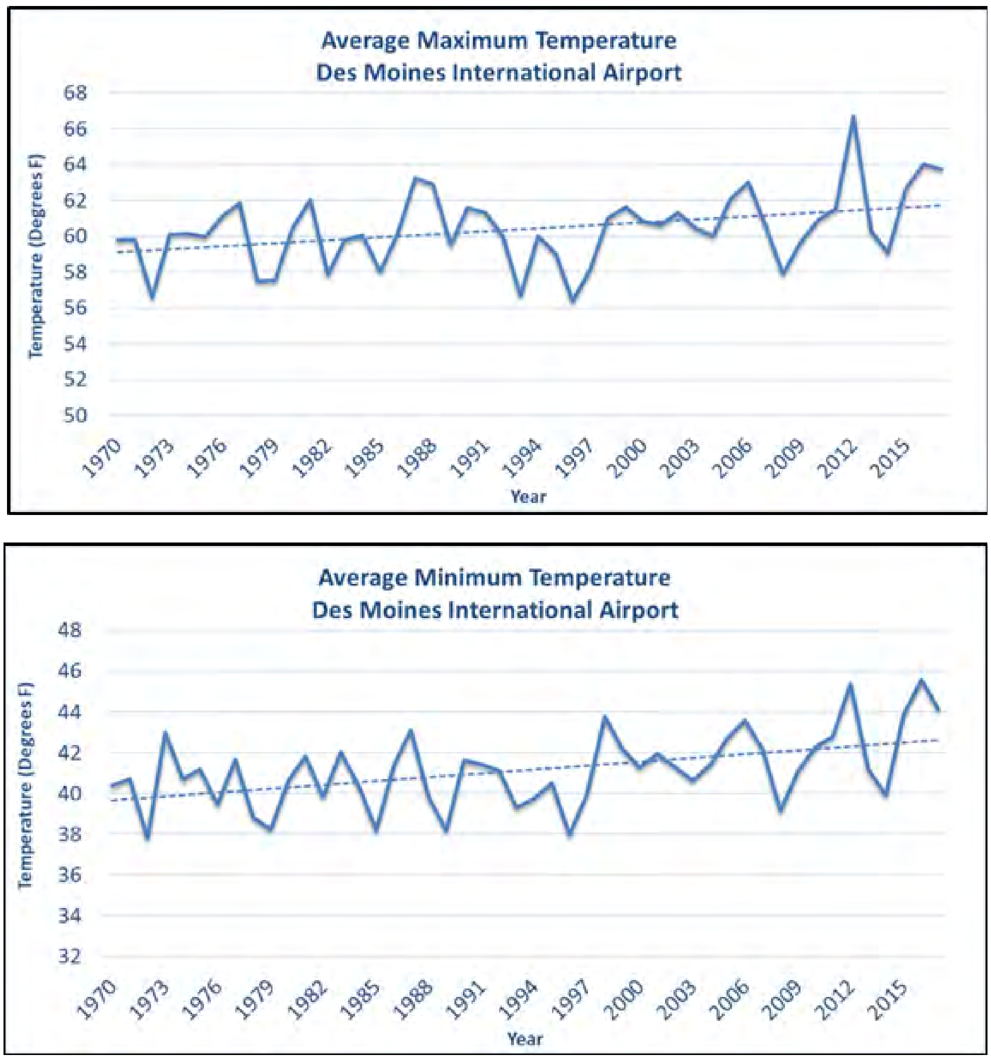


Figure 4.2: Average Annual Maximum and Minimum Temperature for Des Moines, IA. NOAA's Midwestern Regional Climate Center

RAINFALL

Annual average rainfall totals about 35.4 inches with the growing season typically having the highest rainfall totals of about 2 inches to 6 inches per month. Annual rainfall measured at the Des Moines site during the 1970 – 2018 time period has varied from about 22 inches (1988) to 55.8 inches (1993, flood) (Figure 4.3). For the same time period, growing season (May-October) rainfall averaged about 23.6 with values that ranged from about 13.2 inches (2012) to 44.7 inches (1993) (Figure 4.4).

Since the 1970s, Iowa has seen increases in precipitation, changes in timing of precipitation, seasonality, and changes in the frequency of intense rain events (Takle, 2010). Streamflow records in Iowa (including those for the Beaver Creek watershed) suggest that average flows, low flows, and perhaps high flows have all increased and become more variable since the late 1960s or 1970s; however, the relative contributions of land use and climate changes are difficult to sort out. Using land cover information obtained from well documented studies in 1859, 1875, and 2001, Wehmeyer et al. (2011) estimated that the increase in runoff potential in the first 30 years of settlement represents the majority of predicted change in the 1832 to 2001 study period. The study also outlines hydrologic alterations induced by climate change based on evidence provided in the recently released The Climate Science Special Report (USGCRP 2017). This study found that heavy rainfall is increasing in intensity and frequency across the United States and is expected to increase over the next few decades.

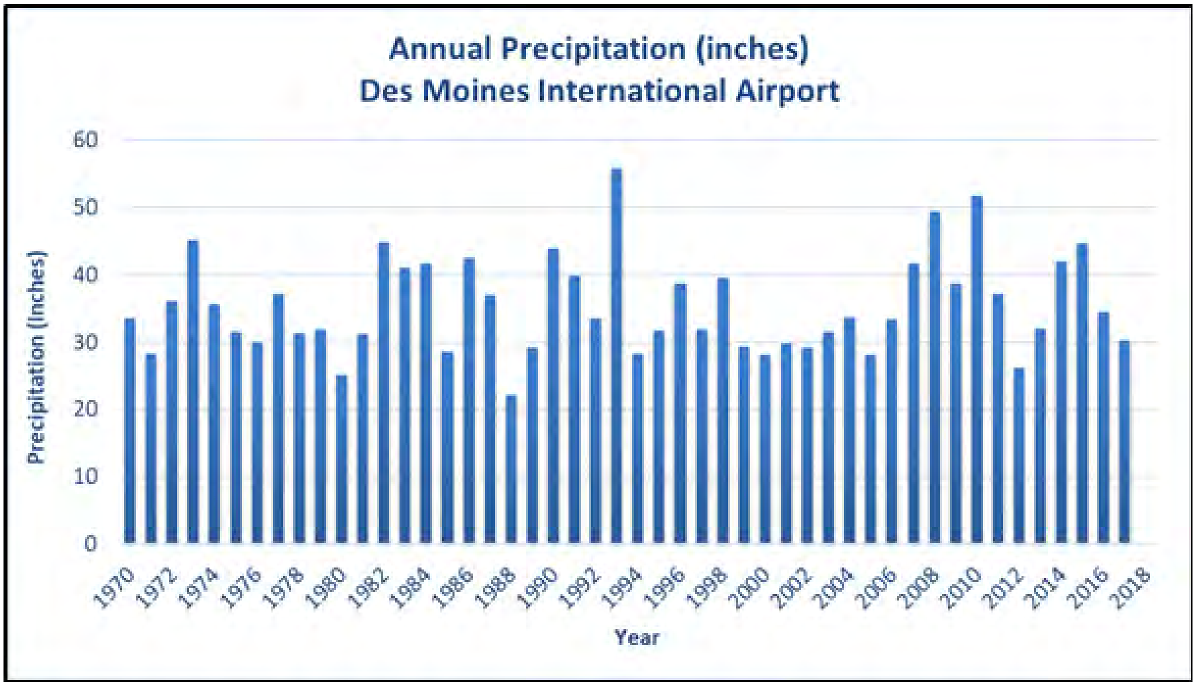


Figure 4.3: Annual Precipitation 1970-2017, Des Moines, IACenter

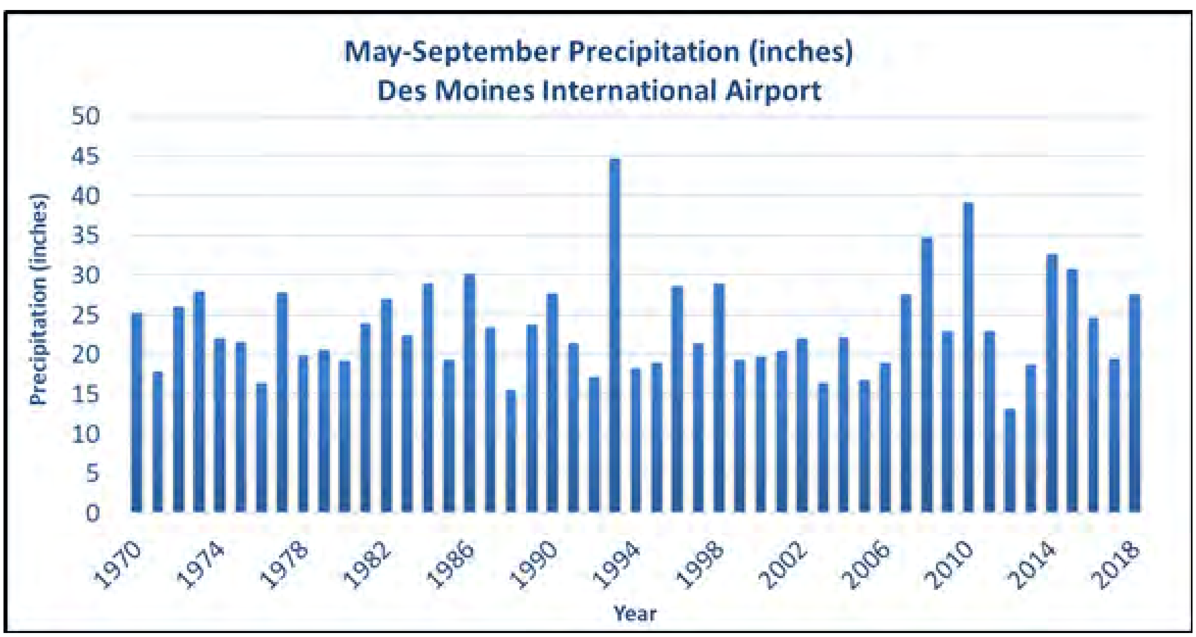


Figure 4.4: Growing Season (May-Sept) Precipitation 1970-2018, Des Moines IA

VARIABLE AND CHANGING CLIMATE

Of the climate data summarized above and from leading Iowa researchers, **there have been several key changes noted over the past 40 years that affect farms, cities, landscapes and waters.** These measured changes include:
Precipitation amounts, the frequency and intensity of large storms, and back-to-back storms have been defined by recent NOAA updates of precipitation data. **In general, the large (and less frequent) storms have increased by 4% to 20+% depending upon location and storm size.** The more frequent storms (occurring less than every ~25 years) have changed small percentages. More precipitation occurs in the first half of the year and less in the second half. Precipitation increases are typically greater on the eastern half of Iowa than the west, with Beaver Creek Watershed being in the middle. **These trends are expected to continue well into the future**.

- **The amount of moisture in the atmosphere has increased as measured by humidity and dew point temperatures by about 13%** (Report to the Governor and Iowa General Assembly, 2011). Atmospheric moisture fuels thunderstorms and severe weather. Beaver Creek Watershed is in the center of America's Heartland, which is a highly active weather area, as evidenced by the number of tornadoes and severe weather events.
- **Growing seasons, or the length of time between spring and fall freezing dates, have increased by about 5 to 10 days**, as defined from the Des Moines, IA weather record (1970-2018).
- **Warmer winter and spring temperatures may translate into earlier and slower snow melts,** reducing springtime flooding incidence at the critical time when vegetation and cover crops are typically at low levels.

- Climatologists have continued to refine changing climate assessment techniques and projections. **In short, there is widespread agreement that many of the above patterns are going to continue, with considerable wet and dry year-to-year variability likely.** In general, factors affecting increased stream flows and flooding are to become more frequent. Hence, **watershed management should incorporate innovations that can address more frequent, high-intensity precipitation events** by retaining water on the land as much as possible.

Source: Report to the Governor and the Iowa General Assembly, 2011. Climate Change Impacts on Iowa. Climate Change Impacts Committee.

http://www.iowadnr.gov/Environment/ClimateChange/ClimateChangeAdvisoryCo.aspx

HISTORIC STREAMFLOW DATA

- **Stream flow data has been collected at a USGS gaging station located north of the NW 70th Avenue Bridge in Johnston, Iowa (USGS 05481950).** Data collection began in April of 1960 and continues through the present day. At this location, Beaver Creek is collecting runoff from an area of 358 square miles (94% of its entire watershed).

ANNUAL FLOWS

- Stream flow varies greatly from year to year. Since 1960, annual flow volumes have ranged from 589 million cubic feet in 1989 to 21.7 billion cubic feet in 2010. To put that in perspective, **the annual volume of flow from 2010 would be enough to completely fill Saylorville Lake**
- **7 times** (Saylorville Lake holds 73,600 acre-ft of water). **An upward trend can be observed in average flow rates**. The value of annual average flow increased by 130 cubic feet per second from 1960 to 2017. This amounts to approximately 2.3% increase every year.

FLOW VARIATION

- Daily average flow rates in Beaver Creek have ranged from very little flow to **11,500 cubic feet per second on July 10, 1993.** Average daily flow rates have exceeded 3,000 cubic feet per second for only 103 days over a period of more than 58 years (less than 0.5% of all days). **The average daily flow rate over the entire period of record is 243 cubic feet per second, or a daily volume of 3.5 million cubic feet.**

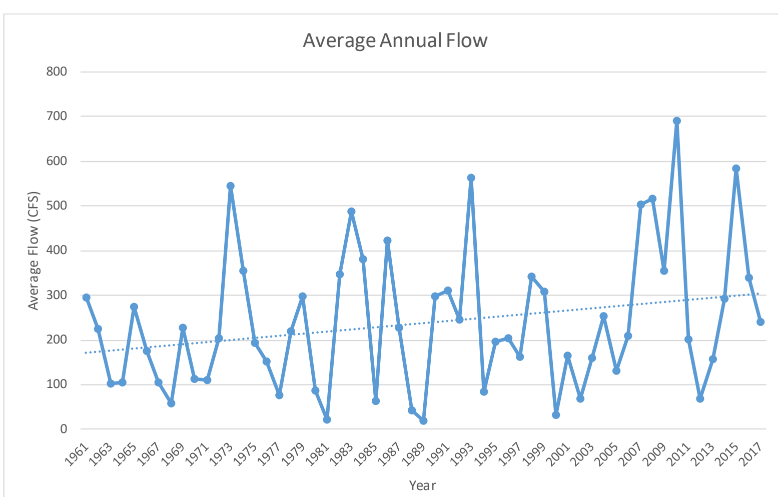
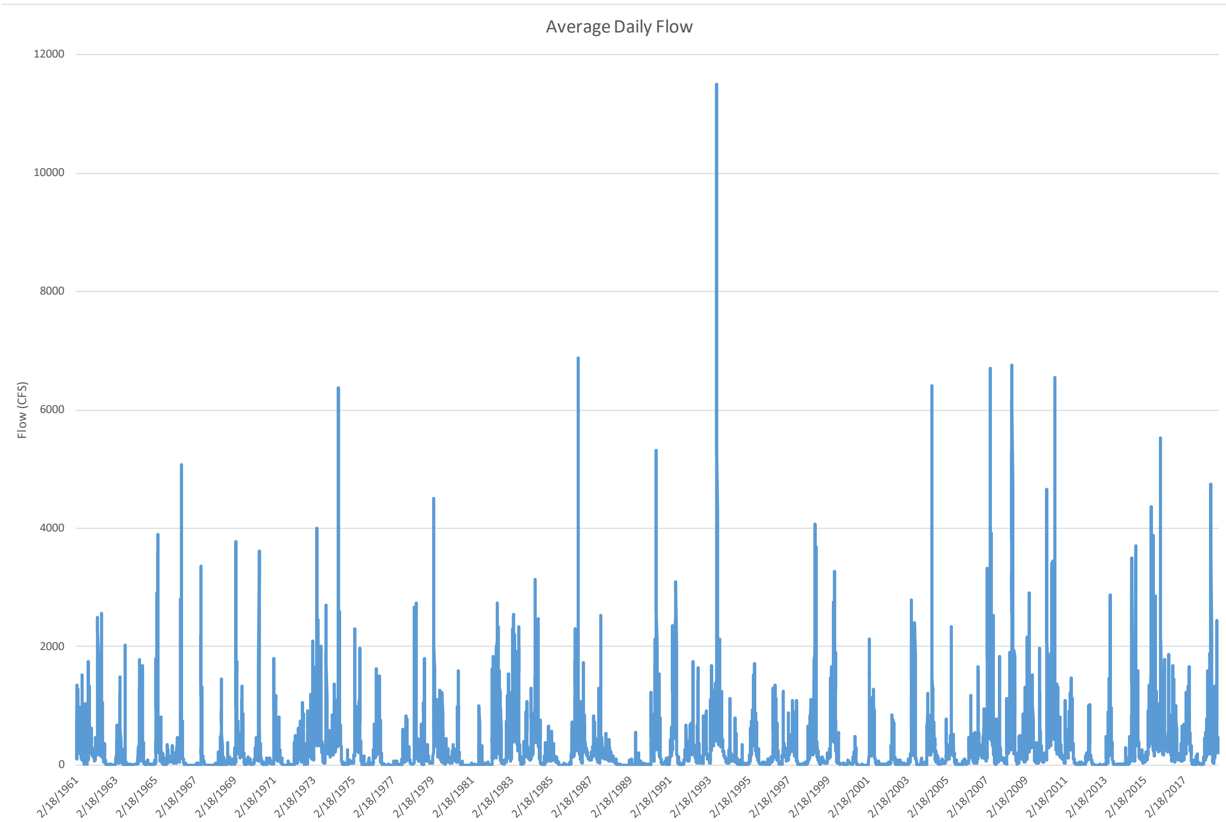


Figure 4.5:Data from USGS Gaging Station #05481950



FLOOD RISK POTENTIAL

Flooding remains a threat within the watershed. As the watershed planning process was getting started, a major event occurred in the downstream portion of the watershed on June 30th, 2018. While the upper portions of the watershed did not experience the rainfall intensity of the lower portion, flash flooding impacts were common in areas of Dallas and Polk County. Beaver Creek remains one of the more undeveloped watersheds that flows through the Des Moines metro area, making flood control and stormwater management planning critically important as development continues. **Flood risk in the watershed have been evaluated multiple times through studies that produce maps indicating different levels of risk associated with the location near a major flow corridor (FEMA Insurance Rate Maps).** These maps are intended to identify the need for flood insurance to be purchased by property owners.

FLOOD HISTORY

At the USGS gauge located north of NW 70th Avenue bridge, major impacts are expected when water levels exceed 16 feet. **Over the 58 years of record, only one year exceeded a gauge height of 16 feet, during the 1993 flood event.**

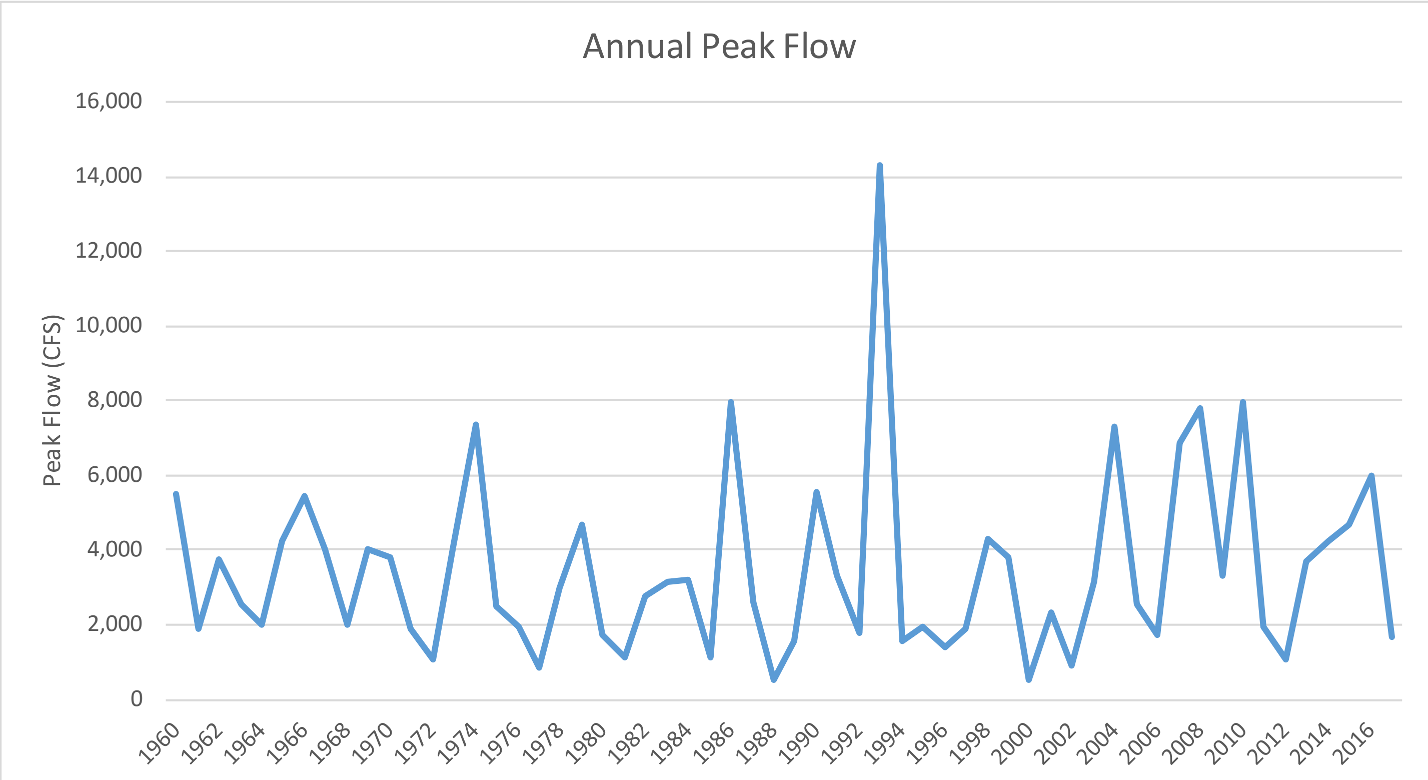


Figure 4.7: Data from USGS Gaging Station #05481950

100 YEAR GAUGE HEIGHT = 16 FT

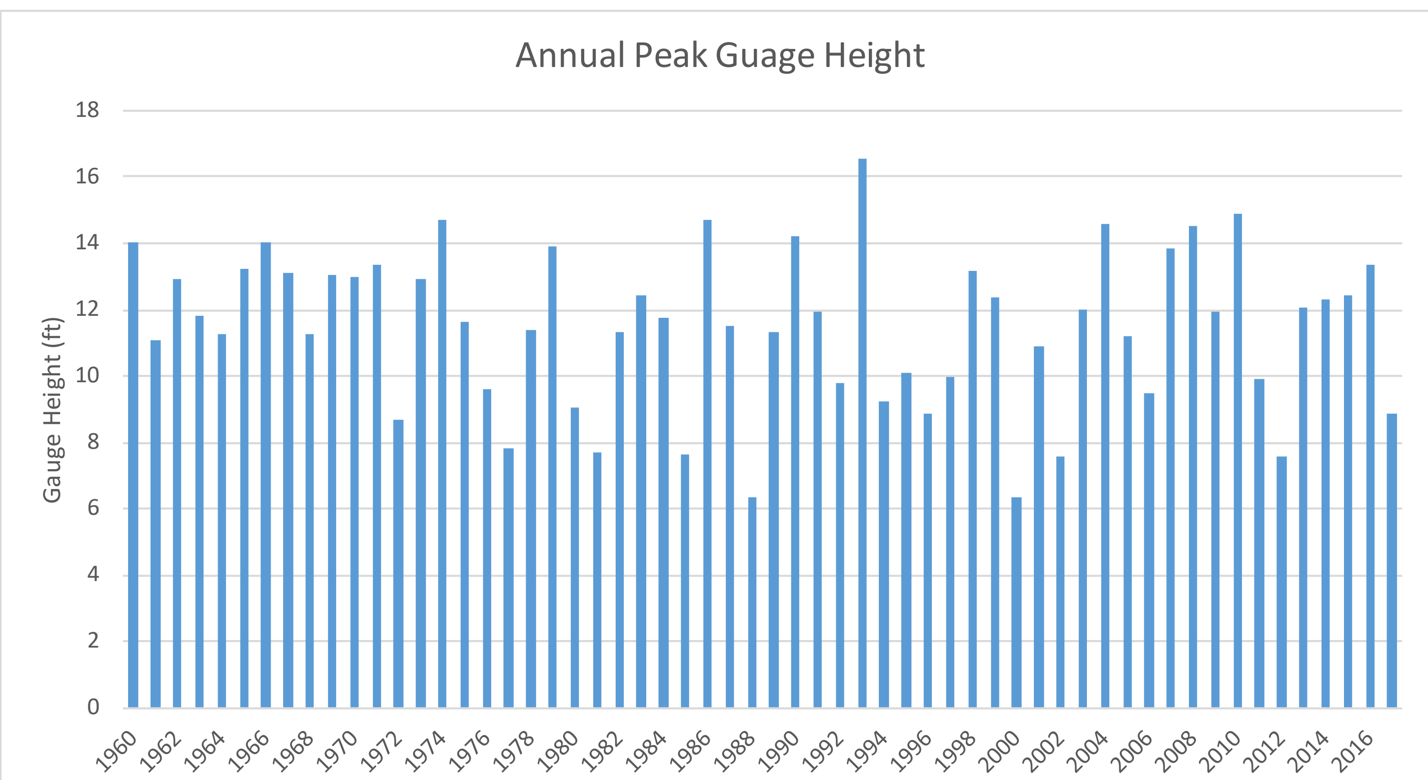


Figure 4.8: Data from USGS Gaging Station #05481950

HYDROLOGIC ASSESSMENT

A hydrologic assessment has been completed to review watershed conditions and estimate the rates and volumes of streamflow that would be expected to be generated by various storm events. This assessment was prepared using information about the land surface and streams throughout the Beaver Creek watershed. Then, **a computer model simulation was created to model the effects created by storm events of various sizes.** The results of this model were compared to available streamgauge data for calibration, to verify that the model is in general agreement with conditions that have been observed at a given point along Beaver Creek.

PREPROCESSING

Hydrologic assessment of the Beaver Creek watershed was performed using Geographic Information System (GIS) tools (ArcMap's GeoHMS v10.2 and HEC-HMS v4.2.1). LiDAR terrain data available through the State of Iowa was used as a basis to create a Digital Elevation Model (DEM), a surface elevation model of the watershed. **This was used to divide the watershed into 85 smaller subwatershed areas, averaging approximately five square miles in area**. For each of these smaller areas, characteristics such as average basin slope, longest flow path, and basin centroid were calculated.

Hydraulic parameters (such as channel shape, size and slope) for Beaver Creek and major tributaries were estimated using the DEM. Identified major tributaries to Beaver Creek include, from upstream to downstream, Middle Beaver Creek, West Beaver Creek, East Beaver Creek, Jim Creek, Beaver Branch, Little Beaver Creek (Boone and Dallas counties), Slough Creek, Royer Creek, and Little Beaver Creek (Polk County).

Reach lengths, channel slopes, and channel dimensions for flow routing were tabulated. Land cover information was used to estimate parameters used to calculate runoff volumes and flow rates for each subwatershed area (NRCS Curve Numbers, time of concentration, etc.). **This collected data was exported into the computer model (HEC-HMS) for analysis.**

RAINFALL EVENTS

The hydrologic model analyzed runoff from events of various return periods. **The return period is an estimate of how frequently a given amount of rain is expected to fall on average over a very long period of time.**

This rainfall was assumed to fall over a 24-hour period, assuming a Type II rainfall distribution pattern. This rainfall pattern is prescribed for use in Iowa, and assumes that most of the rainfall occurs during an intense period in the middle of the storm event.

RETURN PERIOD	RAINFALL DEPTH (INCHES)
2 Year	3.08
10 Year	4.46
25 Year	5.44
100 Year	7.12

Table 4.1: Design Rainfall Depths for the modeled 24-hour storms

MODEL CALIBRATION

Several data sources were used to calibrate the hydrologic model. Principally, flow data from USGS Gage 05481950 along NW 70th Avenue in Grimes was used to compare the hydrologic model to historic flows. In addition, USGS stations 05481690 on West Beaver Creek at Grand Junction and 05481680 on Beaver Creek at Beaver were used to calibrate flows on the upstream reaches. Peak flow estimates from USGS' StreamStats application were obtained to perform an order of magnitude check at non-gaged locations on Beaver Creek and on major tributaries.

Initial runs of the hydrologic model produced a 100-year peak discharge that was nearly 2.5 times larger than the historic largest recorded flow measurement of 14,300 cubic feet per second (cfs) at the Grimes USGS gage during the Flood of 1993. Thus, **several steps were necessary to calibrate the model.** Based on a comparison of the computed hydrograph and the historic gage hydrograph from the Flood of 1993, it was clear that the initial model was not sufficiently attenuating (reducing) flow as it was being routed through the watershed.

The initial model did not include reservoir nodes out of convenience. However, floodplain constrictions such as culverts, bridges, topographic depressions, ponds, agricultural levees, and field berms are prevalent throughout the Beaver Creek watershed and act as flow attenuators, especially during larger rainfall events. Therefore, several reservoir nodes were placed in the model to reduce peak flows. Reservoirs were placed primarily at bridges that appeared to be the largest flow attenuators based on the Zone A floodplain in the watershed. A hydraulic opening and storage curve for each reservoir were estimated based on the DEM.

To further attenuate peak flows in the model to meet calibration data, **channel losses due to percolation were added to the hydrologic model.** Channel losses were estimated in order to avoid overestimating reservoir size and to factor in hydraulic losses in the channel due to the relatively flat slope of Beaver Creek and its tributaries.

Initially, baseflow was factored into the hydrologic model to provide an initial flow value to route through the simulation and improve model stability. However, combining channel losses due to percolation with flat terrain resulted in significant attenuation of baseflow. This resulted in a decrease in flows observed on the computed hydrographs in the downstream portion of the model because baseflow would be attenuated before the runoff generated by each design storm arrived in the stream. **Because of this circumstance, a baseflow method was removed from the hydrologic model.**

MODEL RESULTS

The results of the calibrated hydrologic model are summarized below in Table 4.2 at the outlet of each HUC-12 watershed contained within the Beaver Creek watershed for each design storm. **The calculated discharge at the USGS gage in Johnston was 14,590 cfs. The largest discharge on record at the gage is 14,300 cfs, which was recorded during the Flood of 1993.** Peak flow statistics obtained from USGS at the gage estimate the 100-year peak flood discharge to range between 12,400 and 17,600 depending on the computational method. **Therefore, the hydrologic model has been accurately calibrated to gauge data.**

Source: https://streamstatsags.cr.usgs.gov/gagepages/html/05481950.htm

A comparison of the computed hydrograph at the Johnston USGS gage and the historic hydrograph during the Flood of 1993 is shown in Figures 4.9 and 4.10. This comparison shows that the general appearance of the calculated hydrograph in the hydrologic model is similar to gauge data. While it is important to note that the USGS data does factor in additional rainfall that fell after the peak discharge on July 10, 1993 and the computed hydrograph does not, trends in the hydrograph can be compared.

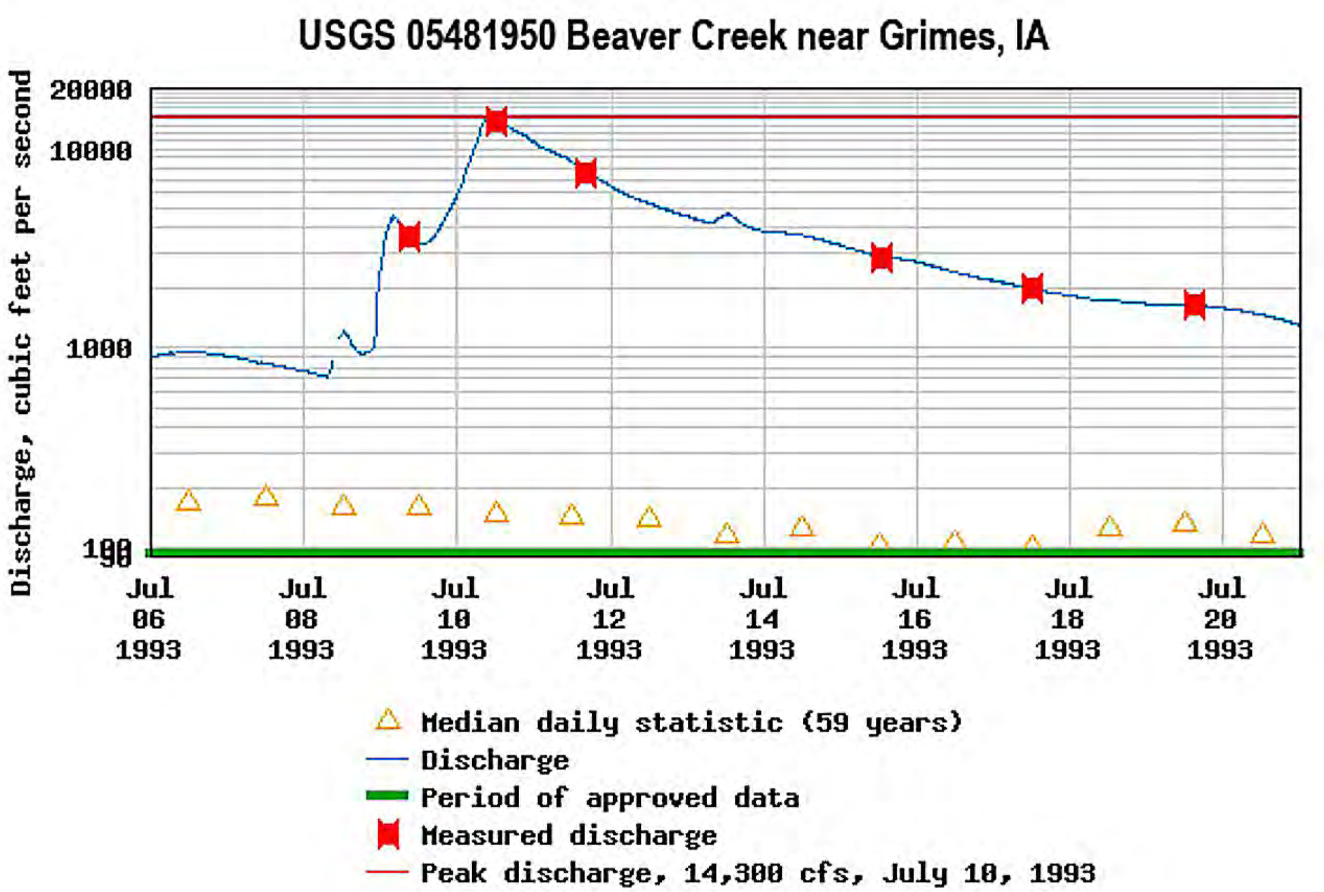
With both hydrographs, **an early jump in flow is observed due to a first flush of runoff from nearby tributaries** being conveyed to the gage prior to the arrival of the peak discharge. **A large jump occurs in the hydrograph as the peak arrives, which combines local rainfall and runoff with conveyed flow from above the gage**. Due to the size of the overall Beaver Creek watershed, conveyed flow continues to be routed from upstream as the simulation continues. Combined with the gentle slope of Beaver Creek and the watershed as a whole, this phenomenon results in a receding limb of the hydrograph that lingers for several days before finally reaching its baseline value. The similarities with both hydrographs, rainfall non-withstanding, provide another source of calibration and improves confidence in the validity of the hydrologic model.

HUC-12 VALUE	HUC-12 NAME	PEAK DISCHARGES (CFS)			
		2 YEAR	10 YEAR	25 YEAR	100 YEAR
71000040801	Little Beaver Creek - West Beaver Creek	600	1130	1530	2260
71000040802	West Beaver Creek	1260	2350	3010	3900
71000040803	Middle Beaver Creek	780	1680	2320	3230
71000040804	Beaver Creek - West Beaver Creek	2380	4490	5670	7460
71000040805	East Beaver Creek	500	960	1310	1960
71000040806	Beaver Creek - Beaver Branch	2710	5330	6650	8870
71000040807	Slough Creek	880	2050	2650	3360
71000040808	Beaver Creek - Slough Creek	2450	5810	8010	10150
71000040809	Little Beaver Creek - Beaver Creek	1200	2540	3610	5580
71000040810	Beaver Creek - Royer Creek	2200	6460	10010	13730
71000040811	Beaver Creek - Middle Des Moines River	2370	7020	10740	15760

Table 4.2: Hydrologic Model Results

Figure 4.9: Computed HEC-HMS Peak Flow Output near Johnston, IA (called the Grimes gauge by USGS)

Figure 4.10: Peak Flow Data from USGS Gage near Johnston, IA (called the Grimes gauge by USGS)



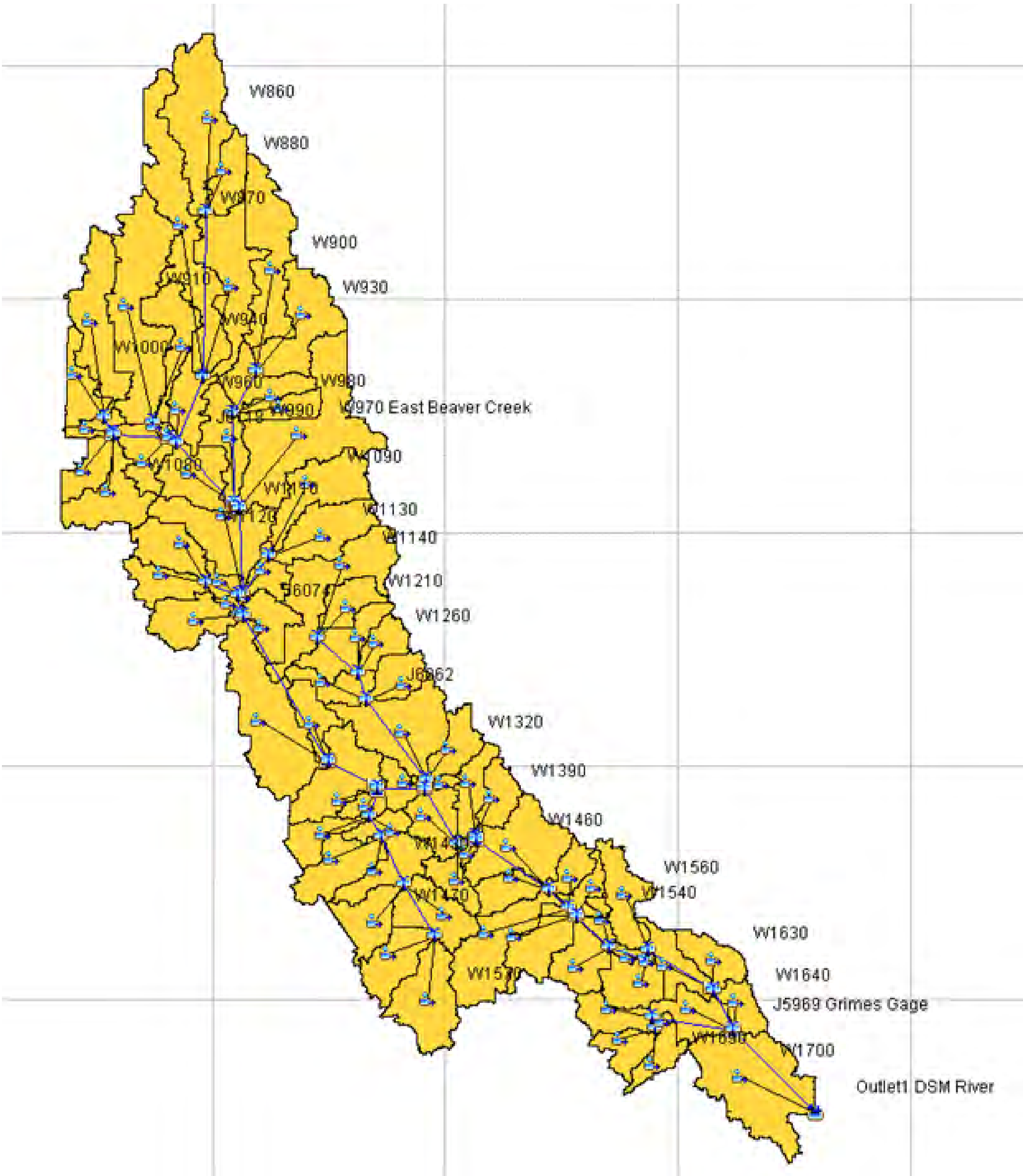


Figure 4.11: HMS Model Schematic

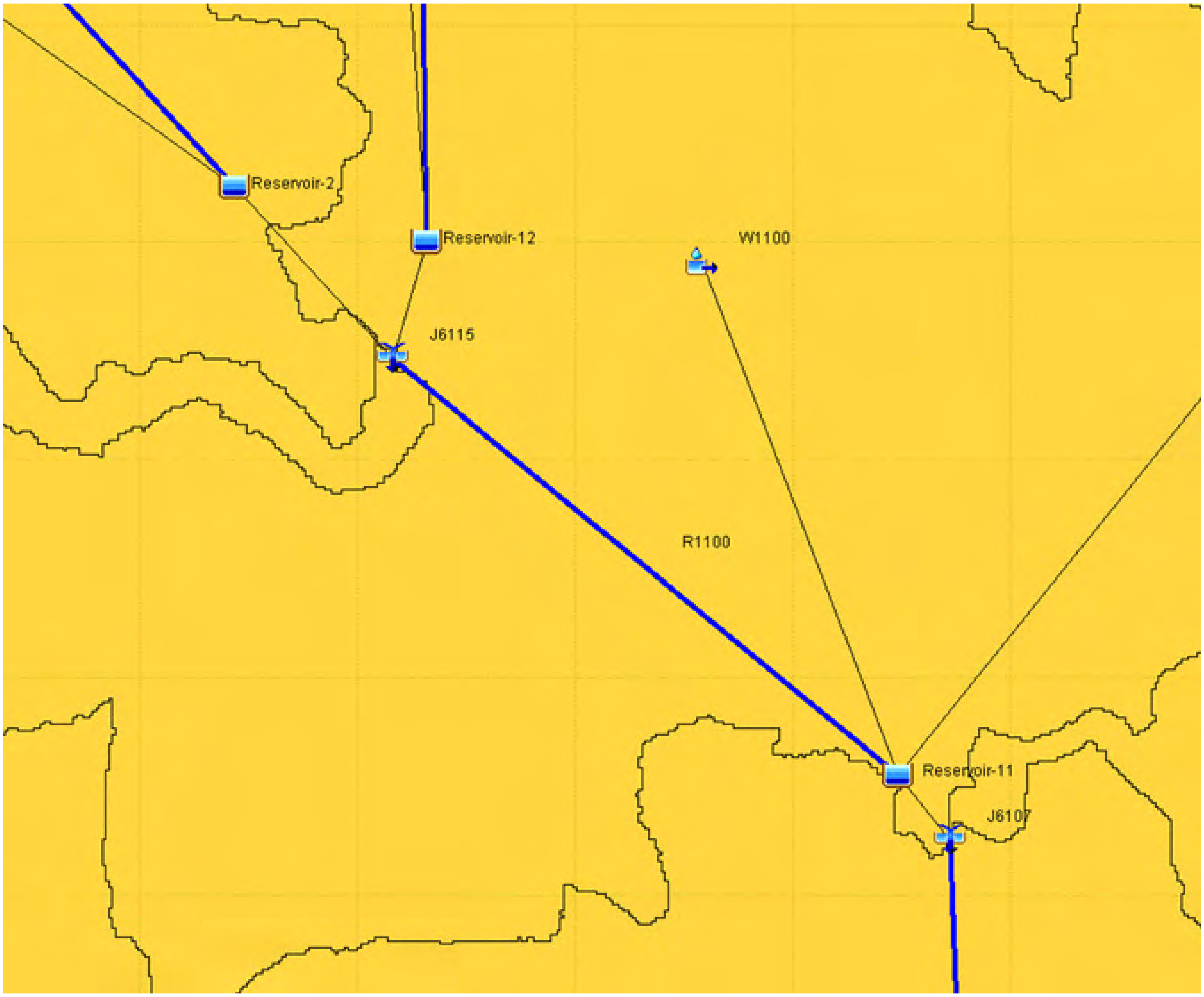


Figure 4.12: Bear Cr HMS Model Close-Up Showing Network of Streams, Reservoirs, Junctions, and Subcatchments

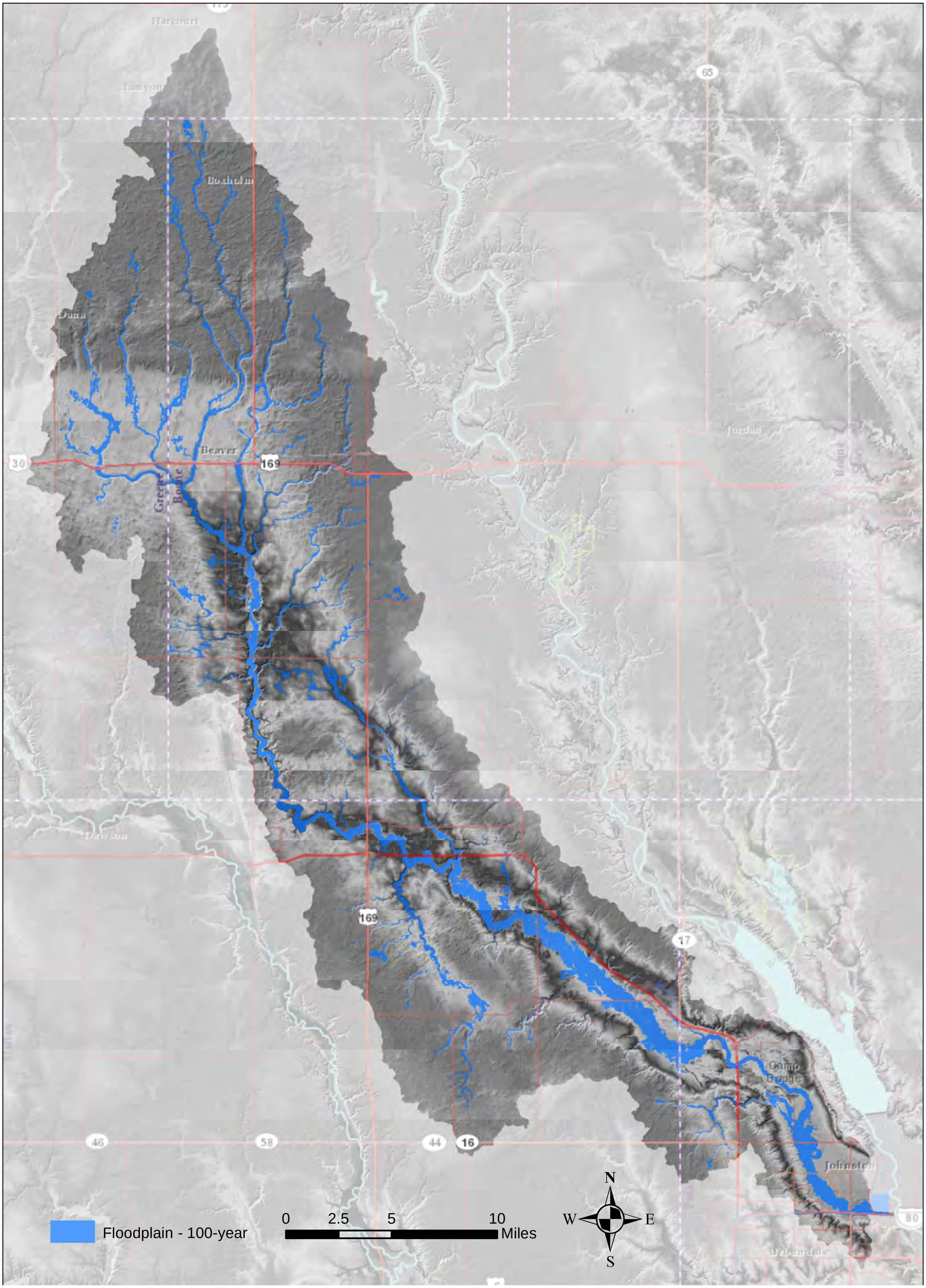
HYDRAULIC MODELING AND FLOOD INUNDATION MAPPING

Following the 2008 flood, the Iowa Statewide Floodplain Mapping project created draft flood hazard maps for the state. In some instances, the data are being used to create or update FEMA Flood Insurance Rate Maps. **On the next page is the preliminary flood hazard map displaying the 100-year event boundary.**

Flooding of farmland in the Beaver Creek watershed.

Drone footage from a flood event in Johnston in 2019 (City of Johnston).

Figure 4.13 - Map of the 100-year floodplain in the Beaver Creek watershed.



05

RELATED STUDIES

A variety of past planning efforts are essential to review and consider in building the foundation of an implementation plan for this watershed. These studies help provide context through data collection, past analyses and projection of future changes that may occur within the watershed.

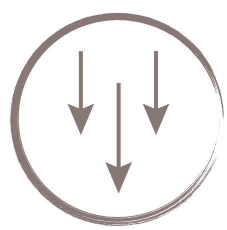
05

Past studies considered during plan development.

Community scale plans

Future land use plans

Smaller
subwatershed plans



Iowa's Nutrient
Reduction Strategy

OVERVIEW OF LOCAL WATERSHED STUDIES

There are a series of previous studies to be considered as part of this assessment and work related to development of a watershed improvement program.

Oxley Creek Watershed Management Plan

The City of Granger created this plan in 2010 to address flood risk, streambank stability, runoff volume reduction and how these issues relate to City policy. The City coordinated with IDALS and local SWCD in the creation of this plan for this 5+ square mile watershed area. The management plan focuses on reduction of sediment delivery, alternative development strategies and informed decision making related to development within the watershed. The plan identified a series of stormwater management projects which could be implemented.

City of Johnston Watershed Assessment and Stormwater Management Action Plan

This document was prepared through an 18-month planning effort, working directly with a steering committee of key stakeholders assembled by the City of Johnston. The project manager for the consultant team leading this current planning effort (Greg Pierce), worked directly with the City and steering committee to complete this plan, during his past employment at Nilles Associates. At the time, **this was a unique effort by the City, to evaluate watershed conditions throughout their community and within its future growth areas.** It included assessments of 25 miles of urban stream corridors and identified over 80 potential improvement projects. Several of these projects were selected for inclusion in a 20-year implementation plan. **This study was a basis for establishment of a new storm water utility to fund projects and updated stormwater requirements for new developments within the City**. Since plan adoption, the City has completed several projects focused on water quality, runoff reduction and stream stabilization.

City of Grimes Watershed Planning

In response to community flooding in 2010, the City completed a community review of stormwater issues. **Through public interaction and assessment of 15 miles of drainage channels, numerous projects were identified to reduce flood risk.** Over $500,000 of projects have been implemented to date.

The City also completed an assessment of their portion of the Little Beaver Creek watershed as part of an application for a Sponsored Project through the SRF program. **This assessment led to identification of a site to create a stormwater wetland to improve water quality.** The City has also moved forward with stream stabilization projects along Little Beaver and Prairie Creeks.

Dallas County Soil and Water Conservation District (SWCD) – 1% Challenge

This program involves networking between farmers to increase implementation of practices which improve soil health. **Such practices include no-till, cover crops and rotation programs, to achieve a goal of improving soil organic matter by 1%.** It is hoped that this effort can be shared with other groups throughout the Beaver Creek watershed. NRCS staff have begun outlining 900 farm parcels that will fall in the area to be covered by this planning effort.

Polk County Conservation Water Quality Monitoring

Polk County Conservation has committed to a routine water quality sampling program across Polk County, including 60 sites in total (7 of which fall within the Beaver Creek watershed). This data will expand the record of available data, allowing for improved calibration of water quality models and evaluation of implemented practices.

Des Moines MPO – Regional Water Trails and Greenways Plan

The Des Moines Metropolitan Planning Organization (MPO) recently completed two separate feasibility studies related to implementation of water trails and greenways improvements throughout the counties and cities that surround the Des Moines metropolitan area. **The location of proposed improvement sites along Beaver Creek identified within the regional feasibility study will be considered as part of development of this plan.**

Nature Conservancy Oxbow Restorations

The Nature Conservancy has been working across Central Iowa since 2016 to locate potential sites for oxbow restoration and implement improvements. This group has allocated funding toward implementing restorations in the Beaver Creek watershed over the next two years.

SUMMARY OF FUTURE LAND USE PLANS

The southern portion of the Beaver Creek watershed is experiencing rapid urban growth. Current and future land uses are a critical consideration in developing a watershed plan that will be able to adjust with anticipated land use changes.

City of Johnston Comprehensive Plan

The City's 2030 Comprehensive Plan was adopted in December 2010, prepared by a consultant team led by Hoisington Koegler Group Inc. Information gathered during the City's watershed assessment (referenced earlier) was considered in the development of this plan. **Chapter 5 of that document details current (at the time) and expected future land uses.** That chapter also details action steps for specific areas, including areas of potential redevelopment. Other important chapters with information related to watershed planning are:

- Chapter 2 – Johnston in 2030
- Chapter 4 – Natural Resources
- Chapter 6 – Transportation
- Chapter 8 – Parks and Recreation
- Chapter 9 – Utilities
- Chapter 10 – Implementation

Current link for additional information: http://www.cityofjohnston.com/109/Comprehensive-Plan

City of Grimes Comprehensive Plan

The Comprehensive Development Plan for Grimes was created in September 2010 and updated in 2018, prepared by RDG Planning & Design. The City is currently working with RDG on an update to this plan, which is expected to be finalized soon. The current version of the plan organizes key information into the following parts:

- Chapter 2 – A Land Use Profile
- Chapter 3 – Public Facilities and Infrastructure
- Section Two – A Community Vision
- Section Three – A Community Plan

Current link for additional information: http://www.grimesiowa.gov/

The Tomorrow Plan

The Tomorrow Plan was created to convey a vision of sustainable development for the Greater Des Moines region over a 40-year period, starting with its adoption in 2013. Access to the outdoors, environmental health, greenway preservation and regional cooperation were all outlined within this document.

Current link for additional information: https://dmampo.org/the-tomorrow-plan/

IOWA NUTRIENT REDUCTION STRATEGY—UPDATED 2017

The subtitle of this report is "a science and technology based framework to assess and reduce nutrients to Iowa waters and the Gulf of Mexico." It was prepared by the Iowa Department of Agriculture and Land Stewardship (IDALS) along with the IDNR and Iowa State University's College of Agriculture and Life Sciences.

It was developed following the creation of the 2008 Gulf Hypoxia Action Plan that calls for states to create strategies to reduce pollutant loadings to the Gulf of Mexico. The Action Plan set a goal of at least 45% reduction in total nitrogen and total phosphorus loads. The Iowa Nutrient Reduction Strategy outlines steps to prioritize watersheds and resources, improve current state programs and increase voluntary efforts to reduce nutrient loadings (Executive Summary).

The Nutrient Strategy assigns pollutant loadings to both point and non-point sources. **It assumes that a 4% reduction in nitrogen and 16% reduction in phosphorus can be accomplished by point source reductions such as improvements at wastewater treatment plants. The remaining 41% of nitrogen and 29% of phosphorus reductions are identified as being accomplished through non-point source reductions** (page 3).

The Strategy expects that nitrogen losses are a greater concern in tile drained landscapes. The largest losses are expected to occur with sustained flows occurring in the spring and at times with little evapotranspiration and nutrient uptake. **In steeper, hilly areas, phosphorus losses can be greater.** Surface runoff and transported sediment are common carriers of phosphorus. The largest losses can occur after rainfall events (page 9). **Streambank erosion is also identified as potentially significant source of phosphorus loading** (page 10). The Strategy includes the Iowa Nonpoint Source Nutrient Reduction Science Assessment. This is based on peer-reviewed studies of in-field, edge-of-field and watershed scale practices and treatments to determine potential reductions in total nitrogen and phosphorus. The framework for the Nutrient Reduction Strategy includes several major points (pages 18-26).

Prioritization of Watersheds. In 2013, the Water Resources Coordinating Council (WRCC) selected nine priority watersheds to focus targeted conservation and water quality efforts.

Determine Watershed Goals. The WRCC is tasked with coordination of indicators to provide stakeholders with information to establish baselines and report progress.

Ensure Effectiveness of Point Source Permits. The goal is to have major Publicly Owned Treatment Works (POTWs) install improvements to reduce nutrient outflow. Permitted animal feeding operations will continue to be monitored. Iowa point sources, IDNR, IDALS and WRCC will work to develop a nutrient trading credit program, based on 2003 EPA guidance.

Agricultural Areas. Setting priorities includes a focus on conservation, in- and off-field practices, pilot projects and implementation of nutrient trading. Research and Technology will continue to identify new technologies and solutions, develop private and public support for more research and continue to gain a better understanding of the Gulf Hypoxia Zone. An approach to improved outreach, education and collaboration is outlined. Programs for farmer recognition and a statewide education and marketing campaign is identified as a need. Sources of potential funding are briefly described.

Storm Water, Septic Systems, Minor POTWs and Source Water Protection. No specific nutrient reductions are identified for urban stormwater runoff. However, a focus is given to infiltration of the water quality volume (runoff from a 1.25" rainfall event). By managing this volume, reductions of 80-85% of annual runoff volumes could be achieved. Septic systems are proposed to be addressed through time of sale inspections to identify and correct leaky systems. The Iowa Source Water Protection Program educates the public and local officials on the importance of protecting groundwater drinking water resources. A link to potential funding sources is provided. Accountability and Verification Measures. A technical work group will define the process for providing a regular nutrient load estimate. The IDNR will track progress of implementing the reduction strategy for permitted point sources. A system for tracking non-point sources and improvements is outlined.

Public Reporting. WRCC will develop public annual reports. Watershed management plans are expected to include strategies to assess and demonstrate progress in achieving load reductions.

Nutrient Criteria Development. IDNR continues to review and assess water quality, with development of a suitable nutrient criteria as a long-term goal.

- Key practices for nitrogen removal:
  - Nitrogen management practices, **cover crops** and **living mulches**.
  - Land use changes to energy crops, **perennial vegetation** or **extended rotations**.
  - Wetlands, **buffers** and **bioreactors** are edge-of-field practices with greatest potential for nitrogen reduction.
- Key practices for phosphorus removal:
  - Reducing tillage and cover crops can significantly reduce phosphorus loss.
  - Land use changes from corn-soybeans to energy crops, perennial vegetation or extended rotations.
  - Edge of field practices that settle sediment such as ponds and stream buffers.
- The Science Team will publish an updated practice list as an addendum to the Reduction Strategy.

Winter rye cover crops.

06

WATER QUALITY ASSESSMENT

Stream and lake monitoring creates a record of monitored stream and lake conditions that can be compared to standards and criteria, used to detect changes over time, and support future watershed rehabilitation efforts. The ability of a monitoring program to detect such changes and the reliability of the comparisons depend upon the nature and design of the monitoring program.

06

4

Water quality sites

Operated by Iowa Soybean Association and Agriculture's Clean Water Alliance (ACWA) included in data reviewed.

Nitrate concentrations

Commonly exceed the water quality standard of 10mg/L at the sites reviewed.

Water quality data is limited

Sources reviewed as part of this plan:

1. Federal
2. State
3. Volunteer monitoring

WATER QUALITY DATA

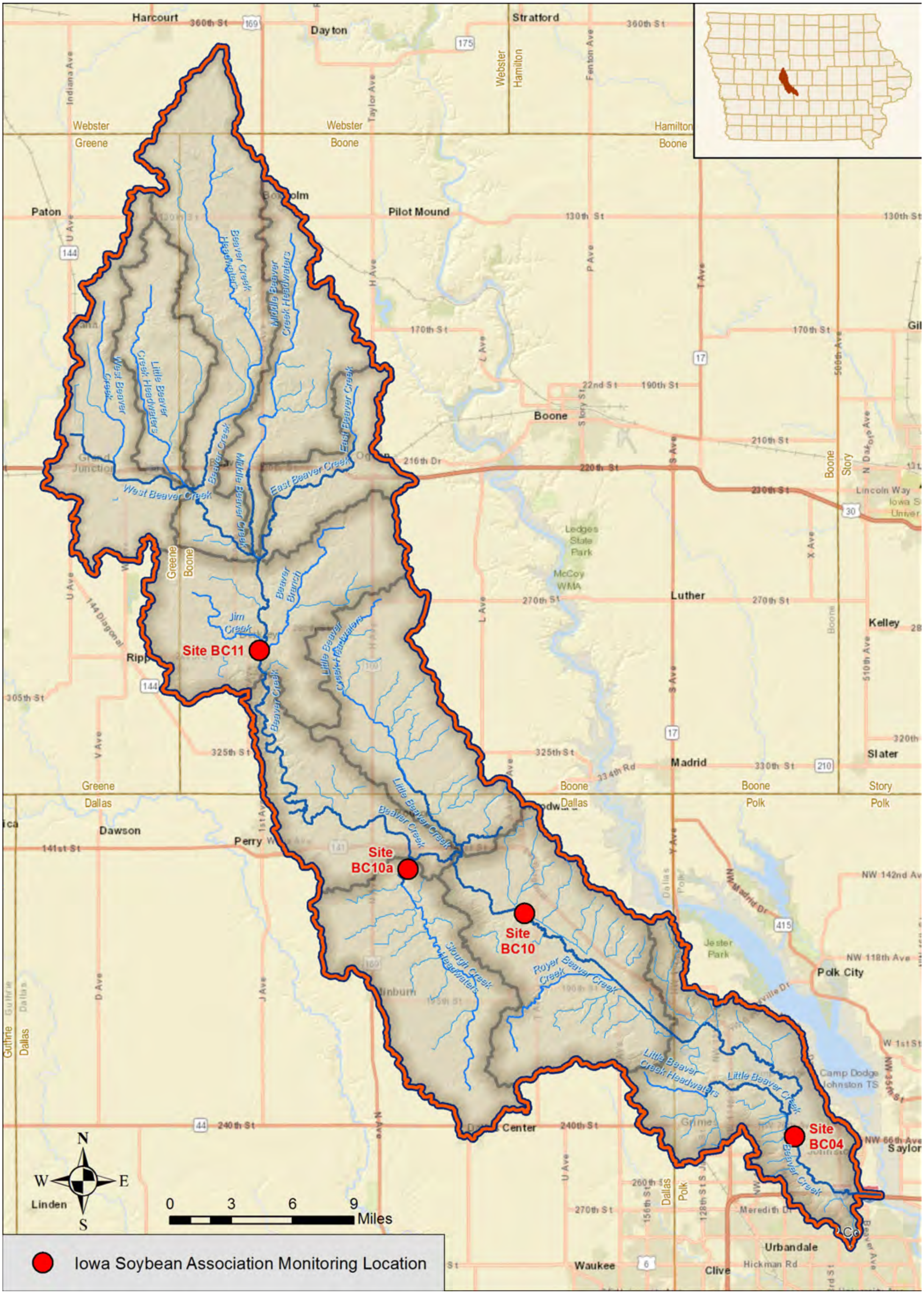
Stream monitoring data has been collected annually during the growing season (April-August) from 2008-2018 by the Iowa Soybean Association (ISA) in coordination with the Agriculture Clean Water Alliance (ACWA) **at four locations within the Beaver Creek Watershed** (Figure 6.1). A review of this information has yielded important information regarding long term average Nitrate-Nitrogen concentration at four locations within the Beaver Creek Watershed.

Additional monitoring efforts of streams in the Beaver Creek Watershed incorporate data collected by the United States Geological Survey (USGS), data collected by the University of Iowa through the Iowa Water Quality Information System and data collected through volunteer-led efforts that engage students and citizens in volunteer monitoring. **The majority of the data found on the EPA's Water Quality Data download portal (formerly STORET) was collected by volunteers through the IOWAWATER program; the IOWAWATER program was discontinued in 2016.** The number of samples per stream reach varied considerably between streams and varied over time. Volunteer monitoring efforts relied upon 'kit' analyses of nitrate and phosphorus concentrations and hence, values were reported in coarse intervals. Given the limited availability and coarse nature of **these sample sets, the foregoing paragraphs were framed in terms of the general nature of observed water quality concentrations** rather than an in-depth statistical analysis of the actual data. In contrast, the nitrate-nitrogen dataset collected by the ISA/ACWA is a consistent long-term dataset from which trends can be evaluated.

Iowa Water Quality Information System:
IWQIS- https://iwqis.iowawis.org/app

Water quality sampling using IOWATER volunteer sampling kit.

Figure 6.1: Iowa Soybean Association / ACWA Monitoring Locations



NITRATE/NITROGEN

Nitrogen is an important nutrient, particularly the dissolved forms, as it increases plant productivity on farm fields, urban lawns and streams/lakes. Nitrate (NO_3) nitrogen is the dominant dissolved fraction with typically very small amounts of nitrite nitrogen present (which can be quite ephemeral). Hence, discussion will focus on nitrate nitrogen. While (NO_3)is one of the primary forms of nitrogen used by plants for growth, **excess amounts in groundwater and streams can cause human health concerns.** At concentrations greater than 10 milligrams per liter (mg/L), nitrate has been linked to methemoglobinemia ("blue baby syndrome"), which primarily impacts infants and susceptible adults. **At high concentrations, nitrates are also toxic to aquatic life and can cause eutrophic conditions.** Sometimes these eutrophic conditions become extreme and can result in areas with little to no oxygen (hypoxic zones). These hypoxic zones cause aquatic life to retreat from the area, or worse, they may suffocate and die resulting in massive fish kills. The applicable water quality standard for nitrate is 10 mg/L.

Table 6.1 displays monthly and overall average (NO_3) concentrations for the four monitored locations in the Beaver Creek Watershed that were annually monitored from April - August by the ACWA. **Observed average (NO3) concentrations (April-August) ranged from a low of 8.4mg/L (Beaver Creek – BC-04) to a high of 12.9 mg/L (Slough Creek – BC-10a).**

Average monthly (NO3) concentrations during the months of May and June consistently exceeded the 10 mg/L standard along every stream reach. In contrast, monthly (NO_3) concentrations during July and August were all below 10 mg/L, with the exception of Slough Creek during the month of July. Observed seasonal changes in (NO_3) concentrations are reflective of a land use change from perennial grasslands to seasonal row crops, which rely on subsurface tile drainage. Given that land use within the Beaver Creek Watershed District is predominately (>75%) agricultural and that tile drainage occurs mostly in the spring, it is not surpising to see elevated (NO_3) concentrations in the spring. Similar seasonal patterns in nitrate concentrations have been observed throughout Iowa, including the Middle Cedar River, and the Raccoon River watershed in west Central Iowa (Schilling, 2004).

Table 6.1: Average Monthly Nitrate Nitrogen Concentrations at 3 monitoring locations on Beaver Creek & 1 monitoring location on Slough Creek from 2008-2018.

STREAM REACH NAME	AVERAGE MONTHLY NITRATE NITROGEN CONCENTRATION (MG/L)					APRIL - AUGUST AVERAGE NITRATE NITROGEN CONCENTRATION (MG/L)
	APRIL	MAY	JUNE	JULY	AUGUST	
Beaver Creek - BC-04	8.8	10.8	11.7	8.0	2.9	8.4
Beaver Creek - BC-10	10.3	12.9	14.3	9.5	3.1	10.0
Slough Creek - BC-10a	13.0	16.3	17.6	12.5	5.1	12.9
Beaver Creek - BC-11	10.9	13.7	14.2	9.3	3.3	10.3

Average annual NO3 concentrations were lowest at BC-04, which is the most downstream reach in the Beaver Creek Watershed (Table 6.2). The highest observed average annual nitrate concentrations across all four monitored streams occurred during the 2013 monitoring season. Precipitation totals during the 2012 and 2013 growing season were lower than average with only 13.2 (2012) and 18.77 (2013) inches of rainfall occuring from May-September. **High nitrate concentrations during periods of time with low rainfall totals indicate point sources may be a potentially significant nitrogen source.**

Table 6.2: Average Yearly Nitrate Nitrogen Concentrations

STREAM REACH NAME	AVERAGE ANNUAL CONCENTRATION											
	'08	'09	'10	'11	'12	'13	'14	'15	'16	'17	'18	11 YEAR AVERAGE
Beaver Creek - BC-4	8.5	7.3	6.3	7.0	7.2	15.5	7.2	10.3	8.3	8.6	8.0	8.7
Beaver Creek - BC-10	10.4	8.3	7.8	7.9	7.7	17.2	9.7	16.4	9.4	9.0	10.3	10.4
Slough Creek - BC-10a	12.3	8.9	11.0	10.0	10.3	24.8	16.8	15.2	12.9	11.3	12.7	13.3
Beaver Creek - BC-11	9.9	8.3	8.2	8.1	7.5	19.6	9.9	15.1	9.3	9.7	11.2	10.6

TOTAL PHOSPHORUS

Phosphorus concentration in water is a primary focus of applied watershed management as this element drives a wide array of river, stream and lake biological responses affecting beneficial uses. **Excess phosphorus concentrations lead to increased algae growth, increased organic matter, and increased bacteria** that lead to boom-bust daily oxygen concentration cycles that limit aquatic life. In severe cases, massive algal mats and scums can be generated by blue-green algae. **Blue-green algae can also produce toxins, such as microcystin, which negatively impact wildlife and drinking water supplies.**

The Environmental Protection Agency (EPA) has developed national nutrient criteria recommendations by ecoregion based on nutrient data from a large number of the nation's lakes and rivers (EPA 2000). Ecoregions are defined as areas of similar ecosystem and geography. The 25th percentile Total Phosphorus (TP) concentration for streams in the Western Corn Belt Plains ecoregion is 0.118 mg/L. **A review of data downloaded from the EPA for the Beaver Creek Watershed revealed the average growing season TP concentration often exceeds this standard for most streams within the watershed**. No distinct seasonal patterns were observed in terms of average monthly TP concentration.

TOTAL SUSPENDED SOLIDS

Total Suspended Solids (TSS) is a measurement of the amount of material suspended instream, which is often referred to as turbidity. As more material is suspended in the stream, less light can pass through, making the water less transparent. **Suspended materials may include soil, algae, plankton, and microbes.**

Excess turbidity can significantly degrade the aesthetic qualities of waterbodies. People are less likely to recreate in waters degraded by excess turbidity. Turbidity can also make the water more expensive to treat for drinking or food processing uses. Excess turbidity can also harm aquatic life, aquatic organisms may have trouble finding food, gill function may be affected, and spawning beds may be buried. **Turbidity can also lead to higher water temperatures which can promote bacteria growth.**

Monthly TSS concentrations were highest from April through June, which correspond to the period of the year where row crops have not yet become established. During this time, bare soil from agricultural fields is more likely to become detached during precipitation events, given the rate and magnitude of water erosion is usually greatest during short-duration, high-intensity thunderstorms; during snowmelt; when soils have high moisture content; and when vegetative cover is minimal.

BACTERIA (E. COLI)

Bacteria are present in the bodies of humans and animals and exist in countless forms in both land and water. Most forms of bacteria are beneficial, but approximately 10% can be harmful when ingested by humans. Symptoms from ingesting harmful bacteria may include gastrointestinal illnesses, fatigue, and a number of other problems. Because there are so many forms of bacteria, testing for E. coli is used as an indicator for possible presence of pathogens in water. Bacteria levels can be affected by many factors, including seasonal weather, stream flow, water temperature, livestock management practices, and sewage over flows. Some types of bacteria are also used as an indicator species for other pathogens (E.coli and fecal coliform). Some viruses, parasites and other organisms are more difficult to test for but may flourish in conditions that also would foster higher levels of these indicator bacteria. So, the risks associated with high levels of E.coli are not limited to illness caused by that specific bacteria, but could also include risks associated with other pathogens.

The Iowa State Standard Maximum Single Sample MPN/100ml E.coli concentration is 235 MPN/100ml. Comparing observed data collected in the Beaver Creek watershed with the 235 MPN/100ml State Standard suggests **all tributaries and mainstem reaches are significantly impaired due to excessive bacteria contributions from the watershed with average E. coli concentrations exceeding 1,200 MPN/100ml.**

Source -- https://www.pca.state.mn.us/sites/default/files/wq-iw3-20.pdf

Cattle in the stream within the Beaver Creek watershed.

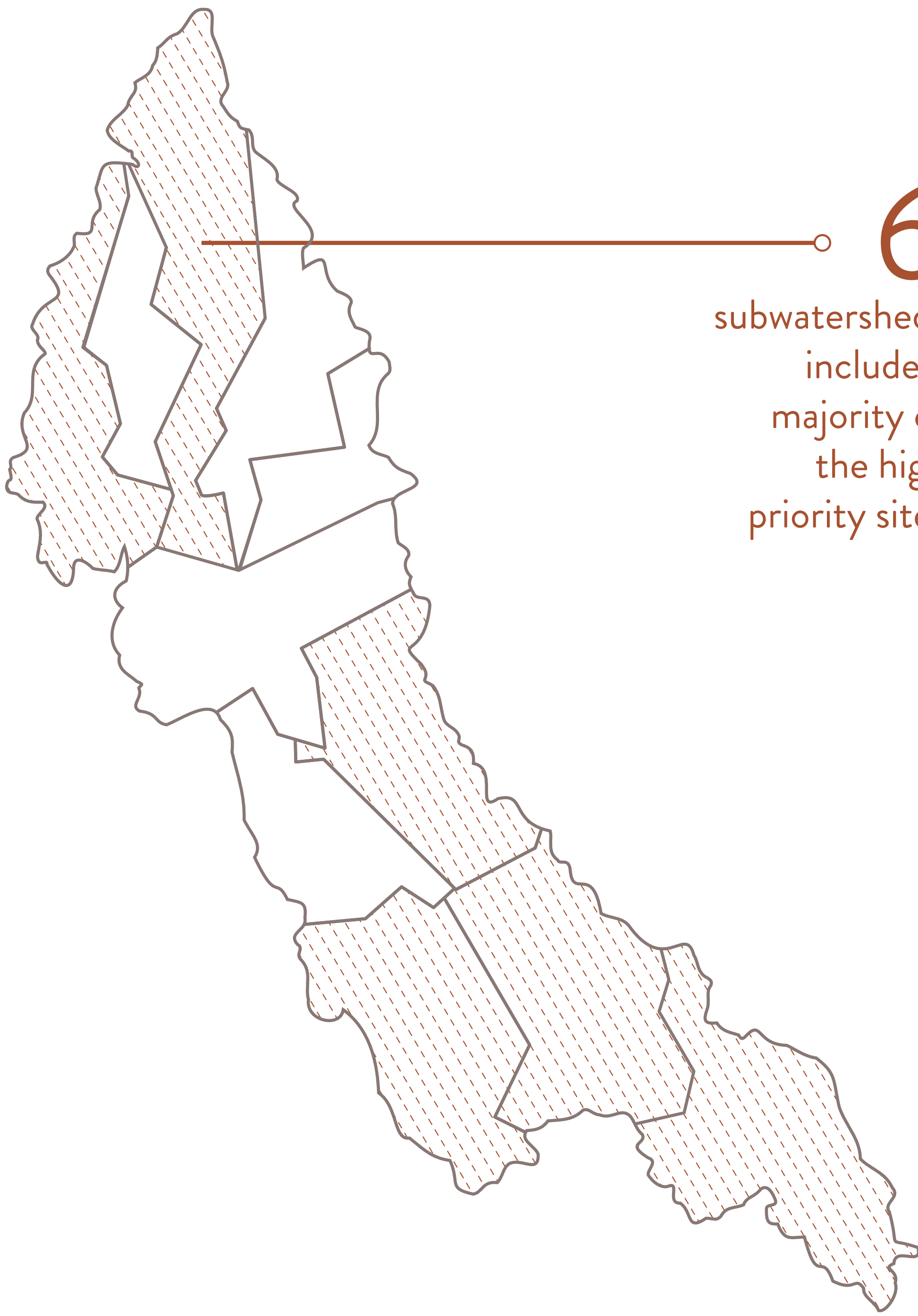
07

STREAMBANK ASSESSMENT

Due to the area of land included as part of this planning effort, a detailed field assessment of conditions along major streams throughout the watershed was not feasible to be completed. GIS data was used to perform a screening level evaluation of conditions along each stream corridor.

07

1,315 high priority sites address channel erosion.



6

subwatersheds include a majority of the high priority sites

STREAMBANK ASSESSMENT

Stream geomorphology and hydrology have a direct influence on stream health and biological integrity. Streams essentially act as conveyance channels for water and sediment flowing through the watershed. Land-use and climate change have a strong influence on stream stability and water quality as described in previous sections. There have been substantial flow increases in most Iowa Rivers over the recent decades, contributing to sediment loading from streambanks. **The sediment that is eroded contributes to water quality degradation and impairs in-stream aquatic life.** The inherent potential for soil to erode is largely determined by the slope and topography of the land; steeply sloped riparian areas maintained in non-natural land uses (row crops, urban settings) represent likely locations for stream bank failures to occur.

LiDAR data was used to evaluate stream bank stability within the Beaver Creek Watershed by combining Stream Power Index (SPI), Topographic Position Index (TPI), and non-natural riparian landcover with steeply sloped near channel areas within 150 feet of a mapped stream channel. For this exercises, steeply sloped, near channel areas were defined as those areas in which critical slopes (> 15%), represented at least 10% of the total area within 150 feet of the mapped stream. As previously mentioned, slopes exceeding 15% represent less than 3% of the total watershed area. Steeply sloped areas in close proximity to the stream channel represent areas more prone to streambank failure.
The stream power index (SPI) calculation measures the erosive power of overland flow as a function of local slope and upstream drainage area which is derived from the LIDAR data. High SPI values located in riparian areas with steep slopes are typically correlated with near-channel, active erosion problems (e.g., gullies, ravines) on the landscape. High SPI signatures were intersected with the steeply sloped, near channel areas to further prioritize critical streambank sites within the watershed (Figure 7.1).

The results of the SPI/steeply sloped area intersection were intersected with non-natural stream riparian areas (areas where less than 25% of the land area within 150 feet of the stream was comprised of natural (Forest, Grasslands, Wetlands) land cover.

Next, high stream banks and valued, man-made features (roadways, buildings) were identified using the National Resources Conservation Service (NRCS) Engineering Toolbox Topographic Position Index (TPI) tool, which uses LiDAR data to calculate the difference in height between a given raster cell and the adjacent cells around it. Screening the results from the TPI calculation to include only those raster cells in the top 25% of the TPI score (cells more than 4.25 feet higher in elevation than their surrounding cells) **produced a map which identified both high stream banks, roadways, and buildings.** The intersection of the Top 25% TPI layer with the previous non-natural land use/SPI/steeply sloped area intersection resulted in **1,315 high priority sites that were largely grouped in 6 key areas within the Beaver Creek Watershed** (Figure 7.2).

Figure 7.1: Streambank Assessment - Potential for streambank failure

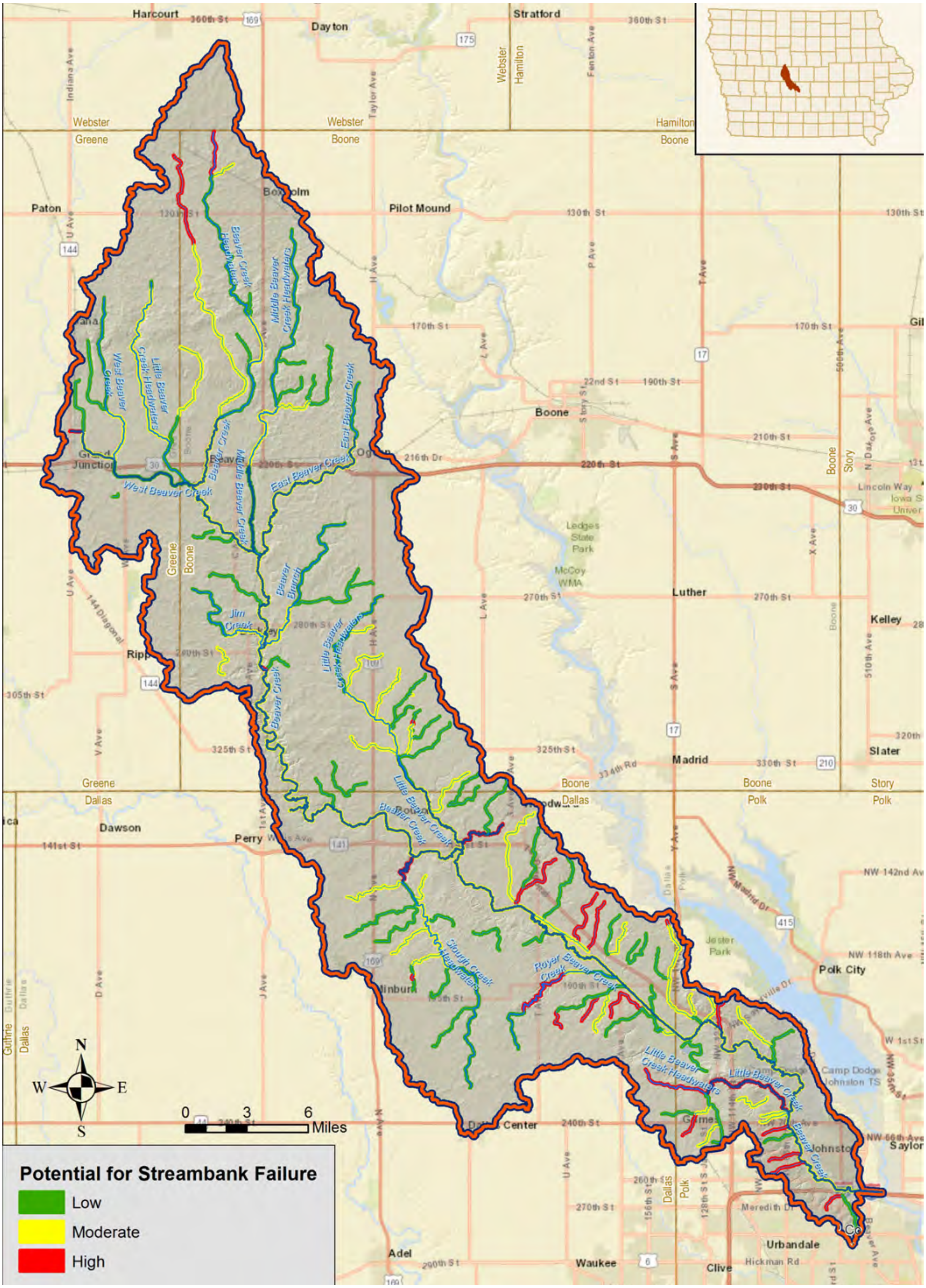
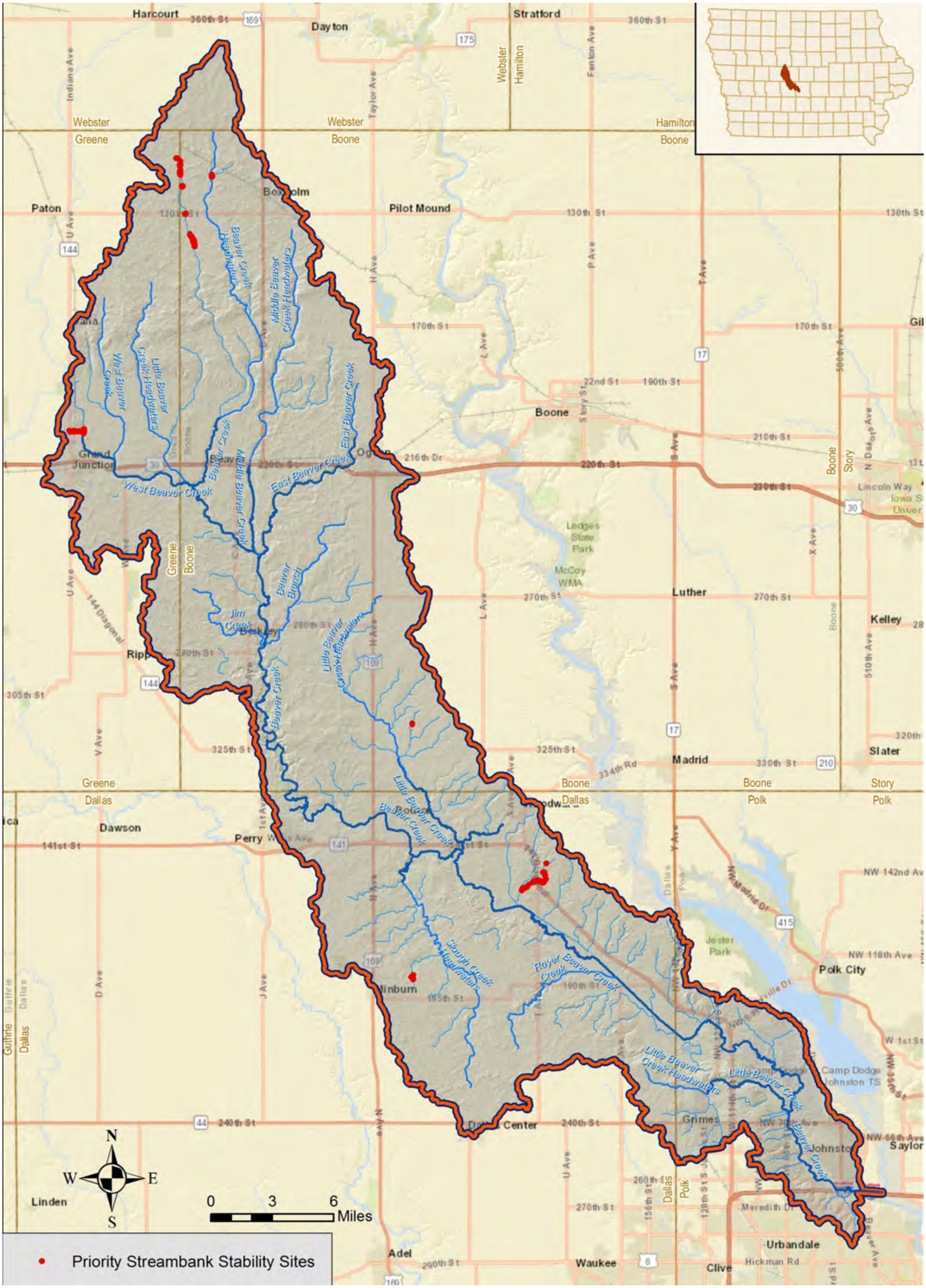


Figure 7.2: Priority streambank sites

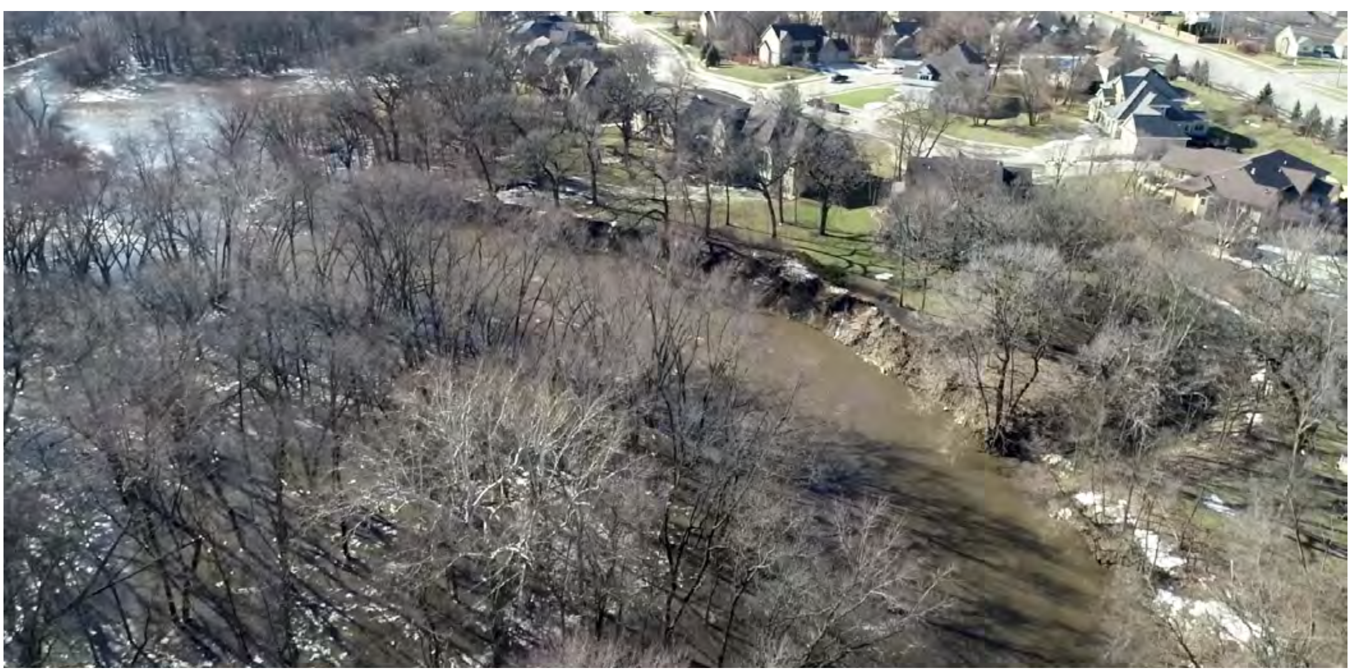


Monitoring conducted near an unstable stream bank (City of Johnston).

Bank erosion near a public trail (City of Johnston).

Bank erosion along a tributary to Beaver Creek.

Bank movement has left this tile outlet projecting into the stream in the Beaver Creek watershed.



Aerial image of an unstable streambank (City of Johnston).

EXISTING CONSERVATION PRACTICES

The Iowa DNR - in coordination with Iowa State University - embarked on a project to map agricultural conservation practices that exist in the landscape across Iowa. **The goal of the Iowa BMP (Best Management Practices) Mapping Project was to provide a complete baseline set of BMPs dating from the 2007-2010 timeframe for use in watershed modeling, historic occurrence, and future practice tracking.** The BMPs mapped are: Terraces, Water and Sediment Control Basins (WASCOB), Grassed Waterways, Pond Dams, Contour Strip Cropping and Contour Buffer Strips. The project can't guarantee that mapped practices meet NRCS standards or that they are actually the indicated practice since no ground truthing was performed. Data utilized to digitize the BMPs included LiDAR derived products such as DEM, Hillshade and Slope grids; CIR aerial photography from the 2007-2010 timeframe, NAIP aerial photography and historic aerial photography. This project was funded by the Iowa Department of Natural Resources, Iowa Department of Agriculture and Land Stewardship, Iowa Nutrient Research Center at ISU, National Laboratory for Agriculture and the Environment and Iowa Nutrient Research and Education Council.

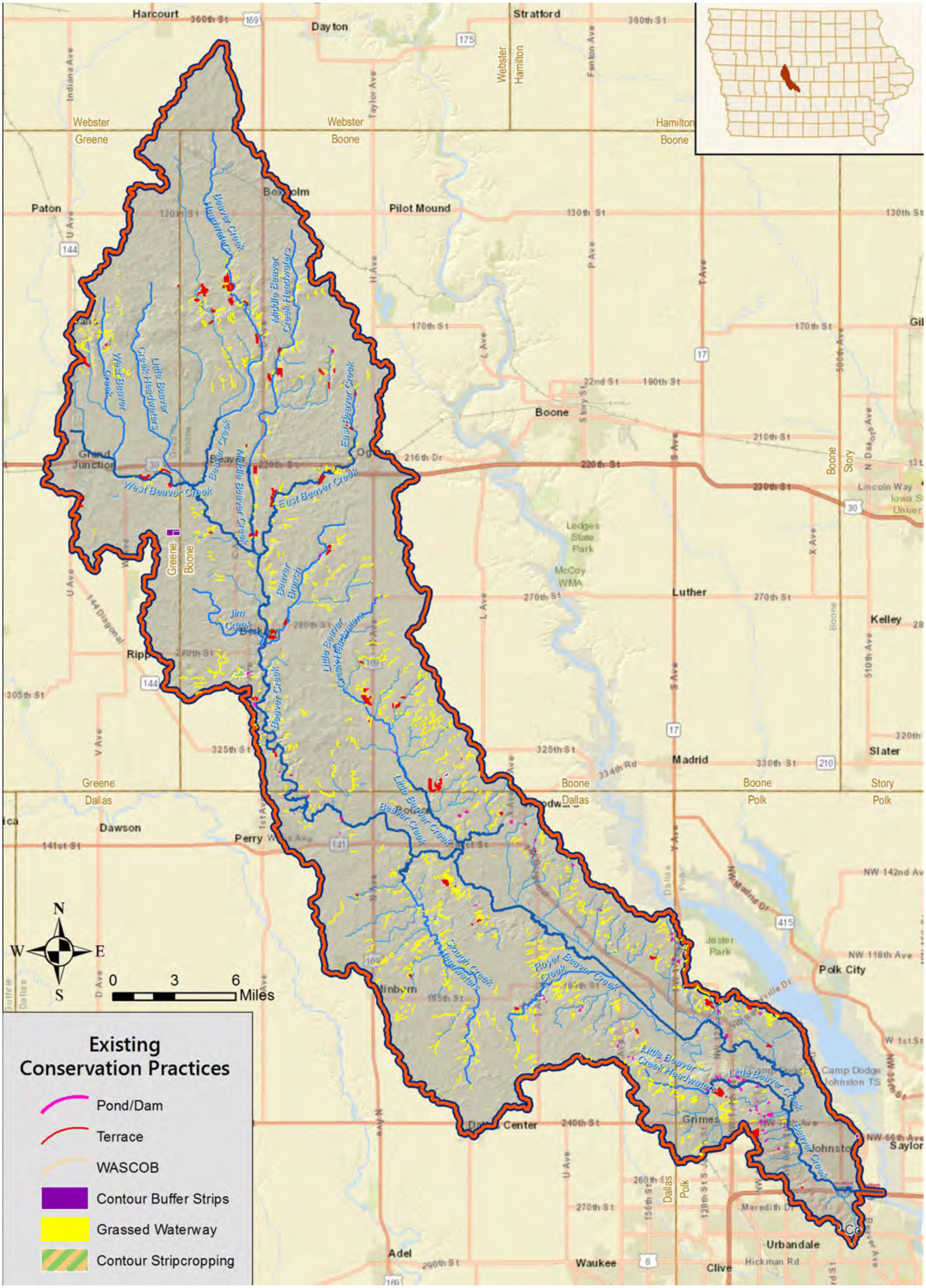
The existing agricultural conservation practices in Beaver Creek Watershed are shown in Figure 7.3.

A summary of the estimated current adoption rate of conservation practices by subwatershed area is included in Chapter 11 (see Table 11.1)

Buffering between cropland and the stream.

Bank stabilization project along Beaver Creek (City of Johnston).

Figure 7.3: .Existing agricultural conservation practices.



08

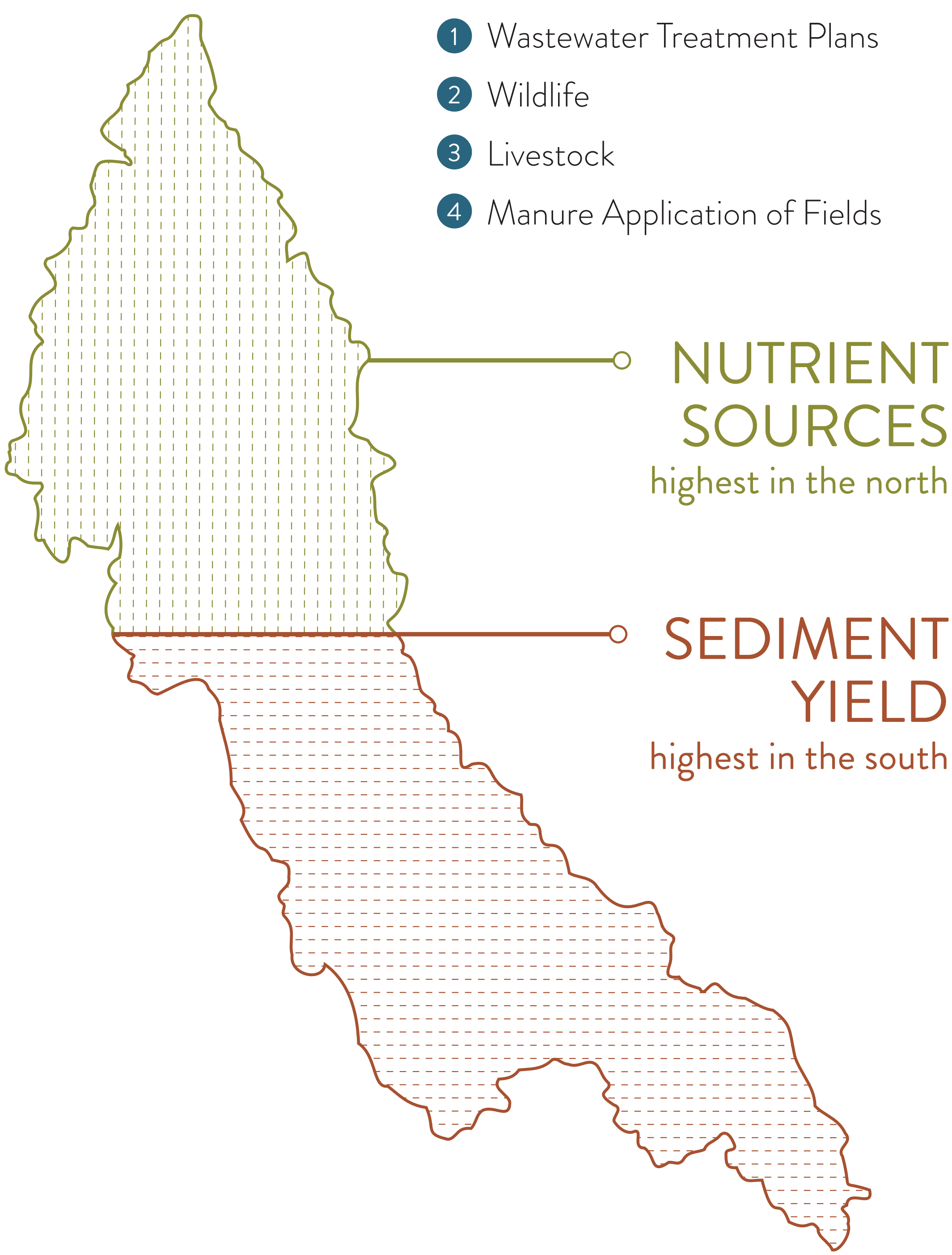
POLLUTANT SOURCE ASSESSMENT

Key pollutants of concern within the Beaver Creek watershed have been defined by considering past studies, collection of stakeholder input and an overview of available water quality monitoring information. This chapter reviews potential sources for these key pollutants, identified as phosphorus, nitrogen, total suspended solids (TSS) and bacteria.

08

Sources of bacteria loadings:

1. Wastewater Treatment Plans
2. Wildlife
3. Livestock
4. Manure Application of Fields



TOTAL PHOSPHORUS

Phosphorus is a primary nutrient for plant growth on the land and in the water. On the land, soil phosphorus concentrations, measured in the part per million range, are closely followed by agricultural and urban land owners. However, in water, phosphorus concentrations in the part per billion range are monitored, with excess phosphorus levels occurring at concentrations much lower than values measured in soils.

Phosphorus loads in water come from a variety of sources, including nonpoint sources (e.g. runoff from pasture and croplands, streambank erosion, urban runoff, non-agricultural runoff, individual sewage treatment systems) and point sources (e.g. municipal and industrial wastewater treatment facilities). The magnitude of phosphorus can vary greatly depending on the landscape characteristics of the watershed.

Source -- https://www.pca.state.mn.us/sites/default/files/wq-iw3-12.pdf

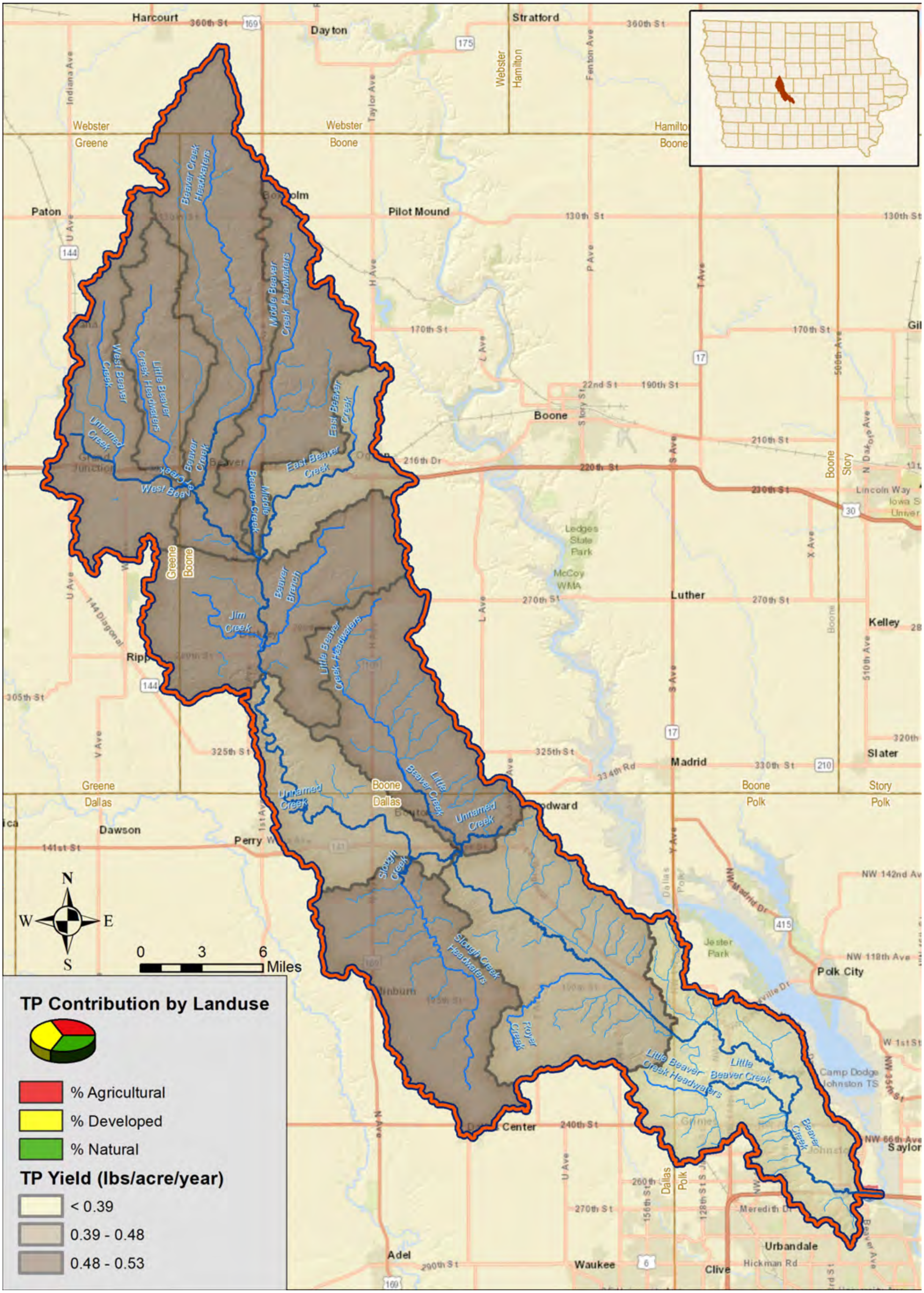
Phosphorus is typically monitored in two forms: dissolved phosphorus (forms most readily used by crops and aquatic plants, resulting in increased productivity); **and total phosphorus** (found in both dissolved and particulate forms).

Total phosphorus (TP) loads were estimated in the watershed by attributing different phosphorus loading rates to the landscape according to land use categories. The three primary high-level land use categories in the watershed are agricultural, developed, and natural areas, and each of these categories contributes phosphorus to receiving waters at a different rate per unit of area (for example, per acre) – often referred to as its unit area load (UAL). In the Beaver Creek watershed, annual TP loads were estimated to range from 0.39 to 0.53 pounds per acre.

A variety of sources were used to verify the UAL values used in the watershed, including values from the Minnesota Pollution Control Agency, the U.S. Army Corps of Engineers, the U.S. Environmental Protection Agency, and from the SWAT model that was constructed and calibrated for the nearby Squaw Creek Watershed. Additionally, the overall predicted TP loading from the watershed was compared to a 2004 report by the Iowa DNR, and the numbers were found to be in general agreement.

Within each subwatershed, the UAL values were multiplied by the total land area in each land use category to estimate the overall contribution of total phosphorus to Beaver Creek. Since agricultural lands account for most of the land area in the watershed, the vast majority of total phosphorus loading originates in those areas.

Figure 8.1: Beaver Creek Watershed Total Phosphorus Yields (Pounds/Acre/Year) by HUC-12 Subwatershed



TOTAL NITROGEN

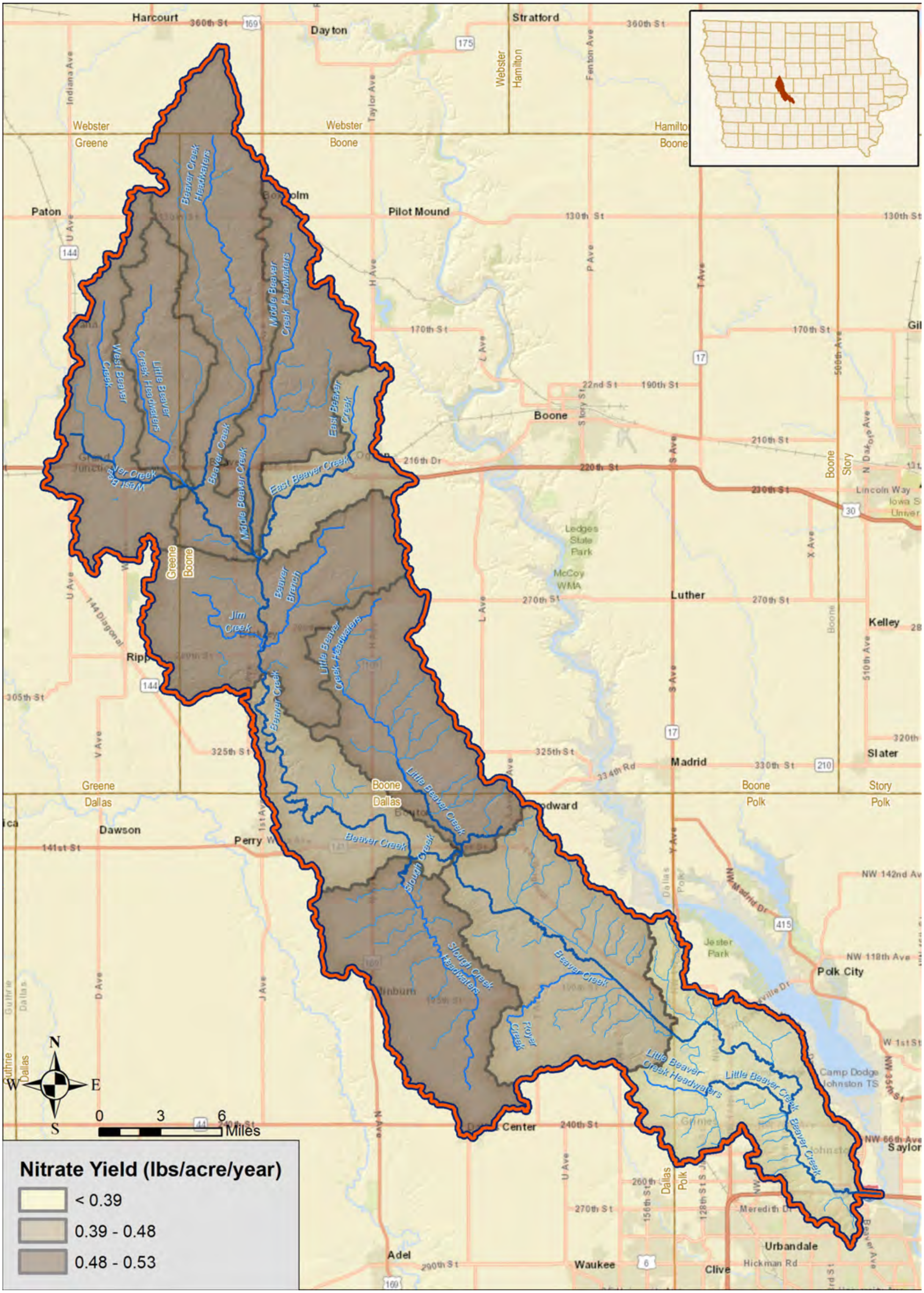
As stated in chapter 6, Nitrate nitrogen is the dominant dissolved form of nitrogen in groundwater and in surface water with high levels of nitrogen. Dissolved nitrite nitrogen is found in much lower levels and is typically measured together with nitrate nitrogen. Therefore, this discussion will focus on the combined nitrate plus nitrite nitrogen, with concentrations that vary seasonally from biological activity and nutrient inputs (fertilizer, wastewater, and urban runoff). Nitrates and other forms of nitrogen can come from natural sources like atmospheric deposition or decaying plant debris, but when the levels of nitrates exceed water quality standards, sources are typically associated with human activities, including fertilizer application, feedlots, or sewage treatment systems.

Source -- https://www.pca.state.mn.us/sites/default/files/wq-s6-26a2.pdf

Total nitrogen consists of dissolved (nitrate plus nitrite) **and organic nitrogen** (total Kjeldahl nitrogen). Nitrate and nitrite are inorganic and dissolved forms of nitrogen used for increasing productivity, with concentrations that vary seasonally from biological activity and nutrient inputs. They are formed through the oxidation of ammonia (NH 3-N) by nitrifying bacteria (nitrification). They are converted to other nitrogen forms by denitrification and plant uptake. Nitrite concentrations are typically quite low in aquatic systems and hence, discussions of nitrogen in streams typically focus on nitrate nitrogen levels.

Nitrate loading rates in the watershed were estimated using values from the SWAT model that was constructed and calibrated for the Des Moines River, to which Beaver Creek is tributary. A unique annual loading rate was assigned to each subwatershed, with values ranging from 12.7 to 20.1 pounds per acre. Since the vast majority of nitrate contributions to the creek come from agricultural lands, the lowest nitrate loading rates were observed in the most highly developed subwatersheds, as well as in subwatersheds with more remnant natural areas – such as those with forested riparian areas near the river."

Figure 8.2: Beaver Creek Watershed Total Nitrate Yields (Pounds/Acre/Year)by HUC-12 Subwatershed)



TOTAL SUSPENDED SOLIDS

Turbidity or TSS in excess can significantly degrade the aesthetic qualities of waterbodies and can also harm aquatic life. Sources of turbidity in water include natural sources (e.g. erosion from upland, riparian, stream bank and stream channel areas) and human sources (e.g. wastewater treatment facilities, nutrient runoff from cropland, and urban stormwater runoff). The following discussion highlights sources of turbidity in the environment and mechanisms that drive the delivery of sediment to surface waters.

Subwatershed (HUC-12) sediment yield (total sediment loss derived from sheet and rill erosion) and hillside soil loss (the portion of the total sediment yield that is potentially available for delivery to downstream water resources) data were extracted from Iowa's Daily Erosion Project dataset. Sediment yield data provides valuable information on Landscape sediment sources, which are those eroded by sheet or rill flow (i.e., very small channels), the type of erosion often associated with agricultural row-cropped fields but can apply to any landcover type. Sediment delivery data provides an additional weight of evidence that shows the proportion of the total sediment yield derived from the landscape that is delivered, or translocated to a downslope position where ephemeral gulley/ravine erosion processes dominate. Erosional features (ravines, gullies) that occur in close proximity to the watershed's stream channels represent near-channel sources. Collectively, landscape and near-channel sources comprise a watershed's contribution of sediment to downstream water resources.

A 2011 USGS study of select Minnesota Rivers reported an average annual basin TSS yield for the Des Moines River near the border of Minnesota and Iowa at 313 pounds/acre/year; equivalent to 0.15 tons/acre/year (Ellison et. al., 2013). **Modeled sediment delivery rates for subwatersheds in the Beaver Creek Watershed (0.91-2.09 tons/acre/year) were comparatively higher, suggesting TSS loading rates in the Beaver Creek watershed are relatively high**.

Figure 8.3: Beaver Creek Watershed Subwatershed (HUC-12) Total Suspended Solids Yield (Tons/Acre/Year)

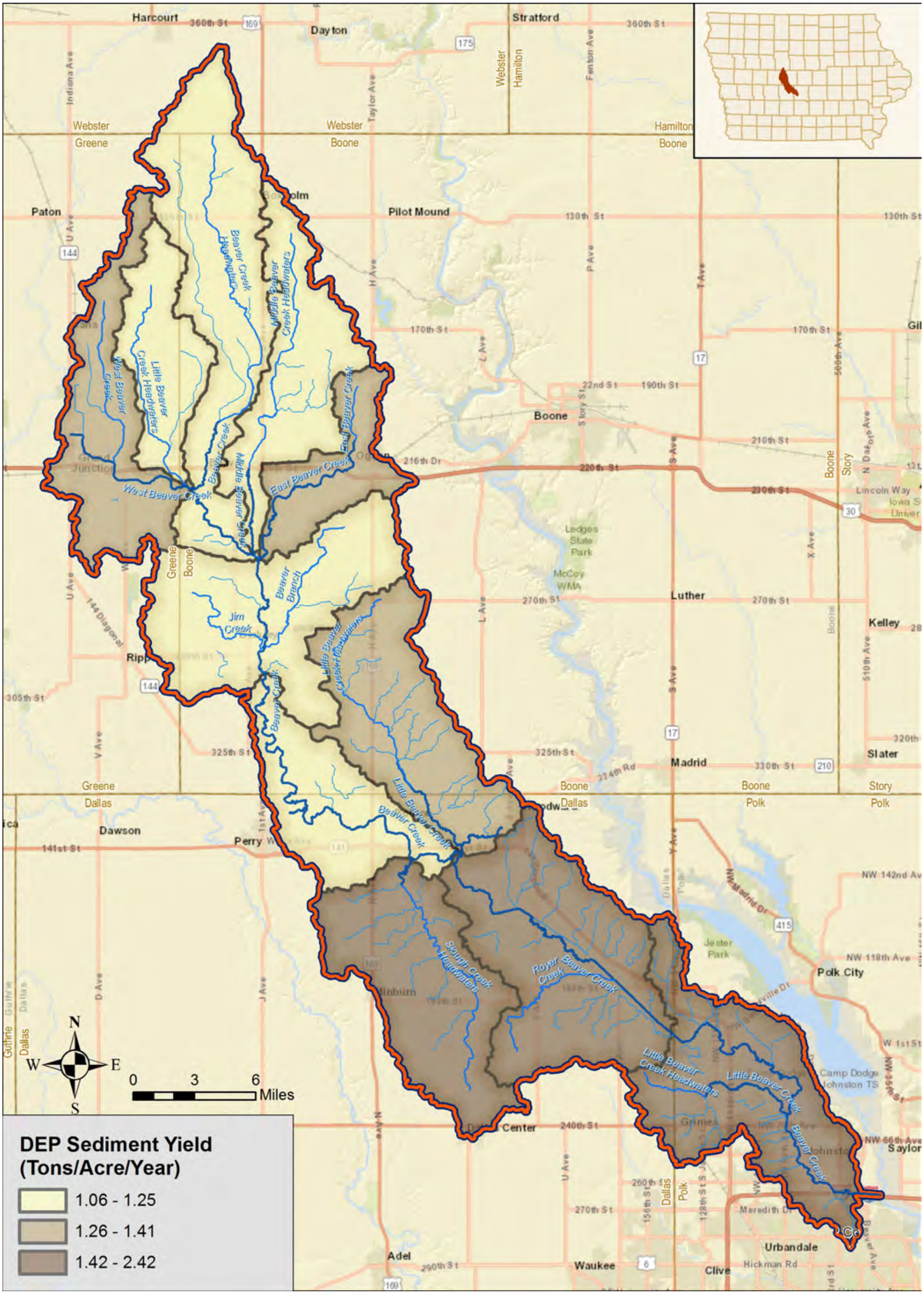
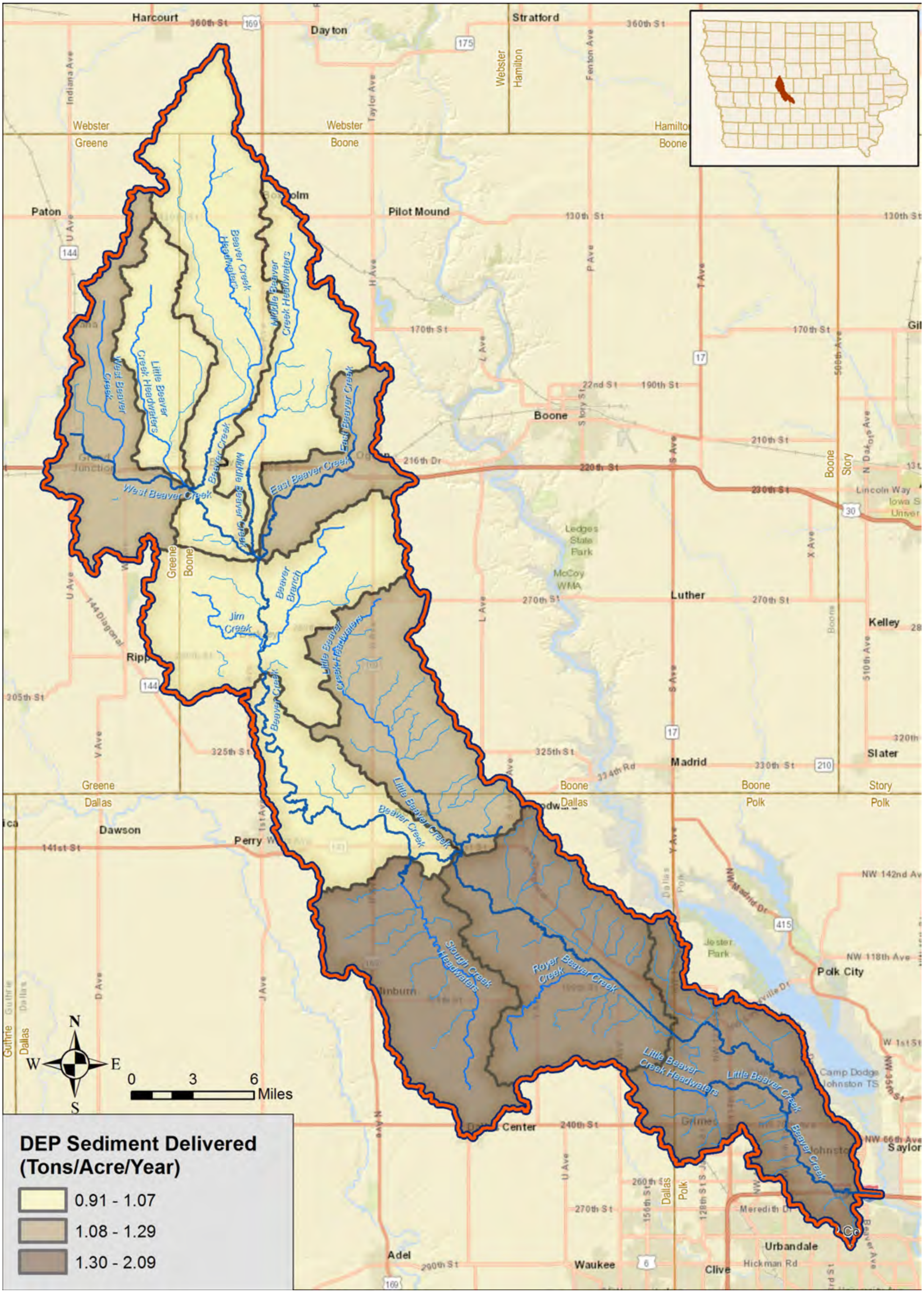


Figure 8.4: Beaver CreekWatershed Hillside Soil Loss (Tons/Acre/Year)by HUC-12 Subwatershed



BACTERIA

Humans, pets, livestock, and wildlife all contribute bacteria to the environment. These bacteria, after being excreted in animal waste, are dispersed throughout the environment by an array of natural and man-made mechanisms. Bacteria fate and transport is affected by disposal and treatment mechanisms, methods of manure reuse, imperviousness of land surfaces, and natural decay and die-off due to environmental factors such as ultraviolet (UV) exposure and detention time in the landscape. The following discussion highlights sources of bacteria in the environment and mechanisms that drive the delivery of bacteria to surface waters.

To evaluate the potential sources of bacteria to surface waters and to assist in targeting future reduction strategies, a desktop analysis was conducted for sources that are potentially contributing E. coli in the Beaver Creek Watershed. These populations may include livestock (cattle, swine or poultry), humans and wildlife (deer, geese). Populations were calculated using published estimates for each source on an individual subwatershed basis in the Beaver Creek Watershed.

Bacteria production estimates are based on the bacteria content in feces and an average excretion rate (with units of colony forming units (cfu)/day-head; where head implies an individual animal). Bacteria content and excretion rates vary by animal type, as shown in Table 8.1. All production rates obtained from the literature are for fecal coliform rather than E. coli due to the lack of E. coli data. The fecal coliform production rates were converted to E. coli production rates using the conversion of 200 fecal coliforms to 126 E. coli per 100 mL, based on relationships determined by the State of Minnesota in establishing their Standards (note EPA has determined a similar relationship).

Table 8.1: Bacteria production by source

SOURCE CATEGORY	PRODUCER	E.COLI PRODUCTION RATE [CFU/DAY-HEAD]	LITERATURE SOURCE
Humans	Humans	1.26×10^9	Metcalf and Eddy 1991
Companion Animals	Dogs	3.15×10^9	Horsley and Witten 1996
Livestock	Cattle	2.08×10^{10}	Zeckoski et al. 2005
	Hogs	6.93×10^9	Zeckoski et al. 2005
	Poultry	6.76×10^7	Zeckoski et al. 2005
Wildlife	Deer	2.21×10^8	Zeckoski et al. 2005
	Geese	2.5×10^{10}	LIRPB 1978

Wildlife

Deer population estimates in Iowa have remained consistent from 2014-2018 at around 500,000 animals. The Iowa DNR manages deer harvest numbers to be somewhere between 100,000 and 120,000 animals annually or approximately 20% of the total population prior to the hunting season.

The Iowa DNR maintains records of the total number of deer harvested by county annually from which population estimates can be derived. Estimates of deer populations for the Beaver Creek watershed were generated by area-weighting county-wide annual deer harvest totals from the **2017-2018 Trends in Iowa Wildlife** Populations and Harvest report to the total area of each county that is within the Beaver Creek watershed. It was assumed that annual harvest totals represented 20% of the deer herd present in each County.

Geese populations are difficult to estimate. An estimate of 3 geese per square mile was used based on other Iowa TMDLs.

Humans

Human sources are divided by whether the waste is collected and sent to a Waste Water Treatment Facility (WWTF) or if it is treated by an individual system.

WASTE WATER TREATMENT FACILITIES

The WWTFs located in the Beaver Creek Watershed with surface water discharges are summarized in Table 8.2. Bacteria loads from NPDES-permitted WWTFs was estimated based on the design flow and permitted bacteria effluent limit of 126 org/100 mL. According to available information on the DNR website, **there are 16 NPDES permits for wastewater treatment, including six municipalities operating waste water treatment plants and 10 miscellaneous dischargers.** The latter includes two Municipal Separate Storm Sewer Systems (MS4), six industrial dischargers, one Army National Guard Base, and one feedlot.

A deer bounds across a field in the Beaver Creek watershed.

Table 8.2: WWTP design flows and permitted bacteria loads

SUBBASIN	NAME OF WWTF	PERMIT #	DESIGN FLOW [MGD]	EQUIVALENT BACTERIA LOAD AS E.COLI (BILLION ORG/ DAY)
Beaver Creek	Brenton Brothers, Inc-FD-1*	7758687		
	Grimes Water And Wastewater Treatment Facilities	7736001	1.36	6.46
	Grimes, City Of MS4**	7736002	0.01	0.05
	Iowa Army National Guard - Johnston	7700901	0.31	1.46
	Johnston City Of Stp (Green Meadows)	7740001		
	Johnston, City of Ms4**	7740002	0.05	0.22
City of Bouton	McCreary Community Building Mun. Swimmiung Pool***	2561103		
East Beaver Creek	Ogden City of Stp-FD-1	858001	.34	1.62
	Northern Natural Gas Co - Odgen Compressor***	800101		
Headwaters Beaver Creek	Boxholm City of Stp-FD-1	825001	0.03	0.16
Little Beaver Creek-Beaver Creek	Woodward City of Stp-FD-1	2576001	0.34	1.61
Royer Creek-Beaver Creek	Beneventi Chevrolet - Oasis Laser Wash-FD-1	2537001	0.21	0.98
	Granger City of Stp-FD-1	2537102	0.01	0.03

** Brenton Brothers, Inc. Feedlot has a Waste Load Allocation of 0 according to the Des Moines River TMDL, **City of Grimes, Johnston MS4 Wasteload Allocation – Des Moines River TMDL, ***Not found in Des Moines River TMDL – Not a source of bacteria*

CURRENT COMPLIANCE STATUS OF BEAVER CREEK WATERSHED'S WWTPS

Comments regarding the current compliance status for individual facilities in Beaver Creek Watershed are shown below in Table 8.3. Orange highlights indicate a compliance schedule, and **purple highlights indicate an expired permit, with the future permit having the potential for a compliance schedule.** Granger and Woodward currently have adequately functioning treatment systems with NPDES permits valid through 2020. Hyperlinks to the Iowa NPDES Permits databased maintained by the DNR are provided for each facility.

Table 8.3: Compliance Status of Beaver Creek Watershed's WWTPs

MUNICIPAL FACILITY	CURRENT COMPLIANCE STATUS
Boxholm	Permit in compliance
Grand Junction	Lagoons, expired permit awaiting stream designation
Granger	Lagoons, expired permit awaiting stream designation
Grimes	Trickling filter, compliance schedule for ammonia N, total phosphorus and E Coli by June, 2021
Johnston	Closed
Ogden	Trickling filter, compliance schedule for ammonia N, Dissolved Oxygen and E Coli by March, 2019
Woodward	Lagoons, permit in compliance

CURRENT COMPLIANCE STATUS OF BEAVER CREEK WATERSHED'S MISCELLANEOUS DISCHARGERS

The current compliance status for Beaver Creek Watershed's miscellaneous dischargers including stormwater, feedlot, and industrial facilities are shown below in Table 8.3. **Purple highlights indicate an expired permit, with the future permit having the potential for a compliance schedule.**

Table 8.4: Compliance Status of Beaver Creek Watershed's Miscellaneous Dischargers

MUNICIPAL FACILITY	CURRENT COMPLIANCE STATUS
Brenton Brothers, Inc.	Permit in compliance
Louis Dreyfus Commodities	Discharge consists of noncontact cooling water, softener regeneration, reverse osmosis reject and multimedia filter backwash
McCreary Community Building Municipal Swimming Pool	Discharge of swimming pool filter backwash water, permit is expired and application is past due.
Northern Natural Gas Co. Ogden Station	Cooling water from Natural Gas Compression, expired permit awaiting stream designation and review of wasteload allocation.
Iowa Army National Guard - Johnston-FD-1	Lagoons, expired permit awaiting stream designation
Beneventi Chevrolet- Oasis Laser Wash	Discharge from a car wash wastewater reclamation system consisting of reverse osmosis and water softener reject water and overflow of treated wastewater from the wastewater reclamation system. NPDES Permit recently expired and application process has been initiated.

Based on the purple and orange highlighting, it appears that there is potential improvement for NPDES dischargers in the watershed. Most of the compliance schedules are for meeting EPA requirements for ammonia-nitrogen, dissolved oxygen, or E coli. The facilities with permits on hold due to changes in the stream designation will remain on hold until a new permit can be issued. **Before the permit can be issued, the individual streams must be assessed, the recommendations of the assessment must be adopted, and finally, the assessment must meet EPA's approval.** According to DNR, many of the streams that have been through the 2006-2010 assessment have been through the approval process, but **there are still quite a few streams that are still awaiting EPA approval.**

CURRENT STATUS OF BEAVER CREEK WATERSHED'S ONSITE TREATMENT SYSTEMS

In 2009, Iowa passed regulations for an inspection program for time-of-transfer properties for onsite septic systems, requiring systems to be exposed and pumped. If the system fails or does not have a secondary system, they must upgrade to current standards. **While this inspection program has been very effective in bringing noncompliant systems up to code, the state-established list of exemptions** (with no home rule for counties), leaves room for improvement. Exemptions include foreclosures, decedent's estates, consanguinity, or tax sales. **Many of these exemptions are a subset of properties with inadequate systems.**

The DNR is taking measures to bring the municipalities and other dischargers up to EPA standards. Several counties within the Beaver Creek Watershed including **Boone County and Dallas County are being proactive with stringent design and inspection standards for onsite treatment.**

BACTERIA LOADING ESTIMATE: FAILING ONSITE TREATMENT SYSTEMS

Wastewater treatment plants are typically cost-prohibitive for small populations, so residential populations in rural areas can represent an imminent threat to public health and safety (ITPHS) if the alternative methods of handling raw sewage – such as onsite treatment systems (OTS) – fail to adequately protect groundwater from contamination. In general, it is known that a percentage of OTS (also called septic systems) can be considered "failing" at any given time – although even approximating the number of failing systems is difficult at this scale. In populations served by OTS – often referred to as "unsewered" populations – ITPHS can also be associated with so-called "straight pipes", another form of failure where raw sewage is discharged directly to surface waters without any treatment.

The unsewered population in each subwatershed was estimated using data from the 2010 census by excluding areas within the city limits of municipalities with WWTP. The population estimates are shown in Table 8.5 along with the potential ITPHS loads associated with two different OTS failure rates. For reference, according to survey data from 1990 (published by the EPA in the 2002 Onsite Wastewater Treatment Systems Manual), between 50% and 70% of OTS in Minnesota and between 30% and 50% of OTS in Missouri were estimated to be in a state of failure (data for Iowa were not available).

It should be noted that these numbers are merely intend to suggest the potential for ITPHS contributions of excess bacteria to surface waters in the Beaver Creek watershed, and that no watershed-scale data are available to validate these estimates.

SUBWATERSHED - HUC 12	Estimated Rural Population	ITPHS Load 10% Failure Rate (billion org/day)	ITPHS Load 50% Failure Rate (billion org/day)
Beaver Branch-Beaver Creek	181	22.8	114.0
Beaver Creek	2213	278.8	1394.2
City of Bouton-Beaver Creek	618	77.9	389.3
East Beaver Creek	78	9.8	49.1
Headwaters Beaver Creek	151	19.0	95.1
Little Beaver Creek-Beaver Creek	400	50.4	252.0
Little Beaver Creek-West Beaver Creek	97	12.2	61.1
Middle Beaver Creek	226	28.5	142.4
Royer Creek-Beaver Creek	1031	129.9	649.5
Slough Creek	435	54.8	274.1
West Beaver Creek	229	28.9	144.3

Table 8.5: Estimates of rural population based on 2010 Census data and ITPHS population in each subwatershed

Livestock

The total number of livestock in each subwatershed was estimated by the Iowa DNR animal feeding operation (AFO) database (Figure 8.5). The DNR AFO database is current to 2017 and the registered number of animals is known. **AFO's with less than 500 animal units (AU) are not required to register with the Iowa DNR or obtain a manure management plan.** Therefore, in order to estimate the number of unregistered animals in the county, data from the 2012 USDA Agricultural Census was used. **According to the 2012 census, there are approximately 12,035 cattle, 88,389 swine, and 106,888 poultry (chickens and turkeys) within Beaver Creek Watershed.** The total number of cattle, swine, and poultry was subtracted from the number of registered animals and then area-weighted to the subwatersheds in the county that have registered feedlots.

Table 8.6: Livestock summary results by subwatershed in animal units

SUBWATERSHED	REGISTERED			ESTIMATED UNREGISTERED		
	COWS	PIGS	POULTRY	COWS	PIGS	POULTRY
	POPULATION					
Beaver Branch-Beaver Creek	1,633	35,879	106	327	4,117	22
Beaver Creek*	32,795				645	23
City of Bouton-Beaver Creek		5,495	8	198	1,585	14
East Beaver Creek		23,549		67	330	9
Headwaters Beaver Creek		43,028		551	5,417	24
Little Beaver Creek-Beaver Creek	3,606	12,666		2	4,633	19
Little Beaver Creek-West Beaver	5,103	56,221				10
Middle Beaver Creek	2,188	9,980		40	3,397	15
Royer Creek-Beaver Creek		9,263	308	765	2,298	25
Slough Creek	2,467	18,615	11	232	303	20
West Beaver Creek	5,681	71,680				16

** Beaver Creek watershed contains a large feedlot operation (Benton Brothers, Inc.) which houses between 6,500 and 9,000 cattle. This single operation accounts for 33% of all cattle present in Dallas and Polk Counties combined.*

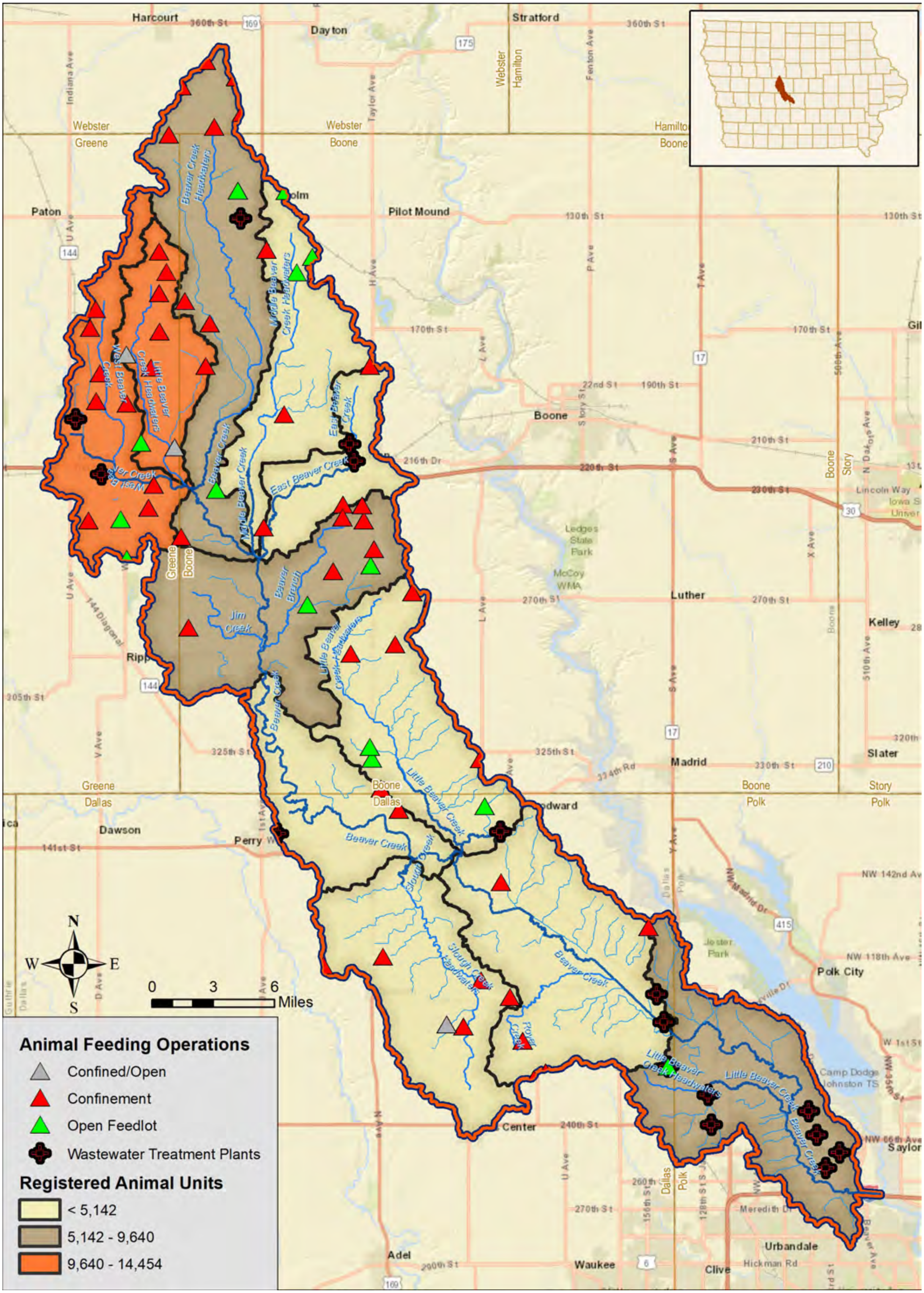


Figure 8.7: Beaver Creek Watershed Subwatershed (HUC-12) Bacteria Sources – Animal Feeding Operations