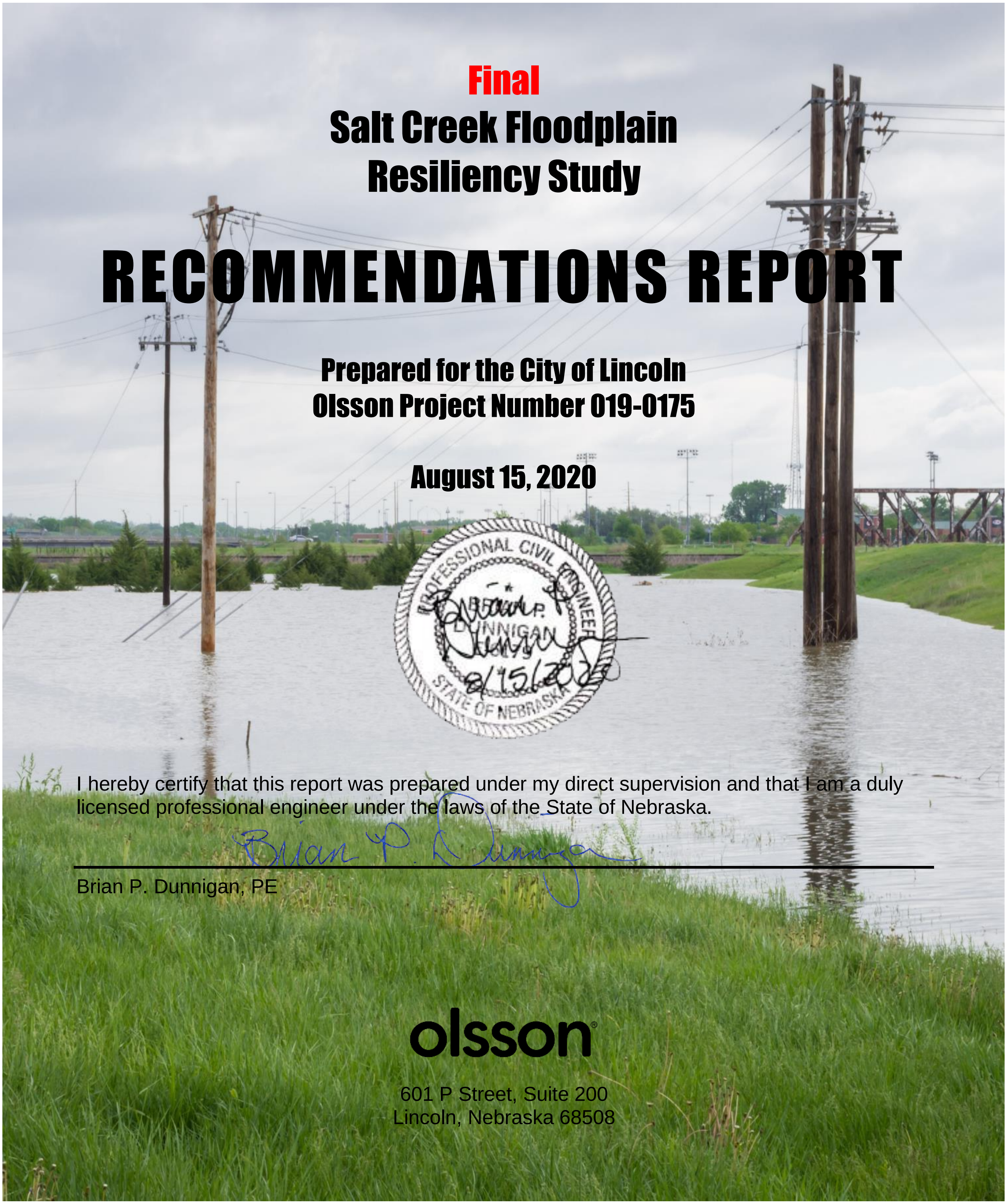

Final

Salt Creek Floodplain Resiliency Study

RECOMMENDATIONS REPORT

Prepared for the City of Lincoln
Olsson Project Number 019-0175

August 15, 2020

I hereby certify that this report was prepared under my direct supervision and that I am a duly licensed professional engineer under the laws of the State of Nebraska.

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ACRONYMS AND ABBREVIATIONS

ACS .... American Community Survey
BFE .... base flood elevation
BMP .... best management practices
BRIC .... Building Resilient Infrastructure and Communities
cfs .... cubic feet per second
CMSWS .... Charlotte-Mecklenburg Storm Water Services
CRS .... Community Rating System
FEMA .... Federal Emergency Management Agency
FIRM .... Flood Insurance Rate Map
FIS .... Flood Insurance Study
GCM .... general circulation model
HMGP .... Hazard Mitigation Grant Program
IPCC .... Intergovernmental Panel on Climate Change
LCFRC .... Lackawanna County Flood Risk Coalition
LID .... low-impact development
LOCA .... localized constructed analogs
LOMC .... Letter of Map Change
LOMR .... Letter of Map Revision
LPSNRD .... Lower Platte South Natural Resources District
NAI .... no adverse impact
NAS .... National Academy of Sciences
NeDNR .... Nebraska Department of Natural Resources
NFIP .... National Flood Insurance Program
NOAA .... National Oceanic and Atmospheric Administration
NSP .... Nebraska State Penitentiary
NRCS .... Natural Resources Conservation Service
NWS .... National Weather Service
PDM .... pre-disaster mitigation
P-MRNRD .... Papio-Missouri River Natural Resources District
PPP .... public-private partnerships
RCP .... representative concentration pathway
RNPN .... Resilient Nation Partnership Network
SCFSA .... Salt Creek flood storage areas
SFHA .... Special Flood Hazard Area
SWIF .... systemwide improvement framework
TMAC .... Technical Mapping Advisory Council
TP40 .... Technical Paper 40
USACE .... U.S. Army Corps of Engineers
USCB .... United States Census Bureau
USGS .... U.S. Geological Survey
WRN .... Weather-ready Nation

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EXECUTIVE SUMMARY

The City of Lincoln and the Lower Platte South Natural Resources District (LPSNRD) have addressed flood control and floodplain management in a variety of ways in the Salt Creek watershed over the last century. It is important to understand the history of the watershed and how flooding has been addressed in the past. It is also important to look at how national floodplain best management practices (BMPs) and state-of-the-art climate science may effectively be used to address watershed resiliency in the future.

The primary focus of this study is to illuminate how existing non-structural and structural floodplain management measures can be strengthened to further reduce flooding impacts to existing infrastructure, local businesses, residences, and future developments and to enhance the floodplain resiliency of Salt Creek.

For this study, the city and LPSNRD determined a public education plan would be beneficial to improve public awareness about floodplain management and resiliency. To develop a dynamic education plan, a diverse stakeholder group was assembled to help guide the education process. The stakeholder group was comprised of individuals with an interest in the Salt Creek floodplain area. Stakeholders were invited to participate in three stakeholder meetings during the study to review study content and outcomes. Stakeholders were provided tools and information through a project website to share information about floodplain management and the resiliency study with their communities.

The study examines the following eight subject areas:

1. National floodplain BMPs
2. Floodplain BMPs from communities across the country
3. Lincoln's current floodplain management practices
4. A review of floodplain studies involving Salt Creek
5. A rigorous climate evaluation of past, current, and future conditions
6. Potential flood resiliency measures and recommendations
7. A review of potential funding sources
8. Recommendations

National Floodplain Best Management Practices (BMPs)

The study team examined national BMPs for relevant and critical guidance and strategies from six organizations that are leaders in the field of floodplain management. These organizations offer expertise and insight into national trends and include the Federal Emergency Management Agency (FEMA); the National Oceanic and Atmospheric Administration (NOAA); the Pew Charitable Trust; Resilient Nation Partnership Network (RNPN); the Technical Mapping Advisory Council (TMAC); and the National Academy of Sciences (NAS). Each organization brings a unique mission and perspective to how floodplain management is evolving in the United States. Selected BMPs that each organization is implementing and their relevance to Lincoln and Salt Creek are evaluated.

Community Floodplain BMPs

Eight communities from across the county that stand out in the Community Rating System (CRS) program; have done a notable job of implementing a proactive floodplain management strategy or strategies; and have elements of their communities, geography, or risk that are relatable to Lincoln were selected for review. The communities include Beatrice, Nebraska; Boulder County, Colorado; Cedar Falls, Iowa; Fort Collins, Colorado; Mecklenburg County, North Carolina; Papillion, Nebraska; Platte County, Missouri; and Shawnee, Kansas. The summary and analysis of each community's BMPs include benefits and drawbacks of the strategies and how they may relate to Lincoln's floodplain program.

Lincoln's Floodplain Management Practices

The city and the LPSNRD have partnered together to reduce flooding and to protect the citizens of Lincoln from the hazards associated with flooding. The many successes of this partnership are the result of a blended approach to floodplain management. A summary of current floodplain management practices is provided in Section 3 along with an evaluation of the pros and cons of each practice. The practices include education and outreach; policies; local detention requirements; post-construction stormwater BMPs; Salt Creek flood storage areas (SCFSA); freeboard requirements; FEMA's CRS; floodplain preservation; flood protection and buyouts; flood risk reduction projects; and a no adverse impact policy in new growth areas.

Floodplain Studies Involving Salt Creek

Twenty-one flood studies involving Salt Creek, from 1954 thru 2016, are referenced in this report. Participants in the studies included the city, LPSNRD, FEMA, the University of Nebraska-Lincoln, and U.S. Army Corps of Engineers.

Local Climate Evaluation

Optimal resiliency planning requires a forward-looking approach: Planners must consider not just events and hazards that may occur in the present day, but they must also account for future hazards and how those hazards may evolve over time. The study evaluated local historical and existing precipitation patterns, developed probable future storm magnitudes, and developed future flood discharges that can be used for future conditions flood hazard analysis. The results of the study indicate that flood hazards on Salt Creek and its tributaries can be expected to increase in the future. The degree of increase is uncertain, but generally Lincoln should expect floodwater surface elevations multiple feet higher than the existing flood hazard data. When considering resiliency and potential flood hazard reductions measures, it is critical to allow for these increases.

Potential Flood Resiliency Measures and Recommendations

A resilient flood management plan requires a comprehensive flood impact reduction strategy that takes both structural and non-structural measures into consideration. The foundation of a flood resiliency plan includes robust non-structural measures such as floodplain management policy, buyouts, relocations, floodproofing, and preservation of open space. These non-structural measures may be complemented by structural flood risk impact reduction measures. The proposed measures must be designed to manage the events and hazards that may occur in the present day, but they must also account for future hazards and how those hazards may evolve over time.

Non-structural Measures

The study recommends the city and LPSNRD take six nonstructural flood resiliency measures under further consideration. The non-structural strategies include cluster subdivisions regulations; overlay zoning; voluntary buy program; setbacks and riparian preservation; low-impact development regulations; and higher floodplain management standards. The strategies selected were evaluated based on conversations with the project team, the review of comparative regulatory levels from other communities, feedback from the stakeholder group, and anticipated benefits associated with their implementation. Each recommendation includes a reference to the BMP in which it was first identified; a description of the recommendation; an overview of why the recommendation is beneficial to the Salt Creek watershed; evaluation of potential CRS points; and identified next steps.

For the nonstructural flood resiliency measures recommendations, the City of Lincoln, in partnership with LPSNRD, should do the following:

1. Identify the recommendations that are top priorities and chart a path to implementation.
2. Evaluate the cost to implement the identified recommendations.
3. Identify local funding sources that are sufficient to match potential federal funding sources.
4. Position projects for potential grant funding.

Structural Measures

A conceptual system of structural flood management measures was evaluated based on the three conditions described below:

Existing Conditions

The **existing conditions** precipitation is derived from the U.S. Weather Bureau's Technical Paper 40 (TP40) (U.S. Department of Commerce 1961). The flood flows and flood elevations provided in the Flood Insurance Study (FIS) for Lancaster County, Nebraska, and Incorporated Areas (NFIP 2013) are based on the TP40 precipitation amounts and are referred to as the **existing conditions**. One goal of the study was to analyze a conceptual system of flood management measures to bring the 1 percent annual chance flood elevations to a level below the top of levee and low enough to provide the 3 feet of freeboard required to accredit a levee system, where possible.

Updated Conditions

Updated precipitation values are provided in the National Oceanic and Atmospheric Administration's Atlas 14 (NOAA 2013) Precipitation Analysis (Atlas 14). The Atlas 14 precipitation values, developed for Nebraska in 2013, are used to develop the **updated conditions** flood flows. The conceptual system of flood management measures was intended to show a reduction in the increased 1 percent annual chance flood elevations associated with **updated conditions** flood events to a level equal to or below the **existing conditions** flood elevations (as shown in the FIS) for a majority of the Salt Creek levee segments.

Future Conditions

A detailed climate modeling effort was performed as part of this study to determine potential future precipitation values for the year 2100. The precipitation values that were derived from the climate modeling effort, which assumed greenhouse emissions trends would continue to increase, were used as the basis for computing the **future conditions** flood flows for Salt Creek. The conceptual system of flood management measures was also intended to show a reduction in the increased 1 percent annual chance flood elevations associated with **future conditions** flood events to a level equal to or below the **existing conditions** flood elevations (as shown in the FIS) for a majority of the Salt Creek levee segments.

The conceptual system of structural flood management measures analyzed 16 dams within the Salt Creek tributary subbasins. The study concluded that the conceptual system of flood management measures analyzed reduce flood elevations for the 1 percent annual chance flood event for the existing conditions flood (as shown in the FIS) below the top of levee throughout the levee system, and provides the necessary freeboard at most locations.

The conceptual system of flood management measures analyzed also reduce flood elevations for the 1 percent annual chance flood event for the updated and proposed conditions to a level below the existing conditions flood elevations (as shown in the FIS) throughout most of the Salt Creek levee system. At a conceptual level, the structural flood management measures do not provide the necessary amount of freeboard to remove areas outside of the levees from the floodplain.

Funding Sources

The study shows that actual flood risks and potential flood damages in Lincoln are greater than depicted in the current regulatory models, maps, and public information. And, as the climate models illustrate, the flood hazards on Salt Creek are expected to increase in the future. Both structural and nonstructural solutions to reduce the flood risks along Salt Creek and its tributaries are presented. The solutions for structural controls are multimillion-dollar projects. Several of the primary options for funding through federal, state, and local agencies are presented along with options to partner with private enterprises in public-private partnerships. As the preferred solution is selected, the appropriate funding strategy will be identified based on the details of the proposed project(s).

Recommendations

Six recommendations for the city and LPSNRD to consider are presented below:

- Continue active participation in the CRS program to continue to qualify for reduced flood insurance rates.

- Adopt higher floodplain regulatory standards to mitigate higher flood elevations in the future.

- Initiate the development of new floodplain maps to incorporate up-to-date precipitation information.

- Use the national BMPs identified to guide planning objectives.

- Consider implementation of six additional nonstructural flood resiliency strategies that include:

    - Cluster subdivisions
    - Overlay zoning
    - Voluntary buyouts
    - Setbacks and riparian preservation
    - Low-impact development regulations
    - Higher floodplain management standards

- Continue with the development of a comprehensive flood resiliency strategy for Salt Creek and the City of Lincoln.

INTRODUCTION

The City of Lincoln and the Lower Platte South Natural Resources District (LPSNRD) have been steadfast and reliable partners in their efforts to increase flood resiliency measures that residents and property owners within the city now enjoy. Through the implementation of a comprehensive floodplain management approach that includes non-structural measures, structural measures, and flood risk awareness, floodplain management has been transformed from an unknown issue into a comprehensive effort.

Lincoln's continued commitment to sound floodplain management is impressive. From early efforts in the 1950s and 1960s, when effective flood management measures were put in place—including upstream dams and the Salt Creek levee system—to being one of the first communities in Nebraska to enroll in the Regular Program of the newly created National Flood Insurance Program (NFIP) in the early 1970s; from being a stellar participant in the NFIP's Community Rating System (CRS) since 1991; to appointing a Mayor's Floodplain Task Force in the early 2000s, which was charged with formulating recommendations regarding the development of new floodplain standards; and to Lincoln's most recent implementation of a systemwide improvement framework plan for the Salt Creek levee system, which will guide flood resiliency efforts for many years to come, the City of Lincoln and the LPSNRD should be proud of their foresight and diligence.

Salt Creek is the receiving stream for all the runoff generated within the city and most of the runoff generated within Lancaster County. Throughout the city, levees along Salt Creek provide significant protection from floods in the stream reach between Calvert Street at the upstream end, to Superior Street at the downstream end. However, the 1 percent annual chance flood, or 100-year flood event as it is commonly called, will overtop the levees and cause widespread flooding to properties on the landward side.

Defining Flood Events

When we evaluate and describe flooding and flood events, we typically evaluate them based on the probability of a given flood event (or runoff event) occurring in a single year. For example, for a 1-percent annual chance flood event, there is a one in 100 chance of an equal or greater runoff event occurring in a given year. The 1-percent annual chance flood event is commonly referred to as the 100-year event. Generally, the chance of the flood event is based on the chance of the corresponding precipitation, or rainfall, event. The 1-percent annual chance flood event typically occurs when a 1-percent annual chance rainfall event occurs. Currently, the 1-percent annual chance rainfall event in Lincoln is 6.7 inches of rain in 24 hours. Most of the rainfall occurs during the peak two to three hours of the storm. Rainfall amounts associated with the various frequency events have recently been updated and published by the National Oceanic and Atmospheric Administration (NOAA) in Atlas 14 (NOAA Atlas 14). The total precipitation for the 1-percent annual chance flood event from NOAA Atlas 14 is 7.3 inches in Lincoln, Nebraska.

Typically, a range of runoff events are analyzed. For example, the City of Lincoln requires detention cells for new development sites to be designed to keep the 50-percent (2-year), 10-percent (10-year), and 1-percent annual chance (100-year) event peak discharges at or below predevelopment conditions. For floodplain analysis, the Federal Emergency Management Agency (FEMA) provides flood information (peak flow rates and peak flood elevations) for the 10-percent (10-year), 2-percent (50-year), 1-percent (100-year), and 0.2-percent (500-year) annual chance events. **Table 1** provides a description of events and a comparison of corresponding precipitation values from the Drainage Criteria Manual and NOAA Atlas 14.

Table 1. Comparison of Corresponding Precipitation Values from the City of Lincoln's Drainage Criteria Manual and NOAA Atlas 14 for Five Annual Chance Events.

Probability (percent annual chance)	Common Event Name	Total Precipitation from City of Lincoln Drainage Criteria Manual (inches)	Total Precipitation from NOAA Atlas 14 (inches)
50	2-year	3.00	3.04
10	10-year	4.69	4.48
2	50-year	6.00	6.40
1	100-year	6.68	7.33
0.2	500-year		9.79

The primary focus of this study is to illuminate how existing non-structural and structural floodplain management measures can be strengthened to further reduce flooding impacts to existing infrastructure, local businesses, residences, and future developments and enhance the floodplain resiliency in Salt Creek.

What does floodplain resiliency mean? In the context of this study, floodplain resiliency is defined as the ability to meet the floodplain challenges of today and safeguard against the uncertainties of the future.

To accomplish these objectives, the study examines the following seven subject areas:

1. National floodplain BMPs
2. Floodplain BMPs from selected communities across the country
3. Lincoln's current floodplain management practices
4. Inventory of past technical studies relevant to Salt Creek
5. Rigorous climate evaluation of past, current, and future precipitation values and their associated discharges
6. Potential flood resiliency measures for the Salt Creek floodplain and recommendations for implementation
7. Funding sources that could be used to implement flood resiliency measures

SECTION 1 – NATIONAL FLOODPLAIN BEST MANAGEMENT PRACTICES (BMP) REVIEW

The study team examined national best management practices (BMPs) for relevant and critical guidance and strategies from leaders and innovators in the field of floodplain management. Each organization described is a leader in the field of floodplain management and offers expertise and insight into national trends. FEMA, NOAA, Pew Charitable Trust, Resilient Nation Partnership Network (RNPN), Technical Mapping Advisory Council (TMAC), and the National Academy of Sciences (NAS) each bring a unique mission and perspective to how the field of floodplain management is evolving in the United States. The innovative research and guidance that each organization has completed, and the strategies and outcomes realized, are a focus of this section.

Lincoln can use each organizational review to guide its decision-making process for selecting strategic BMPs for investing and for managing current local initiatives and practices effectively. Each review includes an overview of the organization, including its mission and goals, and more detailed guidance on a relevant best practice.

The guidance from these organizations can provide pieces of a roadmap for continued improvement as Lincoln continues to grow as a national leader in the field of floodplain management and as it excels in protecting the health, safety, and economic wellbeing of the community. **Table 2** offers an overview of the topics surveyed from national BMPs.

The U.S. Army Corps of Engineers (USACE) is the federal government's largest water resources development and management agency. USACE has broad authority for floodplain planning, flood warning/preparedness, flood risk impact reduction, stormwater management, and floodproofing. USACE typically partners with state and local agencies to complete flood management projects. These projects are often larger-scale structural projects (levees, dams, flood management channels, etc.). Because of the size of the projects, congressional authorization is often required for project design, permitting, and construction funds. The City of Lincoln partnered with USACE on the Salt Creek and Tributaries Flood Control project (Salt Creek levees and dams) and the Antelope Valley project and is currently partnering with the USACE for the Deadmans Run Flood Reduction project. The technical services and support USACE provide are well known to the City of Lincoln and the LPSNRD. USACE will continue to be a valuable partner in floodplain management and flood risk impact reduction. This study focuses on describing the services and support available from other agencies.

Table 2. Organizations and Topics Surveyed as National Best Management Practices.

Entity* and Abbreviated Best Management Practice Title						
Topic	**FEMA**	**NOAA**	**Pew**	**RNPN**	**TMAC**	**NAS**
Public Policy			Use Flood-ready Infrastructure Statement of Principles			Invest in socially vulnerable populations
Land Use/ Infrastructure		Open space preservation or converting developed areas to green space				
Public Outreach/ Education	Outreach to community members impacted by levees	Establishing a culture of preparedness and a well-informed public	Use Flood-prepared Communities Project			Urban flood risk communication
Technical Modeling/ Mapping					Mapping residual risk behind levees and flood management structures; future conditions flood risk products; FEMA transition plan for 1-percent annual chance flood	
Operations	Practice effective levee operation and maintenance	National Weather Service, Weather-ready Nation				
Collaboration				Resilience Network		

* FEMA = Federal Emergency Management Agency; NOAA = National Oceanic and Atmospheric Administration; Pew = Pew Charitable Trust; RNPN = Resilient Nation Partnership Network; TMAC = Technical Mapping Advisory Council; NAS = National Academy of Sciences

1.1 Federal Emergency Management Agency (FEMA) Levee Policy/Guidance

Mission/Goals

FEMA's mission is to help people before, during, and after disasters. For many communities, levees are a critical feature in providing flood risk reduction. As a part of reducing flood risk and fulfilling the agency's mission, FEMA provides information on levee systems about their risk, safety, flood hazard mapping, and accreditation.

Best Practice/Guidance No. 1: Provide outreach to community members affected by Salt Creek levees.

Levees undeniably provide a valuable flood protection benefit; however, history has demonstrated how susceptible levees are to failure. FEMA provides a wealth of information and outreach materials for those who own property behind levees. These materials generally underscore the reality that levees may reduce risk during certain flood events, but levees do not provide absolute protection from flooding. These resources can help the City of Lincoln educate citizens to recognize flood risk behind levees.

FEMA's experience working with state and local partners and with communities has led to the development of several communication and education materials that can be used by Lincoln regarding levees:

- Fact sheet: *What is a Levee* (FEMA 2016) – a three-page fact sheet about levees, describing what they are and how they affect flood risk.
- *So, You Live Behind a Levee!* (ASCE 2010) A brochure produced by the American Society of Civil Engineers, in cooperation with FEMA, in 2010. This brochure was created to help answer questions about levees and the risks associated with them.
- Webpage: *Living with Levees: Ideas for Effective Outreach* (FEMA 2019). This webpage provides a framework for successful levee-related outreach. This framework includes tips for proactive media engagement and stresses the importance of clear messages about flood risk.
- The USACE National Levee Database (USACE 2020) offers information for inspectors and developers and provides mapped data on the nation's levees.

Evaluation of the Best Practice/Guidance No. 1

Table 3 provides an evaluation of the pros, cons, constraints, and opportunities for the BMP outlined above.

Table 3. Evaluation of Best Practice/Guidance for Providing Outreach to Community Members Impacted by the Salt Creek Levees.

Pros	Cons	Constraints	Opportunities
The belief that levees provide absolute protection from flood risk is all too common; successful outreach will help residents truly understand the risks associated with levees and will help them be more prepared to act.	Many outreach materials published by FEMA are specifically geared toward levees that are accredited and designed to the 1-percent annual chance flood event.	Outreach materials must be specifically customized for the Salt Creek levee system.	Outreach will help residents behind levees be more prepared for a flood.

Applicability to Salt Creek Floodplain

According to the National Levee Database, the Salt Creek levee systems are associated with 1,229 structures at risk, 5,912 people at risk, and $847 million in property value. Effective outreach to residents affected by these levee systems could significantly improve flood preparedness and resiliency.

The existing Salt Creek levee systems are not accredited by FEMA to provide protection during the 1 percent annual chance flood event, and an investment to bring levees to accreditation level would be immense. Planning for all potential futures to protect the community should include education on living within and behind a levee and ensuring that emergency plans are in place.

All outreach materials should be reviewed and customized as necessary to educate residents about the flood risk behind the Salt Creek levee systems specifically. Alternatively, Lincoln could develop its own fact sheet that is specifically tailored to the Salt Creek levee systems.

<u>Best Practice/Guidance No. 2:</u> Practice effective levee operation and maintenance as detailed in FEMA levee accreditation regulations. It is noted that a Salt Creek systemwide improvement framework has been developed for the Salt Creek levee system.

FEMA only provides guidance for accrediting levees that are designed to provide flood protection during the 1 percent annual chance flood events. Most of the Salt Creek levee system in the City of Lincoln is vulnerable to overtopping during the 2 percent annual chance flood event; therefore, as currently constructed, the levees do not meet the requirements for accreditation. However, as a BMP, it still may be beneficial to review levee operation and maintenance plans for the levee system to make sure they align with FEMA guidance to the extent possible. FEMA regulations for levee accreditation are detailed in 44 Code of Federal Regulations (CFR), Part 65.10 (ECFR 2020).

FEMA accreditation regulations for operation and maintenance plans for levees include the following:

- Operation plans for closures
- Operation plans for interior drainage systems
- Operation of emergency warning systems
- Levee maintenance plans and criteria

Evaluation of the Best Practice/Guidance No. 2

Table 4 provides an evaluation of the pros, cons, constraints, and opportunities for the BMP outlined above.

Table 4. Evaluation of Best Practice/Guidance for Practicing Effective Levee Operation and Maintenance.

Pros	Cons	Constraints	Opportunities
Robust operations and maintenance plans for levee systems, aligned with FEMA guidance, will improve levee safety.	Some guidance may be particular to levees that meet accreditation criteria and may require adjusting for Salt Creek levees design.	Revising operations and maintenance plans to align with FEMA regulations will not result in accredited levees – the Salt Creek levee system is vulnerable to overtopping during the 2-percent annual chance flood event.	These materials can still provide a resilience benefit by assisting with planning for operations and emergencies, so the community is safer and better prepared.

Applicability to Salt Creek Floodplain

Aligning levee system operation and maintenance plans to FEMA regulations will not lead to FEMA accreditation without significant levee improvements. However, aligning to FEMA regulations would be a BMP that could lead to a safer levee system.

1.2 National Oceanic and Atmospheric Administration

NOAA National Oceanic and Atmospheric Administration
U.S. Department of Commerce

Mission/Goals

NOAA's mission is science, service, and stewardship. They strive:

1. To understand and predict changes in climate, weather, oceans, and coasts
2. To share that knowledge and information with others
3. To conserve and manage coastal and marine ecosystems and resources

Best Practice/Guidance No. 1: Preserve open spaces or convert developed areas to green spaces.

Land use decisions are foundational to preventing future flood risks. Although communities do not have the ability to turn back the clocks and make better-informed decisions, moving forward with the ability to preserve open space or convert developed areas to green space can significantly reduce flooding risk. Many communities have begun establishing multifunctional green space that provides a valuable amenity while also increasing stormwater holding capacity.

In the Salt Creek floodplain, the preservation of open space is critical to flood resiliency strategies. Infiltration, storage capacity, and uptake of water by vegetation all have significant impact. Additionally, by preserving green space within the floodplain and throughout the community, Lincoln can potentially receive additional credits for its CRS participation.

FEMA's CRS is an incentive program under the NFIP that rewards communities going beyond the minimum standards by providing credits toward the reduction of flood insurance premiums for community homeowners. NOAA has developed a methodology and “how-to” for identifying open space in your community, which may qualify for credit under CRS Activity 420, open space preservation (FEMA 2017). The methodology focuses on coastal communities and coastal land cover data but can be broadly applied to any community that has available open space and that is interested in identifying credit opportunities for CRS.

The NOAA methodology is a seven-step process:

1. Calculate the community’s special flood hazard area.
2. Identify lands that may qualify for open space preservation credit.
3. Exclude areas that do not qualify for open space credit
4. Calculate the possible credit for the community’s open space.
5. Determine whether preserved open space parcels qualify for “extra credit.”
6. Gather supporting documentation for each parcel or area.
7. Identify opportunities to earn more open space credit.

Communities such as Currituk County, North Carolina, have already begun using the methodology to develop a geographic information system workflow to coordinate data with the CRS Explorer (an app that helps planners identify areas that are eligible for CRS open space preservation credits). The county was then eligible to accrue points and move to a different rating.

A few great examples of the value of preservation of green space can be found in Fourth Ward Park in Atlanta, Georgia (ASCE 2019) and Meriden Green in Meriden, Connecticut (Meriden 2020). Although not specific to the NOAA methodology, or to the benefit of CRS credit, these case studies have shown dramatic flood reduction and economic benefits that would be specifically relevant to Lincoln.

Fourth Ward Park

Formerly a brownfield plagued with stormwater runoff and flooding, Fourth Ward Park is now an Atlanta revitalization success story. Historic Fourth Ward Park offers 17 acres of green space; a park packed with numerous amenities including open and passive lawns; a playground; a splashpad; an outdoor theater; and a 2-acre lake. The lake provides a beautiful, natural gathering place and functions as a stormwater detention basin. Through multipurpose design, the lake increases the sewer system’s capacity, reducing the burden on the city infrastructure, and it minimizes downstream flooding. This solution was achieved through a partnership with the City of Atlanta’s Department of Watershed Management and saves Atlanta more than $15 million over a more traditional stormwater tunnel system.

Meriden Green

In 1970, a one-story retail shopping mall, Meriden Hub, was constructed in the floodplain. Built over the underlying river, the mall’s asphalt parking lots covered soil that had been contaminated over decades by the prior industrial and manufacturing activities. Centrally located within the city’s urban core, the underground conduit that contained Harbor Brook became a constriction point. As development expanded and the intensity of rain events increased, floods occurred in 1982, in 1992, and again in 1996, causing significant destruction and economic losses.

The solution was to reduce flood hazards by storing and conveying floodwaters through a renaturalization of the brook corridor, reconnecting the floodplain, and creating wetlands upstream. This would promote opportunities for recreation and economic development. Meriden Hub provided a perfect centerpiece for urban revitalization efforts, and it was also strategically located to serve as the primary flood storage basin for the mitigation project.

Key components of the vision entailed alleviating the flooding that historically had plagued the downtown area, daylighting and restoring Harbor Brook to a more natural system, and remediating the contaminated soils present at the hub site. Ultimately, the project aimed to create a traditional “New England green” in the center of Meriden. With the concept of a centralized open green space in the works, the city and the design team held several community workshops to engage the public and business owners in the design process. The two most complex parts of the design were ensuring that the park’s floodwater storage volume was enough to offset the reduction in downtown flood elevations and addressing the soils contaminated by former land uses. As the flood management plans advanced, continued coordination with the city’s economic development staff led to the inclusion of several building development pads intended for future use that would be located outside of the revised 1 percent annual chance floodplain.

The City of Meriden is an incredible example of how implementing natural infrastructure into redevelopment spurred by past flooding disasters and the loss of economic vitality of a mall can enhance the city’s flood resilience to dramatically boost the economy and social well-being of the community.

Evaluation of Best Practice/Guidance No. 1

Table 5 provides an evaluation of the pros, cons, constraints, and opportunities for the BMP outlined above.

Table 5. Evaluation of Best Practice/Guidance for Preserving Open Spaces or Converting Developed Areas to Green Spaces.

Pros	Cons	Constraints	Opportunities
The preservation of open space or the conversion of developed areas into multiuse green space provides credits for CRS. Beyond CRS, green space allows for the infiltration of water, increases holding capacity, and reduces impact to development.	None	Open space is often at a premium in urban communities. Transitioning from developed land to open space can be expensive.	Lincoln can use the NOAA “how-to” resource to identify opportunities for the preservation of green space or to convert potential developed/impervious areas into functional green space for flood reduction.

*CRS (Community Rating System)

For more information on the benefits of preserving open space and green infrastructure, please see these resources: NOAA 2019; ASFPM 2017; NOAA 2015.

<u>Best Practice/Guidance No. 2</u>: Create a network to improve preparedness and response to extreme weather events.

NOAA’s National Weather Service (NWS) program, Weather-ready Nation (WRN), is an effort to transform operations and provide information in a way that better supports communities, organizations, first responders, and the public to make fast, smart decisions when facing extreme weather (NWS 2020a). WRN requires action from all scales of government.

WRN can help start a dialogue within our local communities that will ultimately reduce the risk of being adversely affected by extreme weather and water events and increase community resilience (the ability to recover) for future extreme events.

The WRN ambassador’s initiative enhances communication with the NWS and its partners. NWS provides ambassadors with information such as toolkits for preparedness weeks and planning information for WRN-sponsored events. Increased dialogue among partners and additional resources will lead to new innovative opportunities for collaboration, resulting in greater preparedness, responsiveness, and overall resilience to extreme weather events.

Weather-ready Nation Ambassadors – A Snapshot

If the City of Lincoln becomes a WRN ambassador, the NWS can help Lincoln extend its reach to a broader and increasingly diverse audience, while also connecting Lincoln to additional partners, information, and resources as they become available. The following is a subset of state and local organizations that are WRN ambassadors to the NWS:

- Nebraska Emergency Management Agency
- Nebraska School Activities Association
- News Channel Nebraska
- Nebraska Telemundo
- Nebraska Department of Transportation, District 6
- Nebraska Department of Environment and Energy
- University of Nebraska-Lincoln
- University of Nebraska Medical Center

There are several success stories on the benefits of being a WRN ambassador. The Oklahoma State Department of Health's emergency preparedness and response service shares WRN information with staff and coordinates sharing the WRN building lobby preparedness table. This table provides information to citizens regarding extreme weather preparation and response as they enter a building. The WRN also shares this information on Facebook and Twitter accounts. More information about the benefits and resources available to WRN ambassadors can be found at the WRN website.

Evaluation of Best Practice/Guidance No. 2

Table 6 provides an evaluation of the pros, cons, constraints, and opportunities for the BMP outlined above.

Table 6. Evaluation of Best Practice/Guidance for Considering Participation in a National Network to Improve Preparedness and Response to Extreme Weather Events.

Pros	Cons	Constraints	Opportunities
An increased network of partners collaborating to promote resilience and improved response.	None	The awareness and benefits of WRN are sometimes not apparent.	The City of Lincoln or Lincoln-Lancaster County Emergency Management can work with NOAA's WRN to become an ambassador.

For more information on NOAA and WRN resources, please see the National Weather Service Flood Related Products (NWS 2020b); and Weather-ready Nation Ambassadors: In Their Own Words (NWS 2020c) on the NWS website.

Best Practice/Guidance No. 3: Establish a culture of preparedness and a well-informed public.

Pre-disaster planning is by far the best opportunity to reduce the impacts to life and property. NOAA's NWS provides guidance on best practices to implement before, during, and after a flood. Institutionalizing these principles across the City of Lincoln's departments and informing the public prior to a disaster will yield improved results during times of extreme weather. Below are some actions communities can take to be prepared and to be safe during floods:

- Preparation Before a Flood (NWS 2020d)
    - Create a communications plan
    - Assemble an emergency kit
    - Know your risk
    - Sign up for notifications
    - Prepare your home
    - Prepare your family/pets
    - Charge your essential electronics
    - Leave
- Informed Response During a Flood (NWS 2020e)
    - Stay informed
    - Get to higher ground
    - Obey evacuation orders
    - Practice electrical safety
    - Avoid floodwaters
- Proper Action After a Flood (NWS 2020f)
    - Stay informed
    - Avoid floodwaters
    - Avoid disaster areas
    - Heed road closed and cautionary signs
    - Wait for the all clear
    - Contact your family and loved ones

Evaluation of Best Practice/Guidance No. 3

Table 7 provides an evaluation of the pros, cons, constraints, and opportunities for the BMP outlined above.

Table 7. Evaluation of Best Practice/Guidance for Establishing a Culture of Preparedness and a Well-informed Public.

Pros	Cons	Constraints	Opportunities
An increased community capacity for self-reliance in event of an extreme weather event.	None	It can be difficult to get community members' attention or buy-in for these resources.	The City of Lincoln or Lincoln-Lancaster County Emergency Management can share information with community using these ready-made resources.

For more information on the NOAA guidance for establishing a culture of preparedness and a well-informed community, please visit the NOAA National Weather Service Flood Safety Tips and Resources website (NWS 2020g).

Applicability to Salt Creek Floodplain

If the City of Lincoln becomes a collaborative partner with NOAA, it can use NOAA's tools, resources, and leadership to increase community resilience. Critical to this is understanding how the preservation or beneficial use of green space can be implemented across the city to supplement current stormwater infrastructure, or most simply at its core, to limit development in flood-prone areas while providing valuable public amenities. Preparation and awareness are critical before, during, and after a disaster. Institutionalizing NOAA's WRN principles can help the City of Lincoln increase its resilience to extreme weather and flooding.

1.3 Pew Charitable Trusts' Flood-prepared Communities Project

Mission/Goals

The Pew Charitable Trusts' (Pew) mission is to:

- Improve public policy by conducting rigorous analysis, linking diverse interests to pursue common cause, and insisting on tangible results.
- Inform the public by providing useful data that illuminate the issues and trends shaping our world.
- Invigorate civic life by encouraging democratic participation and strong communities. In Pew's hometown of Philadelphia, the trust supports arts and culture organizations as well as institutions that enhance the well-being of the region's neediest citizens.

Pew leads the Flood-prepared Communities project (Pew 2020). The goals of the program are large. These include modernizing the NFIP, shifting investment from disaster recovery to disaster mitigation, prioritizing flood-ready infrastructure, and leveraging green infrastructure. Pew has identified several critical issues with the current status quo that it aims to change.

Best Practice/Guidance No. 1: Use the resources of the Flood-prepared Communities project.

Pew recognized that the NFIP is billions of dollars in debt and faces an unsustainable future. Reforms to policy should better communicate actual risk, break the cycle of repeated loss and rebuilding in the most flood-prone areas, and incentivize homeowners to be proactive to better prepare for floods. One of Pew's recommendations is to consider a state revolving loan fund to stabilize source funding. Additionally, Pew advocates for federal legislators to protect their taxpayers by:

- Encouraging communities to improve management of the most flood-prone areas
- Linking buyouts of flood-prone properties with protection and restoration of natural resources
- Protecting homebuyers by requiring sellers to accurately and fully disclose flood history and risk
- Providing ratepayers with information about their actual flood risk

One strategy Pew highlights to help stabilize the rising costs of disaster recovery is to take proactive mitigation actions. With the number of disasters on the rise, the federal government must break the cycle of paying to rebuild in vulnerable areas. It can do so with a $6 to $1 return on investment by increasing mitigation investments to help communities prepare for extreme weather events and reduce the rising costs associated with flood disasters (National Institute of Building Sciences 2019a). Floodproofing infrastructure is another critical component of Pew's mission. The country's aging infrastructure – such as roads, utilities, schools, and hospitals – suffers from years of underfunding and neglect and faces increasing vulnerability caused by the impacts of severe weather, rising population, and changing land use.

Reforms are needed to make the built environment more resilient to future floods and to reduce development in high-risk areas. In addition to building infrastructure, building "green" or natural infrastructure is also a critical strategy highlighted by Pew. Policies and federal funding should favor natural defenses, such as multifunctional green spaces and marshes. Flood planning and preparedness should incorporate nature-based solutions to better protect property and the environment.

The Flood-prepared Communities project works to use information from across the country to drive national flood resiliency policy. In doing so, Pew establishes resources, multimedia, and tools that local communities and states can use to enhance communication with elected officials at all levels.

Evaluation of Best Practice/Guidance No. 1

Table 8 provides an evaluation of the pros, cons, constraints, and opportunities for the BMP outlined above.

Table 8. Evaluation of Best Practice/Guidance for Leveraging the Resources of the Flood-prepared Communities Project.

Pros	Cons	Constraints	Opportunities
Encouraging communities to improve management of the most flood-prone areas	N/A	Time, political will, resident acceptance of management practices	Lincoln is taking steps to improve their flood risk management. Building upon this with tangible management and implementation practices is an excellent opportunity. This can move forward based upon the recommendations of this study.
Linking buyouts of flood-prone properties with protection and restoration of natural resources	Expensive	Buyouts require capital investment and community buy-in	The long-term return on investment has been proven in numerous communities across the country. Reducing or eliminating repetitive-loss properties is a wise decision. The opportunity exists now to begin conversing with the City of Lincoln and its residents/stakeholders about a potential buyout program.
Protecting homebuyers by requiring sellers to accurately and fully disclose flood history and risk	Could have negative impacts on homeowner property values	Not required or regulated; new policy must be enacted locally	Requiring flood history and risk exposure of properties is a very difficult endeavor because there may be significant pushback from the real estate industry and homeowners. This policy issue is likely much larger than Lincoln would want to address. There is an opportunity to engage in these discussions at a higher level (state, national).
Providing ratepayers with information about their actual flood risk	Potentially confusing when discussing hazard vs. risk	Clear strategy to calculate, define, and communicate “actual risk”	This policy issue is likely to be addressed at a national level; however, there is an opportunity for Lincoln to increase awareness of potential risk beyond the flood maps.

More information on flood-ready community resources can be found at the Pew website and the National Institute of Building Sciences website (Pew 2018a); (Pew 2018b); (National Institute of Building Sciences 2019b).

Applicability to Salt Creek Floodplain

The Flood-prepared Communities project resources are specifically tailored to help drive policy at the national level and to provide states and local communities with tools that can better communicate the value of flood mitigation to elected officials. Establishing clear lines of communication with elected officials to drive flood risk mitigation planning and implementation will be a priority if subsequent policy changes are necessary. Encouraging communities to improve management of the most flood-prone areas and linking buyouts of flood-prone properties with protection and restoration of natural resources should be two big priorities for the City of Lincoln moving forward with floodplain resiliency in the Salt Creek floodplain.

Best Practice/Guidance No. 2: Use the Flood-ready Infrastructure Statement of Principles to give clear direction to local policy, funding, and regulations.

Over 250 bipartisan elected leaders from across the country have signed a statement of principles to institute reform and reduce vulnerabilities from extreme weather (Pew 2018c). The statement of principles states:

Signees of the Flood-ready Infrastructure Statement of Principles support prioritizing infrastructure decisions that will:

1. *Improve resiliency requirements for buildings and infrastructure systems built before and after flood-related catastrophes*
2. *Enhance the use of natural defenses in planning and preparedness*
3. *Reduce unsustainable development in high-risk areas*

Nebraska State Senator Patty Pansing Brooks (D-District 28, south-central Lincoln) was one of the signees.

Evaluation of Best Practice/Guidance No. 2

Table 9 provides an evaluation of the pros, cons, constraints, and opportunities for the BMP outlined above.

Table 9. Evaluation of Best Practice/Guidance for Leveraging the Flood-ready Infrastructure Statement of Principles.

Pros	Cons	Constraints	Opportunities
Political will can be a driver of change in the Lincoln area.	Can be dependent upon candidate platforms and priorities of the city council.	The principals may or may not align with elected leaders' platforms.	Partner with Senator Pansing Brooks to promote resilient infrastructure and proactive land use decisions. Lincoln's mayor could take a political stance on resilient infrastructure, particularly considering the recent impacts to the state.

Applicability to Salt Creek Floodplain

The Flood-prepared Communities project and the statement of principles strategically link mitigation efforts with the need to build political support and momentum. Joining forces to build a political platform focusing on reducing flood risk vulnerability and proactive efforts to protect life and property can result in the necessary momentum to move public policy forward. Involvement in larger, organized mitigation communities can garner public support and city council approval, and it can validate the need for funding resources.

1.4 FEMA's Resilient Nation Partnership Network

Mission/Goals

Resilient Nation Partnership Network

The RNPN was established in 2015 to provide a platform for collaboration and to showcase the value of resilience and risk reduction measures for hazards. Currently, more than 150 organizations are involved and represent a diversity of industries and stakeholders. The RNPN aims to raise the profile, quality, and quantity of discussions around resilience and mitigation, bringing new voices to the table and finding ways to operationalize expertise and knowledge at the national, state, and local levels.

Current Members – A Snapshot

The RNPN consists of organizations and individuals representing a variety of fields, industries, populations, and communities with a vested interest in strong, resilient communities. Current members include organizations involved in community planning, floodplain management, insurance, emergency management, building and development, environment and sustainability, academia, and federal agencies. The following list represents a diverse subset of the RNPN and members relevant to the City of Lincoln's geographic region.

- Pew Charitable Trusts
- The World Bank
- NOAA WRN
- National Institute of Building Sciences
- University of Nebraska Medical Center
- University of Colorado Boulder
- National Association of Counties
- National League of Cities
- Miami-Dade, Florida, Resilience
- Association of State Floodplain Managers
- City of Norfolk, Virginia
- Midwest Alliance of Sovereign Tribes

Best Practice/Guidance: Join a network for resilience.

The RNPN highlights the value of knowledge-sharing across diverse stakeholder groups. By leveraging knowledge and expertise in concert with structured RNPN events, partners can identify best practices and form collaborative relationships with other members. This allows for improved access to tested and innovative strategies for reducing flood risk across the nation from a diverse cross-section of partners. Benefits of involvement in the network include:

- Tools and trainings to promote development of your own efforts and the opportunity to learn how to communicate resiliency and its importance in a complex and evolving world
- Thought leadership opportunities to showcase your work and initiatives among a diverse pool of partners
- Dialogue with FEMA, other federal agencies, and over 150 partners with a stake in resilience
- Participation in the RNPN's annual forum that is held each year in Washington D.C. to learn about the latest trends and issues affecting resilience and how we can collectively prepare for tomorrow's risks

The RNPN actively works to include non-traditional or under-represented stakeholders. This helps the RNPN establish a more holistic sense of flooding impacts and solutions. World Bank hosted the 2018 annual forum, where a panel was convened to discuss “Hard to Reach Communities – How Can We Do Better?”. Panelists included representatives from the Institute for Tribal Environmental Professionals and the director of emergency services from Dorchester County, Maryland. Dorchester County is a rural, faith-based, conservative community on the Chesapeake Bay shore. The presentations included the tribal communities’ approach and discussed challenges of resiliency in line with cultural norms and values. Understanding how each group has been successful in its pursuit of resilience and how it has overcome challenges better informs the efforts of the RNPN.

Evaluation of Best Practice/Guidance

Table 10 provides an evaluation of the pros, cons, constraints, and opportunities for the BMP outlined above.

Table 10. Evaluation of Best Practice/Guidance to Consider a Network for Resilience.

Pros	Cons	Constraints	Opportunities
Knowledge sharing establishes trust and fosters collaborative partnerships.	Knowledge sharing takes effort and coordination, which can often be difficult.	Finding a local champion to lead this effort could be difficult.	The RNPN is open to all organizations; establishing a local working group comprised of diverse stakeholder groups from all backgrounds has been successful in many communities.

Applicability to Salt Creek Floodplain

Partnerships are critical to successful resilience initiatives. These partnerships may range from something as simple as a coordination call or as in depth as pursuing funding or pursuing the advancement of flood resiliency policy. The RNPN has established a vast group of diverse stakeholders all working to improve their communities’ flood resilience. Given the synergies among stakeholders at all levels and geographies, collaboration – if well used – can provide increased support and resources to Lincoln as it works to increase its resilience to hazards.

The RNPN has been targeting action at the local level with select communities in FEMA regions. The RNPN is working locally in Lackawanna County, Pennsylvania, and with the Lackawanna County Flood Risk Coalition (LCFRC) to help communicate flood risk changes in the community and to help educate property owners on the importance of mitigation action. Because of this effort, Lackawanna County has hosted seven monthly meetings, has held a media training workshop, has facilitated an insurance training workshop, and more. As a result of the RNPN’s support, the LCFRC continues to increase its membership and its visibility among community stakeholders and residents.

1.5 Technical Mapping Advisory Council

Mission/Goals

The TMAC's mission is to provide counsel to FEMA on strategies and actions that will efficiently and effectively advance the identification, assessment, and management of flood hazards and risk.

The TMAC examines the national flood mapping program's performance metrics, standards and guidelines, map maintenance activities, delegation of mapping activities to state and local mapping partners, interagency coordination and leveraging, and other requirements mandated by the authorizing Biggert-Waters Flood Insurance Reform Act (2012). The TMAC's duties as mandated by the act are as follows:

1. Recommend to FEMA how to improve in a cost-effective manner:
    a. Accuracy, general quality, ease of use, and distribution of flood maps and data
    b. Performance metrics and milestones tracking the progress of mapping the nation for flood risk
2. Recommend to FEMA mapping standards for flood maps, including accuracy standards
3. Recommend to FEMA how to maintain the flood maps and risk data on an ongoing basis
4. Recommend procedures for delegating mapping activities to state and local partners
5. Recommend to FEMA and other participating federal agencies the following:
    a. Methods for improving interagency coordination
    b. A funding strategy to use and coordinate budgets across federal agencies
6. Submit an annual report to FEMA that contains the following:
    a. An evaluation of the status and performance of FEMA's mapping and data
    b. A summary of recommendations, including but not limited to:
        i. Ensuring that FEMA's maps incorporate the best available climate science to assess flood risk
        ii. The best available methodology is used to consider the impact of sea level rise and future development

The TMAC has made many recommendations to enhance FEMA's program. The most pertinent of those recommendations to the City of Lincoln are included below.

Best Practice/Guidance No. 1: Map the residual risk behind levees and other flood management structures.

Residual risk areas associated with levees and dams are of great concern. "Residual risk" is the risk that remains after consideration of natural or human-induced measures to reduce known risks. In the context of this chapter, the TMAC uses the definition of residual risk from FEMA's Coastal Construction Manual (FEMA 2011b): "exposure to loss remaining after other known risks have been countered, accounted for, or eliminated." To create technically credible flood hazard data, FEMA must address residual risk areas in the near term.

The National Flood Mapping Program requires that FEMA review, update, maintain, and publish the Flood Insurance Rate Maps (FIRMs) with respect to residual risk areas, including those areas protected by levees, dams, and other flood management structures. This update should include the level of protection provided and areas that could be inundated as a result of the failure of such structures. Each type of structure has its own history as to how it is identified and portrayed on FEMA's flood mapping products.

Another form of residual risk relates to the damage sustained by structures outside the mapped 1 percent annual chance floodplain. Owners of these structures, which are not subject to the mandatory flood insurance purchase requirements of the NFIP, may not expect these structures to be subject to inundation. For some, the perception is that structures are safe from flooding if there is no requirement to buy flood insurance; but history shows this is inaccurate. Owners of such structures may not currently be aware of the estimated water surface elevation of events beyond the base flood elevation (BFE) and are, therefore, unprepared for the additional flooding risks.

The TMAC recommends that FEMA should develop a series of mapping prototype products aimed at more effectively communicating residual flood risk related to levees, dams, and event-driven coastal erosion. Products developed should incorporate end-user and stakeholder testing, and FEMA should develop standards for routine production and presentation, if applicable.

Evaluation of the Best Practice/Guidance No. 1

Table 11 provides an evaluation of the pros, cons, constraints, and opportunities for the BMP outlined above.

Table 11. Evaluation of Best Practice/Guidance for Mapping the Residual Risk Behind Levees and Other Flood Management Structures.

Pros	Cons	Constraints	Opportunities
The mapping of risk behind levees or in other areas that are not commonly thought or known to be designated as flood-prone would provide those residents with better information upon which to act / protect themselves.	The mapping of risk behind levees or in other areas that are not commonly thought or known to be designated as flood-prone could increase insurance premiums and require outreach to affected residents.	Many of the areas behind the Salt Creek levees are already mapped because the levees only protect to a 50-year event.	Consider residual risk that may occur outside the current 1 percent annual chance floodplain, or if the levees are certified in the future, consider the residual risk behind the levees as part of a comprehensive mapping and floodplain mapping program.

For more information on the TMAC mapping guidance please see the TMAC National Floodplain Mapping Review (TMAC 2016); and the TMAC Annual Report (TMAC 2017).

<u>Best Practice/Guidance No. 2:</u> Provide future conditions flood risk products and information for riverine areas that include the impacts of future development, land use change, erosion, and climate change as actionable science becomes available.

FEMA should take the impacts of future development and land use change on future conditions hydrology into account when computing conditions for riverine areas. TMAC provided numerous recommendations in its 2015 Annual Report (TMAC 2015a) and Future Conditions report (TMAC

2015b) on how to ensure that FIRMs incorporate the best available climate science to assess flood risks and advises FEMA to use the best available data and methods to consider the impacts of sea level rise, long-term erosion (coastal and riverine), climate-affected hydrology, and future development on flood risk.

The TMAC Future Conditions Risk Assessment and Modeling (TMAC 2015c) includes seven recommendations and 37 sub-recommendations to help FEMA ensure that FIRMs incorporate the best available climate science to assess flood risks and ensure that FEMA may use the best available methodology.

Evaluation of the Best Practice/Guidance No. 2

Table 12 provides an evaluation of the pros, cons, constraints, and opportunities for the BMP outlined above.

Table 12. Evaluation of Best Practice/Guidance for Providing Future Conditions Flood Risk Products and Information.

Pros	Cons	Constraints	Opportunities
The City of Lincoln is investigating future-conditions hydrology as part of this project, which will provide greater awareness of future risk so that more resilient actions can be implemented.	Several projects within the City of Lincoln have been constructed to a level of protection very close to the existing 1 percent annual chance flood, and the projects would therefore potentially be vulnerable if predicted flood flows increase.	Time frames for future discharges will not be short-term; projections to approximately year 2050 or 2100 will likely make taking appropriate resilient actions now more difficult.	Building an awareness of future flood threat provides the ability to develop and implement plans to mitigate those risks and build a more resilient City of Lincoln; other opportunities include increasing freeboard, establishing a minimum corridor width and length, and decreasing watershed acres prior to mapping.

The City of Lincoln is proposing to raise the 1 percent design storm depth from the Drainage Criteria Manual from 6.7 inches to 7.3 inches (City of Lincoln Public Works and Utilities Department, 2014). The proposed rainfall depth is from the NOAA Atlas 14 (NOAA 2013). The proposed rainfall depth will not immediately affect the existing infrastructure. When remapping of the floodplain occurs, the increased design storm depth will result in increased peak flood flows and flood elevations. This could lead to increased floodplain extents. Infrastructure that was adequate based on the original design storm depth may not have the capacity to handle the revised design storm depth.

Best Practice/Guidance No. 3: FEMA should develop, in coordination with stakeholders, a transition plan for moving away from the 1 percent annual chance flood event.

The 1 percent annual chance flood event is used by a network of stakeholders with different needs and purposes. The 1 percent annual chance flood event is embedded in federal, state, tribal, and local regulations; regulations that mandate the purchase of flood insurance; federal and stakeholder websites; and program interfaces and systems, training programs, and federal agency lender audit programs.

The development and execution of a comprehensive plan in coordination with stakeholders is essential for transition from the 1 percent annual chance flood event. Stakeholder communication and coordination is essential to determining how the transition would affect requirements, processes, procedures, and current regulations, and to minimize unintended consequences. Stakeholders include, but are not limited to, floodplain managers, mitigation planners, U.S. Fish and Wildlife Service, other federal agencies, relevant state/local/tribal natural resources management agencies, "write-your-own" insurance companies, NFIP direct servicing agents, insurance agents, lenders, federal regulators, private insurers, zone determination companies, and FEMA contractors (e.g., mapping contractors, certified technical providers, the NFIP System of Record for Statistical Reporting and Accounting, and CRS).

The TMAC recommends that FEMA develop, in coordination with stakeholders, a transition plan for moving away from the 1 percent annual chance flood event, including recommending that FEMA establish upper and lower bounds for the 1 percent annual chance exceedance flood elevation using a confidence interval size of FEMA's choosing, and that FEMA use those limits to map the special flood hazard area (SFHA) "boundary zone" – the area where the base floodplain boundary is most likely to be. FEMA should share SFHA boundary zone information with the public, test how it is received, and make improvements prior to formalizing any specific standards or policy for routine map updates.

Evaluation of the Best Practice/Guidance No. 3

Table 13 provides an evaluation of the pros, cons, constraints, and opportunities for the BMP outlined above.

Table 13. Evaluation of Best Practice/Guidance for Moving Away From the 1-percent Annual Chance Flood Event.

Pros	Cons	Constraints	Opportunities
A boundary, rather than a line, more accurately represents the uncertainty associated with flood risk prediction.	Communicating uncertainty to the public will be more difficult than communicating a boundary.	Currently, there is no guidance from FEMA on how uncertainty should be dealt with on the FEMA maps.	The City of Lincoln can begin to consider impacts and adoption of uncertainty prior to a formal adoption of uncertainty recognitions and standards by FEMA.

Applicability to Salt Creek Floodplain

Awareness of FEMA floodplain mapping trends allows the City of Lincoln to consider and prepare for the impacts of these changes before they are rolled out and perhaps to get involved in the conversation that will develop future guidance. This work includes direction to explore climate-affected hydrology, indicating that the City of Lincoln is aligned with a portion of what TMAC is recommending to FEMA, a positive indication that the city's program is progressive and moving in the right direction.

1.6 National Academy of Sciences

Mission/Goals

The NAS is a nonprofit society of scholars tasked with providing independent, objective advice to the nation on matters related to science and technology. As a part of this mission, the NAS formed a committee on urban flooding in the United States. This committee studied the issue of urban flooding with the objective of contributing to existing knowledge and providing real-world examples and recommendations for BMPs.

Best Practice/Guidance No. 1: Invest in interventions to mitigate the impacts of flooding to socially vulnerable populations.

Research has consistently demonstrated that the impacts of flooding tend to fall disproportionately on socially vulnerable populations, including children, the elderly, non-white, immigrants, non-native English speakers, disabled, homeless, poor, renters, and those with low educational attainments. These groups are more vulnerable to flooding because they are more likely to reside in flood zones, have less mobility, lower awareness of flood hazards, higher rates of mortality, and lower resilience to recover after a flood event.

Because of this vulnerability, outreach and mitigation projects should be targeted specifically at socially vulnerable populations. Targeting outreach to these populations is critical to facilitating increased flood awareness. Planning mitigation projects to specifically benefit areas with high social vulnerability is more likely to mitigate the social impacts of future flooding. When crafting policy, it is also critical to include those who serve socially vulnerable populations to avoid creating unintended exclusivity of policy and that the policies will best meet the intention for all populations.

Evaluation of the Best Practice/Guidance No. 1

Table 14 provides an evaluation of the pros, cons, constraints, and opportunities for the BMP outlined above.

Table 14. Evaluation of Best Practice/Guidance for Investing in Interventions to Mitigate the Impacts of Flooding to Socially Vulnerable Populations.

Pros	Cons	Constraints	Opportunities
Targeting outreach and mitigation toward socially vulnerable populations is more likely to mitigate the social impacts of future flooding.	More effort and resources are required to conduct successful outreach to socially vulnerable populations.	Outreach materials may require customization to specific populations (for example, translated to non-English languages).	Effective outreach and mitigation projects benefitting vulnerable populations will achieve greater overall impact in mitigating impacts of flooding.

Applicability to Salt Creek Floodplain

Identifying areas prone to flooding from Salt Creek, in conjunction with identifying and locating vulnerable populations by using such tools as the Social Vulnerability Index (Cutter et al. 2003) will allow for highly targeted outreach. This type of targeted analysis may also promote mitigation projects with the potential for greatest overall benefit.

For more information on investing in protections for socially vulnerable populations, please see these resources: National Academies of Sciences, Engineering and Medicine (2019) and Cutter et al. (2003).

Best Practice/Guidance No. 2: Consider innovative solutions in identifying and communicating urban flood risk.

FEMA has established methods for analyzing riverine flood hazards. However, important aspects of urban flooding, such as the effectiveness of stormwater systems, the importance local drainage patterns, and site-specific drainage designs, are often overlooked as critical factors in flood risk across a community. Innovative solutions are needed to better identify and communicate this risk. Several examples of innovative solutions identified by the NAS include:

- Academic models of urban flood hazards
- Hydrologic and hydraulic models that take into consideration storm drain information or other flooding scenarios that are not frequently accounted for by standard FEMA riverine flood hazard analysis
- Tracking and geographic analysis of nonemergency 311 calls that deal with flooding hazards and stormwater problems
- Flood maps and visualizations that integrate predictions, local observations, and potential impact of flooding, such as local inundation areas or dam breach areas

Evaluation of the Best Practice/Guidance No. 2

Table 15. provides an evaluation of the pros, cons, constraints, and opportunities for the BMP outlined above.

Table 15. Evaluation of Best Practice/Guidance for Considering Innovative Solutions in Identifying and Communicating Urban Flood Risk.

Pros	Cons	Constraints	Opportunities
Innovative solutions in analyzing flood risk may provide a more complete and fuller-spectrum understanding of flood risk that impacts the community; innovative maps or visualizations may increase effectiveness of outreach.	Innovative solutions in flood risk identifications that are not established by FEMA are likely to be costly.	Flood hazards identified using innovative solutions may not be shown on the flood insurance rate map (FIRM).	Improved risk identification and communication will decrease the negative impacts of future flooding.

Applicability to Salt Creek Floodplain

The Salt Creek floodplain has been analyzed from a standard riverine flooding perspective, and the riverine flooding hazard is clearly shown on the effective FIRM. However, the FIRM may not adequately depict hazards specific to urban flooding in adjacent areas. Analyzing and communicating this overland urban flooding risk will lead to greater preparedness for a full spectrum of different types of flooding that may occur.

For more information on identifying and communicating urban flood risks, please see the NAS 2019.

SECTION 2 – COMMUNITY BEST MANAGEMENT PRACTICES REVIEW

2.1 Current Review of Practices Across the U.S.

Lincoln has taken a proactive role in adopting higher regulatory standards and policies and implementing programs for reducing flood risk and protecting the life, property, and economic interest of constituents. In 2004, the standards for new growth areas set regulations for development, institutionalizing several BMPs, including the following (City of Lincoln Public Works and Utilities Department 2004):

- Regulating for no adverse impact, including no net rise
- Providing compensatory storage
- Maintaining a minimum flood corridor

Lincoln has enacted multiple strategies for implementing BMPs. Lincoln has developed customized low-impact development (LID) guidance and continues to offer support for landscaping elements that improve water quality and reduce runoff through a voluntary program. Additionally, the LID program is supported through LID cost-share grants. Critical facilities benefit from elevation to the 0.2 percent annual chance floodplain, and best available information can be used to inform higher regulatory standards. Residential and commercial development is prohibited in the floodway, and stream setbacks and buffers are projected in new growth areas.

The package of regulations, incentives, and policies driving BMPs in Lincoln, paired with community education and outreach, has been recognized by FEMA's CRS program. CRS is an incentive program, which under the NFIP, rewards communities going beyond the minimum standards by providing credits toward the reduction of flood insurance premiums for community homeowners. Because of the exemplary efforts that have been taken by the city, Lincoln currently benefits from flood insurance premium discounts of 25 percent as a result of a CRS Class 5 rating. The suite of BMPs that Lincoln uses were forward-thinking, at the time of adoption, and these regulations remain good floodplain management practices.

Additionally, Lincoln has embarked on large infrastructure projects, constructing dams and levees, to reduce Salt Creek flood damages by an estimated $284 million since efforts began in the 1960s, while adding additional recreation benefit to the community. Section 3 of this report provides a review of the current floodplain management practices in Lincoln and Lancaster County. These include education and outreach, policies, freeboard requirements, CRS, structural measures, and buyout to name a few. The breadth of current measures taken is noteworthy.

Communities across the country continue to innovate and advance similar best practices and have also built an understanding of longitudinal return on investment from implementation. These advancements in BMPs and the availability of additional data substantiate a new look at how BMPs from across the nation can once again assist Lincoln in floodplain management as the city continues to strive to reduce disruptions from minor events and devastation from major flood events in a growing community.

The foundation of any good floodplain management effort is a comprehensive set of measures that include non-structural measures like floodplain regulations and policies, floodplain conservation, public education and outreach, floodproofing or flood protection, and buyouts. Structural measures, such as dams, levees, channel improvements, and offline storage facilities, can build upon the non-structural practices to create a comprehensive set of floodplain practices. The overall goal of the practices is to prevent loss of life, reduce property damage, and enhance the natural and beneficial functions of the floodplain.

Eight communities from across the country were selected for this review and guidance. They include communities that stand out in the CRS program, have done a notable job of implementing a strategy or strategies, and have elements of their communities, geography, or risk that are relatable to Lincoln, Nebraska. For this effort, and in addition to those BMPs identified above that the City of Lincoln is already implementing, we have highlighted BMPs for the city's consideration during future floodplain management policy planning sessions.

The summary and analysis of each community's BMP includes benefits and drawbacks of the strategies other communities are implementing. Some communities may have more restrictive policies; yet, those policies may not necessarily provide additional benefit. In many cases, the policies implemented by the City of Lincoln allow for more flexibility and still meet the no adverse impact (NAI) criteria that form the City of Lincoln's foundation of floodplain management.

The BMPs for the communities shown in **Table 16** were reviewed and analyzed:

Table 16. Best Management Practices Reviewed and Listed by Community.

Community	Best Management Practices
Beatrice, NE	Flood-prone property acquisitions
Boulder County, CO	Cumulative substantial improvement calculation and tracking
Cedar Falls, IA	Higher floodplain standards –0.2-percent annual chance regulation and new-lot prohibition
Fort Collins, CO	Community outreach, LID
Mecklenburg, NC	Education/outreach, buyout program, and floodplain restoration
Papillion, NE	Floodplain buyout program
Platte County, MO	Stormwater grant program
Shawnee, KS	Future floodplains, freeboard, and setback/riparian preservation

For each BMP in each community summary, a BMP evaluation table is included. The components of that table are defined here:

- *Cost to Implement*. Is the BMP achievable, given the anticipated costs?
- *Benefit*. How big is the potential for the community to reduce losses of life and property?
- *Time to Realize Benefit.* How much time must pass before the city can see the benefits that come from implementing this BMP, or before the benefit-cost ratio exceeds 1.0?
- *Complexity of Implementation: Technical feasibility*. Are there constraints that would make a BMP difficult to execute? How complicated, from a capability perspective, is the BMP to implement?
- *Staffing Requirements.* What level of staffing is necessary for implementation, support, and administration to successfully execute the BMP?

A matrix of community BMPs is provided in Appendix A.

2.2 Beatrice, Nebraska

Why was this community selected?

Beatrice is located approximately 40 miles south of Lincoln, and it straddles the Big Blue River, which empties into the Kansas River 80 miles farther south. Beatrice has experienced several large flooding events, the largest on record occurring in 1973. Following the 1973 flood event, the community rallied to put in motion a long-term plan to reduce the damages and expenditures resulting from floods, increase the amount of open space within the city, and increase the community's ability to respond to and recover from future flood events. While not a large city in comparison to Lincoln, Beatrice's ability to create a successful flood mitigation program through property acquisitions makes it an exemplary floodplain BMPs community.

Historical flooding in Beatrice has resulted in 17 flood- and storm-related disasters for Gage County, Nebraska. Since 2015, the following disasters have been declared:

- *DR-4225: June 25, 2015: Severe Storms, Tornadoes, Straight-line Winds, and Flooding. Total Public Assistance Funding: $14.3 million*
- *DR-4325: August 1, 2017: Severe Storms, Tornadoes, and Straight-line Winds. Total Public assistance Funding: $15.1 million*
- *DR-4420: March 21, 2019: Severe Winter Storm, Straight-line Winds, and Flooding. Total Individual Assistance Funding: To be determined*

Best Practice: Flood-prone property acquisitions

The Big Blue River near Beatrice experienced its flood of record in 1973. Damage in Beatrice was devastating, even though the estimated damages only hovered at around $3 million (in 1973 dollars). From 1973 to 2014, the city purchased 120 properties and converted them to open space along the river, starting with FEMA's first Hazard Mitigation Grant Program (HMGP) purchase in 1973. Over that time, three additional large flood events occurred in Beatrice. Following the 2015 flood event, the city avoided an estimated $12.9 million or more in losses by spending only $4.9 million for acquiring flood-prone properties, which is equivalent to a 263 percent return on investment.

Acquisition of flood-prone properties and structures can be one of the costlier and sometimes more complicated approaches to flood risk reduction, but it is immensely effective. Removing existing risk and maintaining the property as open space in perpetuity ensures that the risk is fully mitigated and provides secondary benefits such as increased flood storage to reduce downstream flows, improved water quality, improved ecosystem and riparian habitat, and public recreational opportunities.

Evaluation of Best Practice

Currently, the City of Lincoln employs real estate staff to handle transactions related to acquisition of property, rights-of-way, and easements for public infrastructure projects, which presumably include stormwater projects.

Beatrice differs from the City of Lincoln because it has a long history of acquiring flood-prone property, exemplified by the results of the May 2015 flood on the Big Blue River – the city's third highest peak on record – with virtually no flood damage reported. Beatrice's focus was on mitigating existing risk.

This is important to Lincoln because – with several existing structures and properties in the mapped floodplain – Lincoln could benefit from a similar program to reduce/remove existing risk through acquisition. At the same time, the community can use the acquired land to maintain green space in an urban environment, reducing the pressures on drainage systems and providing a valuable community asset. FEMA's recent focus on increased spending for mitigation translates to more money than ever before that could be made available for acquisition grants. **Table 17** provides an evaluation of the flood-prone property acquisitions BMP.

Table 17. Flood-prone Property Acquisitions Evaluation.

Factor	Low	Low-Med	Med	Med-High	High	Information to support score
Cost to Implement				X		Lincoln's home values are on par with the national average; still, acquisition projects can be costly.
Benefit					X	Return on investment for acquisition is great considering home values and long-term risk reduction.
Time to Realize Benefit				X		Benefits are realized over shorter periods as much or all the risk has been mitigated.
Complexity of Implementation				X		This will require negotiations and transactional capabilities, demolition and removal, environmental remediation.
Staffing Requirements					X	Staffing will require real estate and attorney staff, long-term maintenance.

2.3 Boulder County, Colorado

Why was this community selected?

Boulder County is a geographically large county near the Denver metro area and has a population of approximately 325,000. Boulder, which is the county seat, has approximately 110,000 people and is a university city with a strong work force and hot housing market. The unincorporated areas within the county are experiencing growth and development as well. Boulder County endured its largest flooding disaster in September 2013, when rainfall amounts never seen in this area triggered flash flooding and significant fluvial hazards. Even during flood recovery, the county was able to improve its CRS rating from a Class 7 (which entitles residents to a 15 percent reduction on their flood insurance premiums) to a Class 5 (which entitles residents to a 25 percent reduction on their flood insurance premiums), showing a strong commitment to building back resiliently to not repeat past outcomes.

In addition to the 2013 floods (when individual assistance and public assistance funding totaled $404.5 million), the county has experienced only one other federally declared flooding disaster in the last 40+ years:

- *DR-4229: July 16, 2015: Severe Storms, Tornadoes, Flooding, Landslides, and Mudslides. Total PA Funding: $25.7 million*

Despite infrequency of federally declared disasters, Boulder County has experienced multiple flood events.

Best Practice: Cumulative substantial improvement calculation and tracking

Prior to the 2013 floods, the county would see approximately one to two dozen floodplain development permits per year. Following the 2013 event, that number ballooned to over 200 a year for 2014–2017. New staff and multiple layers of flood recovery projects meant that tracking substantial damage, substantial improvements, and minor projects would be a challenge the county had not yet faced. Boulder County originally established the cumulative substantial improvements tracking in 2010 with a coordinated update to the county's land use code. When handling the onslaught of development permits following the 2013 floods, the county realized that tracking of substantial improvements since 2010 had not been consistent, and there was no detailed policy or approach to tracking and enforcement.

In 2016, the county reset its cumulative substantial improvements tracking date to coincide with the 2013 flood. The new regulation of substantial improvements dictated that each improvement permitted for an existing, nonconforming building would be assigned a percentage based on market value of the building at the time of permitting that improvement. Each permitted improvement for a building would be assigned a percentage, and when the sum of all percent improvements for a building reaches 50 percent, the entire building must be brought into compliance with the county land use code. Tracked improvements do include repairs of damage to the building.

When property owners choose to invest in flood-prone structures in Boulder, the city's ability to track improvements and require full compliance with the code, which includes 2 feet of freeboard, helps ensure long-term resilience, and is a unique way to bring existing development into compliance over time.

Evaluation of Best Practice

Currently, Lincoln uses the NFIP-minimum definition and procedure for substantial improvements, which state that improvements that cost more than 50 percent of the market value of the structure prior to the start of construction of the improvement would necessitate the entire building being brought into compliance with the community's floodplain ordinance; in the case of Lincoln, that means existing, nonconforming buildings that are substantially improved must be elevated 1 foot above the BFE. Improvements that are not considered substantial improvements need not comply with the floodplain ordinance.

Boulder County differs from Lincoln because it does not look at improvements to the same building or structure independent of one another. The county has chosen to track and monitor improvements over time, so it can limit the amount of improvement investments that can be made to flood-prone buildings without bringing the full building into compliance. This approach helps ensure that property owners who choose to make small improvements (which might increase the overall value of the structure over time) must, when the threshold is reached, protect the increased value by elevating the entire structure. Boulder County considered, and is still considering, other ways to implement cumulative substantial improvement tracking and enforcement, such as tracking substantial improvements within a rolling period and other methods.

This is important for Lincoln because several existing flood-prone buildings in the city could conceivably receive several non-substantial improvements over time that would likely trigger a substantial improvement determination had the improvements been done concurrently. The total value of the structure would therefore likely be increased, even though flood protection is not being provided to the entire structure. Managing existing risk is a challenge, but maneuvering to cumulative tracking of substantial improvements would ensure that investments made in Lincoln's existing urban areas are, over time, being made more resilient to flooding. **Table 18** provides an evaluation of the cumulative substantial improvement calculation and tracking BMP.

Table 18. Cumulative Substantial Improvement Calculation and Tracking Evaluation.

Factor	Low	Low-Med	Med	Med-High	High	Information to support score
Cost to Implement	X					Cost for regulatory updates are relatively low.
Benefit				X		Return on investment is relatively high because tracking substantial improvements results in full home elevation, which significantly reduces loss potential.
Time to Realize Benefit			X			This score is a function of average home values and the rate of repairs/improvements in the city.
Complexity of Implementation			X			Code writing and method for tracking/monitoring improvements.
Staffing Requirements		X				There is an increased burden to track/monitor improvements, but likely no additional staff necessary.

2.4 Cedar Falls, Iowa

Why was this community selected?

Cedar Falls, like Lincoln, is a university city prone to large flood events. Both communities have commercial buildings and infrastructure protected by levees. Cedar Falls is also the highest-rated CRS community in the state of Iowa, at a Class 5, which entitles residents to a 25 percent reduction in their flood insurance premiums. Cedar Falls is built along the Cedar River, with tributaries running through agricultural areas, recreational areas, developed neighborhoods, and the University of Northern Iowa campus. Cedar Falls and the Cedar Falls/Waterloo area have seen significant population growth, creating a development demand.

Black Hawk County, where Cedar Falls is situated, has experienced 18 flooding and storm-related federal disaster declarations since 1965. Since 2010, the following disasters have been declared:

- *DR-1930: July 29, 2010: Severe Storms, Flooding, and Tornadoes. Total IA/PA Funding: $78.6 million*
- *DR-4187: August 5, 2014: Severe Storms, Tornadoes, Straight-line Winds, and Flooding. Total PA Funding: $14.3 million*
- *DR-4289: October 31, 2016: Severe Storms and Flooding. Total PA Funding: $15.8 million*

Cedar Falls is within the Middle Cedar watershed, which is part of a state consortium of watershed management authorities across the state that cooperatively engages in watershed planning and management. In response to development and the threat of large, destructive flood events, Cedar Falls has incorporated a variety of mitigation and prevention strategies to make the community more resilient. These strategies include structural fixes, improvements to the stormwater system, property buyouts, higher floodplain management standards, floodplain map updates, and regular updates to the city’s hazard mitigation plan.

<u>Best Practice No. 1:</u> Higher floodplain management standards – 0.2-percent annual chance regulation

In 2010, following the establishment of a Floodplain Ordinance Task Force, Cedar Falls overhauled its NFIP-minimum floodplain regulations to include higher development standards. One of those higher standards was the adoption of the 0.2 percent annual chance floodplain delineations and elevations as the community's locally regulated flood information. Notable provisions of this standard include the following:

- All residential development must have a minimum 1 foot of freeboard above the 0.2 percent annual chance flood elevation.
- All commercial development must have a minimum 1 foot of freeboard above the 0.2 percent annual chance flood elevation, or it must be dry-floodproofed up to 1 foot above the 0.2 percent annual chance flood elevation.
- On-site wastewater treatment and sanitary systems must be protected from flooding up to the 0.2 percent annual chance flood elevation.
- Critical facilities are prohibited in the 0.2 percent annual chance floodplain.

Higher floodplain management development regulations in areas subject to larger magnitude floods ensures that new development will be less likely to be affected by flooding over time.

Evaluation of Best Practice No. 1

Currently, Lincoln does not apply its floodplain development regulations outside of the 1 percent annual chance flood hazard areas (floodplains and flood-prone areas, as defined by the City of Lincoln), and it employs a 1-foot freeboard requirement above the 1 percent annual chance flood elevation. Lincoln does, however, require that critical facilities use a 0.2 percent annual chance flood elevation (without freeboard). Further, Lincoln's regulation extends to hazardous areas associated with drainage areas down to 150 acres.

Cedar Falls differs from the City of Lincoln because it applies its floodplain development regulations to not only the 1 percent annual chance flood hazard areas, but also to the 0.2 percent annual chance flood hazard areas. Cedar Falls also requires freeboard above the 0.2 percent annual chance flood elevations. While this approach exceeds the minimum NFIP requirements for regulating development in flood-prone areas, Cedar Falls does default to FEMA's FIRMs for identification of flood hazard areas. Typically, FEMA will only map hazards associated with drainage areas greater than 1 square mile, but on occasion it does map smaller drainage areas using the same zone designation as that of the 0.2 percent annual chance flood hazards.

This is important for Lincoln because implementing higher floodplain management standards could further support and protect the development of the city's new growth areas. Applying floodplain development regulations to a greater portion of the city areas and using higher regulatory water surface elevations helps account for uncertainty in established regulatory water surface elevations, expected increases in rainfall intensity and duration, and increased runoff/decreased lag times that result from development throughout a watershed. Similar outcomes can be achieved by regulating based on more conservative water surface elevations such as a 1 percent plus elevation, the 0.2 percent annual chance elevation, or some other return period, or by using additional freeboard above the currently regulated 1 percent annual chance water surface elevation. Using 0.2 percent annual chance elevations for sample locations in or near the Lincoln new growth area would result in an average of approximately 2 feet of difference in the regulatory elevation, as shown in **Table 19**.

Table 19. Approximate Water Surface Elevation Difference Between the 1-percent and 0.2-percent Annual Chance Floods for Different Flooding Sources in the Salt Creek Basin.

Flooding Source: Haines Branch	
Cross-section *	**Approximate Water Surface Difference**
K	2.5 feet
L	2.5 feet
M	2.0 feet
N	2.5 feet

Flooding Source: Middle Creek	
Cross-section *	**Approximate Water Surface Difference**
R	2.5 feet
AA	1.4 feet
AM	2.4 feet

Flooding Source: Stevens Creek	
Cross-section *	**Approximate Water Surface Difference**
I	0.5 foot
AJ	1.5 feet
AW	2.0 feet

*The location of the cross-sections are shown in the Flood Insurance Study (NFIP 2013)

Table 20 provides an evaluation of the higher floodplain management standards: 0.2 percent annual chance regulation BMP.

Table 20. Higher Floodplain Management Standards: 0.2-percent Annual Chance Regulation Evaluation.

Factors for 0.2-percent Annual Chance **Regulation**	Low	Low-Med	Med	Med-High	High	Information to support score
Cost to Implement	X					Cost for regulation updates are relatively low.
Benefit				X		Requiring additional elevation reduces flood loss and damages.
Time to Realize Benefit					X	The benefit is only realized as new construction/substantial improvements occur; this score is counter to the rate of development.
Complexity of Implementation	X					Code writing capabilities are necessary.
Staffing Requirements		X				Typical code updates and enforcement will be required.

Best Practice No. 2: New lot prohibition

In 2010, Cedar Falls also adopted an ordinance that prohibits the platting of any new lots within the mapped 0.2 percent annual chance floodplain. Lots that were platted prior to 2010 may still be developed in accordance with the zoning district regulations.

This is an interesting regulation, as it has the potential to significantly limit the value of large properties within the floodplain and restricts the ability to subdivide them for development. However, this strikes at the heart of floodplain management and risk reduction by forever limiting and restricting the ability to develop within areas of known flood hazard.

Evaluation of Best Practice No. 2

Currently, Lincoln operates using an NAI approach in new growth areas, which generally ensures that development occurs with consideration of the impacts of that development, be it flood elevations, velocities, sedimentation, or erosion. This does not, however, preclude development from occurring. In theory, a lot could be platted and developed in accordance with the city's flood design criteria, and while that development could exceed minimum federal standards, there would still be some level of risk associated with development in floodplain and/or flood-prone areas.

Cedar Falls differs from the City of Lincoln because it has adopted a standard that prohibits not only development, but even the platting or subdividing of lots that could accommodate development. By doing so, the city has limited the amount of value/investment that can be made in these areas, thus achieving reduction in potential flood losses for these areas.

This practice may be important for Lincoln to consider as it provides a means of reducing future development in the floodplain. Communities that have supported property acquisitions following flood events have seen firsthand the benefit to keeping floodplains and flood-prone areas free from development. The most cost-effective approach to providing flood attenuation and storage, increasing water quality, and promoting the other natural and beneficial functions of floodplains is to prohibit development in the floodplain in the first place. **Table 21** provides an evaluation of the new lot prohibition BMP.

Table 21. New Lot Prohibition Evaluation.

Factor	Low	Low-Med	Med	Med-High	High	Information to support score
Cost to Implement	X					Cost for regulation updates are relatively low.
Benefit					X	Prohibiting development is one of the most cost-effective approaches.
Time to Realize Benefit		X				Once the regulation is adopted, the benefit begins; there is no project to pursue.
Complexity of Implementation	X					Code writing capabilities are necessary.
Staffing Requirements		X				Staffing for code updates, development review, and enforcement will be required.

2.5 City of Fort Collins, Colorado

Why was this community selected?

Fort Collins has earned a Class 2 CRS rating for exemplary floodplain management. In 2017, the city's population had increased from 145,045 in 2010 to 165,080. Like Lincoln, this area is experiencing growth and continued pressures on development.

Several flood events have shaped the growth of the Fort Collins community and the mitigation actions that have been enacted in response to lessons learned.

- 1864 – Camp Collins was washed away in a flood event and rebuilt as Fort Collins in the current location of Old Town.
- 1997 – Approximately 10 to 14 inches of rain fell in a 31-hour period, resulting in five deaths and an estimated $200 million in damages.

- 2013 – The largest flood event on the Poudre River since 1930 occurred; however, because of a comprehensive floodplain management program, minimal damage to structures occurred.

The effectiveness of the land use regulations, programs to preserve floodplains and riparian corridors, and the ability to build support for community investment and higher regulations through outreach and education continue to make Fort Collins a nationally recognized community in the field of floodplain management.

Best Practice No. 1: Community outreach and education

Fort Collins takes a multiprong and targeted approach to outreach and education. Residents in or near the floodplain receive brochures in the mail annually discussing the local hazard, safety, property protection, and flood insurance.

The community has a robust website with information and quick guides on floodplain regulations. The quick guides break down regulations and organize them into a single location. While builders and property owners must eventually reference regulations in more detail, these guides offer an initial understanding of requirements and also provide an explanation on why the regulations are in place (Fort Collins 2018).

Fort Collins participates in FEMA's High-Water Mark Campaign and posts signs that show the high-water marks in visible locations to remind residents and visitors of prior flood events. These signs also include educational information on mitigation. The city highlighted these signs with launch events to draw awareness to the issue.

Fort Collins has also had success using videos to communicate the story of trauma from flood events and success from mitigation and resilience (Fort Collins 2015). The videos tell a story that communicates need and allows the community to celebrate the proactive measures that have been taken to improve protection.

Evaluation of Best Practice No. 1

Currently, Lincoln does conduct outreach to the community on floodplain activities and offers a Be Flood Smart website (LTU 2020).

Fort Collins differs from the City of Lincoln because it has implemented a more comprehensive suite of engagement services. The city has a coordinated space for online information that includes basic information, downloadable guides, videos, and development guides in the floodplain. Additionally, the city highlights stories of success, which can help bolster support for investment in mitigation.

This is important for Lincoln because new regulation and calls for investment can face community opposition. The more the community understands the critical need and the payoff it will receive from investment and regulation, the less opposition and more support Lincoln can hope to see. **Table 22** provides an evaluation of the community outreach and education BMP.

Table 22. Community Outreach and Education Evaluation.

Community Outreach and Education	Low	Low-Med	Med	Med-High	High	Information to support score
Cost to Implement	X					Engagement activities are relatively low cost.
Benefit		X				Education and outreach do not guarantee action or mitigation activities, but they can build support for funding and initiatives and awareness of programs.
Time to Realize Benefit		X				Core stakeholders will have early awareness, though the broader community members may require more time.
Complexity of Implementation	X					Materials can be easily produced and disseminated.
Staffing Requirements		X				Communications department and technical staff for accuracy and readability will be required.

<u>Best Practice No. 2:</u> Low-impact development (LID)

LID in Fort Collins is baked into the development review process and offers a suite of tools that, among other benefits, treat water, improve water quality and availability, minimize runoff, and provide relief from localized flooding. LID design practices are showcased in the introduction of the City of Fort Collin's LID Implementation Manual (Fort Collins 2017). The manual also provides an applicability matrix, which associates the relative cost of a strategy to a project size.

Currently LID requires one of the following two scenarios:

- No less than 75 percent of any newly developed or redeveloped area, or any area requiring a construction permit, be treated by one or a combination of LID techniques
- No less than 50 percent of development be treated by one or a combination of LID strategies when permeable pavement covering is at least 25 percent of the site

These requirements assist with runoff, water quality, and flooding but also add to the aesthetics of the site and reduce heat islands, which cause elevated air temperatures, air pollutants, and energy consumption in urbanized areas.

Evaluation of Best Practice No. 2

Currently, Lincoln has volunteer LID regulations, but they are not enforced on any development. The City of Lincoln has already explored LID and has developed strategies that are specific to the region. The Lincoln Drainage Criteria Manual (City of Lincoln, Public Works and Utilities Department, 2004) references these LID practices as recommended, but non-mandatory, floodplain standards. As Lincoln continues to urbanize with more impervious surfaces, these strategies could be elevated to be required within appropriate development as a tool to reduce runoff and flooding and to improve water quality.

Fort Collins differs from the City of Lincoln because its regulations are enforceable and required. As the community grows, permeable surfaces on development will be maintained, and the community can expect that 75 percent of newly developed areas will reflect these practices. Additionally, Fort Collins offers an extensive and highly visual manual for developers and property owners to understand what the strategies for LID are and how they will look on their sites.

This is important for Lincoln because increased regulations provide greater predictably when using LID strategies, ensure that the growth Lincoln is experiencing will support resilience on a site level, and can better use the investment that Lincoln has already made to identify locally customized standards for LID strategies. **Table 23** provides an evaluation of LID.

Table 23. Low-impact Development (LID) Evaluation.

Low-impact Development	Low	Low-Med	Med	Med-High	High	Information to Support Score
Cost to Implement			X			The current regulations must be updated.
Benefit			X			LID strategies can be implemented by development at lost cost; benefit is site-specific and will increase with development.
Time to Realize Benefit		X				At a parcel level, there will be a quick realization of benefits.
Complexity of Implementation			X			Inspectors require education on how to evaluate standards are met.
Staffing Requirements			X			Additional staff or contractors may be required.

2.6 Mecklenburg County, North Carolina

Why was this community selected?

Mecklenburg County is the most populous county in North Carolina, with a population of 1,034,070 according to the United States Census Bureau (USCB), spread over 564 square miles (USCB 2015). Several universities and colleges call Mecklenburg County home, and the major industries include banking, manufacturing, and professional services. Mecklenburg County had three federally declared disasters involving flooding in the past 25 years. Flood risk reduction practices are described and ranked in the January 2012 report (Mecklenburg County 2012).

The plan provides 19 potential practices (mitigation techniques) for flood risk reduction, the majority of which are non-structural measures. Potential structural measures include levees or floodwalls, flood management structures (bridges and culverts), and stormwater detention facilities. The plan ranks the practices or techniques based on several factors including cost effectiveness and potential impacts to surroundings. Non-structural practices or techniques were rated the most effective, which reflects the characteristics of Mecklenburg County. The county contains the City of Charlotte and surrounding communities. The county is mostly urbanized; retrofitting appropriately sized structural measures into the built urban environment would have an adverse impact on the surrounding properties.

Best Practice No. 1: Public education and outreach

Charlotte-Mecklenburg Storm Water Services (CMSWS) is responsible for implementing floodplain regulations and for implementing floodplain education and outreach efforts. Most of the education and outreach is focused on stormwater issues. However, education about flood risk and risk reduction is provided in a variety of ways. Mailings that provide information about online floodplain maps, stream gages, and flood warning systems are sent strategically to homeowners in the floodplain. Flood risk reduction projects include public meetings and meetings with property owners. CMSWS maintains a robust online database of floodplain information and publications, including a photobook of stormwater features that helps nontechnical people understand floodplain issues by providing photographic examples.

Evaluation of Best Practice No. 1

Currently, the City of Lincoln's education and outreach efforts are like those efforts of CMSWS.

Mecklenburg County differs from the City of Lincoln because it can promote ongoing programs, not project-specific ones, and it has dedicated funding. City of Lincoln programs are often implemented as part of a specific project or a specific bond issue. These types of programs are not continuous and typically end when the project ends or when the bond issue is completed.

Outreach efforts are important for Lincoln because programs with dedicated funding, like buyouts for floodplain properties or cost-shares for stormwater BMPs, are highly effective tools for public outreach and education. The programs can be employed when needed, without waiting for a new project or bond issue. Consistent communication, education, and outreach that are aligned with ongoing programs also build visibility and strength for engagement and community awareness. **Table 24** provides an evaluation of the public education and outreach BMP.

Table 24. Public Education and Outreach Evaluation.

Factors for Public Outreach and Engagement	Low	Low-Med	Med	Med-High	High	Information to Support Score
Cost to Implement	X					Engagement activities are relatively low cost.
Benefit		X				Education and outreach do not guarantee action or mitigation activities, but they can build support for funding and initiatives and awareness of programs.
Time to Realize Benefit		X				Core stakeholders will have early awareness, though the broader community members may require more time.
Complexity of Implementation	X					Materials can be easily produced and disseminated.
Staffing Requirements		X				This will require coordination between the communications department and technical staff for accuracy and readability.

Best Practice No. 2: Floodplain buyout program and floodplain restoration

CMSWS has spent $67 million to purchase more than 400 homes, apartments, and businesses since 1999 (City of Charlotte 2020). The buyouts have led to the development of 185 acres of public open space through "nondevelopment" of the buyout properties. The properties have been converted to greenway trails/paths, community gardens, reforested natural areas, stream and floodplain restoration areas, stormwater wetlands and retention areas, and informal recreational areas. The buyouts are expected to ultimately provide more than $300 million in benefits by avoiding future losses to the properties that were purchased.

Evaluation of Best Practice No. 2

Currently, the City of Lincoln has employed a project-based buyout program. The Antelope Valley project in Lincoln included approximately 46 property buyouts.

Mecklenburg County differs from the City of Lincoln because it has a dedicated funding source for its buyout program and can strategically make acquisitions in flood-prone areas when the opportunity arises, such as when an individual property owner is ready to sell. Buyouts are not necessarily connected to a larger project or flood event.

This is important for Lincoln because targeted buyouts along Salt Creek, particularly in areas landward of the levee that are susceptible to flooding from interior drainage and from Salt Creek, could be highly effective at reducing future flood losses. A buyout program with dedicated funding would allow the City of Lincoln to purchase targeted homes when they are available on the market, or as needed. **Table 25** provides an evaluation of the floodplain buyout program and floodplain restoration BMP.

Table 25. Floodplain Buyout Program and Floodplain Restoration Evaluation.

Floodplain Buyout Program	Low	Low-Med	Med	Med-High	High	Information to support score
Cost to Implement					X	Property acquisition can be extremely costly.
Benefit					X	Removing known repetitive-loss structures or high-risk structures is a certain way to eliminate the risk.
Time to Realize Benefit			X			Benefit is realized upon acquisition.
Complexity of Implementation				X		Requires prioritization of properties, process development, outreach, and considerations for structure removal, utility disconnection, hazardous materials identification, and long-term maintenance.
Staffing Requirements				X		Multiple skills are necessary for a strategic property acquisition program; however, most capacities should exist within current departments.

2.7 Papillion, Nebraska

Why was this community selected?

According to the USCB Papillion has a population of 19,539 and is 6.47 square miles (USCB 2017). Papillion is a CRS-participating community with a rating of Class 7, which entitles residents to a 15 percent reduction on their flood insurance premiums. It is in Sarpy County and is part of the five-county metro area of Omaha. As part of the greater Omaha metro, Papillion faces impacts associated with growth, including the potential for floodplain encroachment in its jurisdiction and greater surface water runoff as impermeable surfaces expand with the population. The Papio-Missouri River Natural Resources District (P-MRNRD) notes in *It Happened Here Before* that floods in the 1960s and 1970s taught area residents valuable lessons about flooding, and they recognize that flooding will occur again (P-MRNRD 2020).

Papillion shares a similar geography and climate as Lincoln and has experienced similar flood events. The populations of the two cities and their area growths are also relatable. Papillion can serve as an example to Lincoln of a smaller community with smaller capacity using regional partnerships as a springboard for action and resource sharing.

Best Practice: Floodplain buyout program

The P-MRNRD established the Floodway Purchase Program in 1990, which reduces future damages from flooding by purchasing land from willing sellers. After the purchase and removal of structures, the land can return to its natural floodplain functions. To date, the NRD has partnered with other communities, and more than 100 structures have been removed from the floodplain, primarily along the Missouri River in Sarpy County. Even though there have been no buyouts in the City of Papillion, thus far, the cost-share program is a valuable tool available to the community.

Evaluation of Best Practice

Currently, property buyouts in the City of Lincoln are typically done on a project basis. The Antelope Valley project in Lincoln included approximately 46 property buyouts.

Papillion differs from the City of Lincoln because it has a dedicated funding source (through cost-share with the P-MRNRD) and an established strategy for buyouts, though there have been no buyouts in Papillion, to date.

This is important to Lincoln because targeted buyouts along Salt Creek, particularly in areas landward of the levee that are susceptible to flooding from interior drainage and from Salt Creek, could be highly effective at reducing future flood losses. A dedicated funding source would allow for acquisition of targeted properties when they become available on the market, or when necessary. A dedicated funding source for implementation of flood management practices would provide the City of Lincoln with an important tool for reducing potential flooding and flood damages. **Table 26** provides an evaluation of the floodplain buyout program BMP.

Table 26. Floodplain Buyout Program Evaluation.

Floodplain Buyout Program	Low	Low-Med	Med	Med-High	High	Information to support score
Cost to Implement					X	Property acquisition can be extremely costly.
Benefit					X	Removing known repetitive-loss structures or high-risk structures is a certain way to eliminate the risk.
Time to Realize Benefit			X			Benefit is realized upon acquisition.
Complexity of Implementation				X		Requires prioritization of properties, process development, outreach, and considerations for structure removal, utility disconnection, hazardous materials identification, and long-term maintenance.
Staffing Requirements				X		Multiple skills are necessary for a strategic property acquisition program; however, most capacities should exist within current departments.

2.8 Platte County, Missouri

Why was this community selected?

Both Platte County and the City of Lincoln must plan for riverine and lowland flooding and are experiencing development pressures from population growth. Platte County is a mix of suburban, commercial, and agricultural areas, and the flood mitigation strategies it uses must be appropriate for each land use type. Platte County is bounded on the west by the Missouri River and is home to the Platte River valley, Bee Creek, and Lower Line Creek. Platte County has been experiencing growth, with population increasing from 89,322 in the 2010 census to 96,096 in 2015, or an increase of 7.58 percent (USCB 2015).

Platte County residents are no strangers to flooding. Over the years, Platte County has experienced periodic inundation resulting in 21 presidentially declared disasters. The most recent events include the following:

- *DR-4435: Severe Storms, Straight-line Winds, and Flooding. March 11-April 16, 2019. Financial Assistance statistics not yet available.*
- *DR-4238: Severe Storms, Tornadoes, Straight-line Winds, and Flooding. March 15, 2105-July 27, 2015. Total Public Assistance funding: $51,248,735.24.*

In response to growth and respective flood events, Platte County has adopted zoning and building regulations to reduce the impact of flooding events, and the county provides local grants for stormwater management.

Best Practice: Stormwater grant program

The stormwater management grant program uses a half-cent sales tax for parks, recreation, and stormwater to fund improvements to bridges, culverts, storm sewers, and drainage ways that will reduce flood hazards, erosion, infrastructure failure, or other threats to buildings or right-of-way related to drainage.

Entity Eligibility: The entity must be located within Platte County. The entity must be governmental, responsible for maintenance and improvement of public roads or drainage structures, a drainage district, other political subdivision of the state of Missouri, a homeowner's association, or an approved 501(c)(3) nonprofit organization.

Evaluation Criteria: Matching funds are not required, but availability of matching funds can affect project prioritization. Otherwise, projects are evaluated against Platte County's planning goals and the project's ability to mitigate or reduce problem severity (risk).

Evaluation of Best Practice

Currently, Lincoln offers a stormwater-related grant program called Rainscaping Lincoln. This program is a sustainable landscape cost-sharing program with funding provided by the LPSNRD. Previous programs have included the following:

- Rainscaping Lincoln – 2019 Sustainable Landscapes Cost Share Program (2019)
- Antelope Park Subbasin Water Quality Project (2014)
- City of Lincoln Rain Garden Project (2008–2010; 2010–2012)
- Holmes Lake Watershed Water Quality Improvement Program (2007)

The goals of these programs were to improve water quality, reduce and attenuate runoff, and improve infiltration rates. Project grants were tailored to property owners throughout the city and in key subject areas, with a focus on smaller projects with reimbursement typically in the $1,000 to $2,000 range. Funding was typically provided by the City of Lincoln, LPSNRD, the Nebraska Department of Environment and Energy, and other sources.

For larger projects that improve infrastructure and reduce flood risk, the city relies on ballot measure bonds that voters must consider on regular ballot cycles. These voter-approved bonds are funded through property taxes, and many projects are completed with cost-shares with federal, state, and local agencies. The most recent stormwater bond was voted on and approved in May 2019 in the amount of $9.9 million.

Platte County differs from the City of Lincoln because it has a dedicated stormwater grant program that prioritizes applications that help prevent loss of life and reduce flood risk to habitable structures. Currently, Lincoln issues bonds to fund large stormwater projects. The projects are prioritized based on the master plans and subarea drainage plans; however, there is not a prioritization process for the landscape cost-sharing program. Bonds are not a dedicated funding source, and each bond has to be approved by voters. There is no limit on project size for grant applications in Platte County, but cost-sharing is encouraged for larger projects. Funding is also relatively stable, because it comes from sales taxes.

Cost-sharing is important for Lincoln to consider because a regularly funded grant program for larger-scale projects can reduce the burden on city staff through reduction of project management responsibilities and transfer of project execution to grant applicants. Sales tax funding, as opposed to property tax funding, can also reduce the perceived cost burden on residents and will capture funding from the local business and tourism industries. Strategically promoting project goals that not only address water quality concerns but also highlight the ability to increase safety and reduce flood losses can incentivize program participation.

The National Association of Counties recommends establishing a continuous stream of local funding for regular mitigation and resilience activities. The backbone of resilience is resilient funding; while federal spending on mitigation is increasing, counties should not consistently rely on the availability of state and federal money for projects. It is beneficial to establish dedicated funding when possible. **Table 27** provides an evaluation of the stormwater grant program BMP.

Table 27. Stormwater Grant Program Evaluation.

Stormwater Grant Program	Low	Low-Med	Med	Med-High	High	Information to support score
Cost to Implement		X				Program must be designed and rolled out with a focus on making it easy for stakeholders to apply.
Benefit		X				Return on investment is slightly elevated because projects and funding are not a community burden.
Time to Realize Benefit		X				Benefits are tied to projected completion time frames and grant cycles.
Complexity of Implementation			X			Reviewing proposed projects and program administration is an additional responsibility.
Staffing Requirements		X				There would be little program management time required to implement a stormwater grant program.

2.9 Shawnee, Kansas

Why was this community selected?

Shawnee has a population of 62,209 as of 2017 (USCB 2017) and is about 43 square miles. Shawnee is a CRS-participating community with a rating of Class 7. Shawnee's floodplain area is 98 percent open space, which is a model achievement for communities, and the city has only one repetitive-loss property remaining in its floodplain. Shawnee has pursued higher regulatory standards and buyouts to reduce the impacts of flooding on its community. The city's efforts have preserved natural floodplains; developed digital FIRMs for the city, which are based on ultimate or fully developed floodplains; and have built critical key partnerships.

Best Practice No. 1: Future floodplains (urbanized conditions)

The floodplain maps for the City of Shawnee include the future 1 percent annual chance flood event (using anticipated full build-out conditions). This is shown on **Figure 1** as the shaded Zone X area. This shaded area on the map allows property owners and the public to see how much the regulatory floodplain may increase in the future. However, the future 1 percent annual chance event floodplain extents may be smaller than the existing conditions 0.2 percent annual chance event floodplain, particularly for areas that are already fully developed, which would provide a false sense of security for extreme flood events and their potential extents. The City of Lincoln uses the 0.2 percent annual chance event for the shaded Zone X area on the FIRMs.

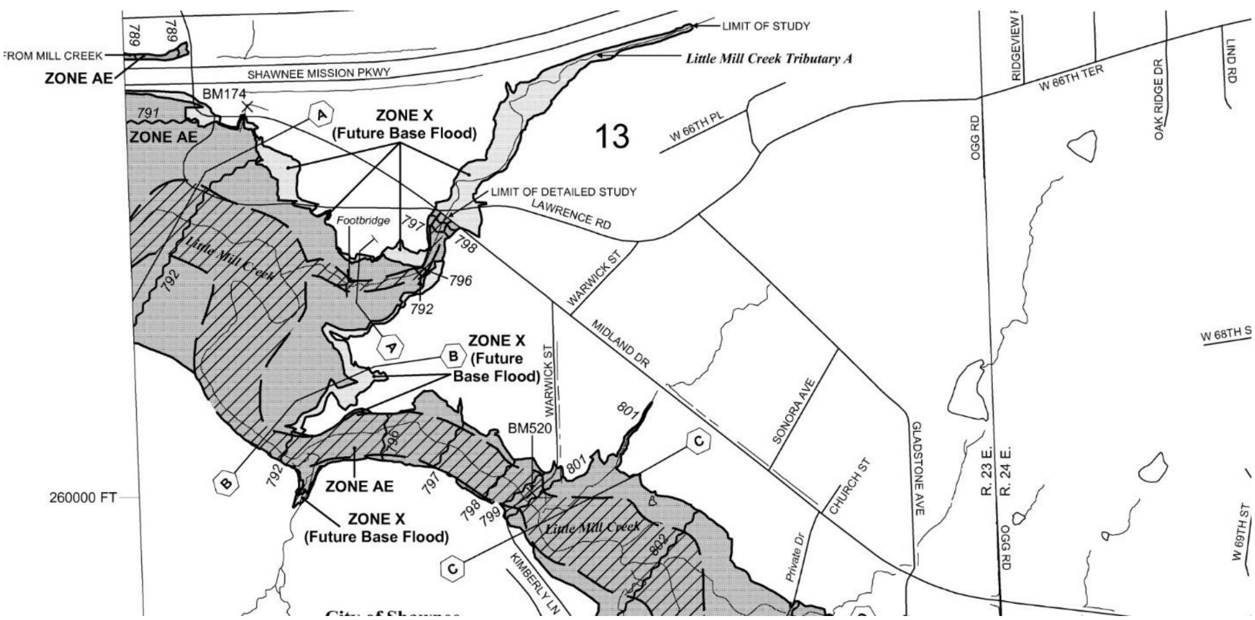


Figure 1. City of Shawnee Floodplain Map
(Flood Insurance Rate Map for Johnson County, Kansas. Map Number 20091 C0019. Revised 8/03/2009)

Evaluation of Best Practice No. 1

The City of Shawnee differs from the City of Lincoln in that floodplain maps for Shawnee include 1 percent annual chance floodplain and the future 1 percent annual chance floodplain. The future floodplain is used in place of the 0.2 percent annual chance floodplain boundary.

This is important for Lincoln to consider because the future 1 percent annual floodplain provides an indication of how the regulatory floodplain may be affected by future development. Having the future 1 percent annual chance floodplain available for reference would be a valuable planning tool and could help the city mitigate future flood damages. **Table 28** provides an evaluation of the future floodplains (urbanized conditions) BMP.

Table 28. Future Floodplains (Urbanized Conditions) Evaluation.

Future Floodplains (Unchanged Conditions)	Low	Low-Med	Med	Med-High	High	Information to support score
Cost to Implement				X		There is a cost for updating regulations and developing future-conditions hydrology.
Benefit			X			Even with increased regulatory standards some structures may be at risk; however, the risk should be greatly reduced.
Time to Realize Benefit				X		Realization of benefits may take longer as infrastructure is designed and improved to meet new design flows.
Complexity of Implementation				X		This requires code writing and engineering for future conditions.
Staffing Requirements		X				Existing staff can likely handle these updates.

Best Practice No. 2: Freeboard

The City of Shawnee also has a 2-foot freeboard requirement for new structures constructed in the floodplain. Residential structures must be elevated so that the lowest floor is 2 feet above the BFE. Nonresidential buildings must be elevated or floodproofed to the same elevation. Shawnee worked with the Johnson County Public Works and Utilities Department’s Stormwater Management Program to develop revised floodplain maps. The revised maps were adopted August 3, 2009, and include the future, or “built out” conditions, floodplain boundary as the shaded Zone X area on the FIRM.

Evaluation of Best Practice No. 2

Currently, the City of Lincoln has a 1-foot freeboard requirement for the lowest finished floor and requires new lots be graded entirely out of the regulatory floodplain.

The City of Shawnee differs from the City of Lincoln in that it requires 2 feet of freeboard for the lowest finished floor.

This is important for Lincoln to consider because a 2-foot freeboard requirement, like that of the City of Shawnee, for lowest finished floor would increase the factor of safety against flooding for proposed structures. **Table 29** provides an evaluation of the freeboard BMP.

Table 29. Freeboard Evaluation.

Best Management Practices (BMP) Evaluation Table						
Freeboard	**Low**	**Low-Med**	**Med**	**Med-High**	**High**	**Information to support score**
Cost to Implement			X			Regulation updates will require funding if beyond internal staffing capacity.
Benefit			X			The higher regulatory standards will protect more facilities and structures, over time.
Time to Realize Benefit				X		This will not protect existing development and structures; however, as development occurs, greater benefit will be realized.
Complexity of Implementation				X		Requires code writing and engineering to update development regulations and supporting data.
Staffing Requirements		X				Existing staff can likely handle this update.

Best Practice No. 3: Setback and riparian preservation

Shawnee has setback ordinances that require new structures to be outside the 1 percent annual chance floodplain by 30 feet, unless they are non-habitable, less than 120 square feet, and without concrete footings. Shawnee also provides a stream buffer zone of 100 feet on either side of the stream for watersheds with a drainage area from 160 to 5,000 acres. For watersheds with a drainage area greater than 5,000 acres, the setback increases to 120 feet on either side of the stream. Most building activities are prohibited in the stream buffer zone. Although the ordinances do not explicitly mention riverine erosion (also known as fluvial hazards and/or erosion zones), the setback ordinances are likely due, in part, to the definition and mapping of erosion zones. Riverine erosion, stream migration, and stream management have been identified by the State of Kansas as important elements in hazard planning and hazard mapping, as outlined in the "Kansas River and Stream Corridor Management Guide" (SCC 2020). Other states (Colorado, Vermont, and Washington) have developed similar guidelines.

Evaluation of Best Practice No. 3

Currently, the City of Lincoln has standards for protecting the riparian area by defining a minimum corridor, in which development is prohibited. The minimum corridor is a function of channel top width and depth, which means the minimum corridor width is tailored to the channel it protects.

The City of Shawnee differs from the City of Lincoln in that its buffer zone policy includes only two possible buffer zone widths to cover the entire range of possible contributing drainage areas. However, the State of Kansas has developed guidelines for determining stream setbacks that are based on the combined impacts of possible channel degradation, migration, and bank erosion. The setbacks developed based on evaluation of these factors are often incorporated into fluvial hazard mapping for the streams in the community.

This is important for Lincoln to consider because setbacks and riparian preservation can provide a broader level of protection for stream corridors. The City of Lincoln may want to perform a comparative analysis between the minimum corridor requirements and the setback requirements associated with fluvial hazard mapping to determine whether additional stream corridor protection is warranted. **Table 30** provides an evaluation of the setback and riparian preservation BMP.

Table 30. Setback and Riparian Preservation Evaluation.

BMP Evaluation Table						
Setback and Riparian Preservation	**Low**	**Low-Med**	**Med**	**Med-High**	**High**	**Information to support score**
Cost to Implement			X			Regulation updates will require funding if beyond the capacity of internal staffing.
Benefit			X			The higher regulatory standards will protect more facilities and structures over time.
Time to Realize Benefit				X		This will not protect existing development and structures; however, as development occurs, greater benefit will be realized.
Complexity of Implementation				X		Requires code writing and engineering to update development regulations and supporting data.
Staffing Requirements		X				Existing staff can likely handle this update.

SECTION 3 – FLOODPLAIN PRACTICE SUMMARY FOR LINCOLN AND THE SALT CREEK WATERSHED

The City of Lincoln and the LPSNRD have partnered together to reduce flooding and protect the citizens of Lincoln from the hazards associated with flooding. The many successes of this partnership are the result of a blended approach to floodplain management. The approach is founded on non-structural practices such as education and outreach, public policy, floodplain preservation, flood protection, and property buyouts. The non-structural measures are complemented by structural measures, where necessary, in the form of flood management and flood risk reduction projects. Combined, the non-structural and structural measures have resulted in substantial reductions in flooding and associated flood damages for the City of Lincoln and the surrounding area.

3.1 Review of Current Practices

Education and Outreach

Many people – even those who live or work next to a river or stream – are often not aware of the hazards associated with floodplains. That's why education and outreach efforts are so critical to a good floodplain management program. Together, the City of Lincoln and the LPSNRD have created several opportunities for the people of Lincoln to learn about floodplains, flood risks, policies related to floodplains, and best floodplain management practices. The City of Lincoln and the LPSNRD provide these opportunities through many communication platforms, which include:

- Websites – The websites for the City of Lincoln and the LPSNRD provide links to a wide range of information on floodplain and stormwater management. Provided in **Figure 2**.

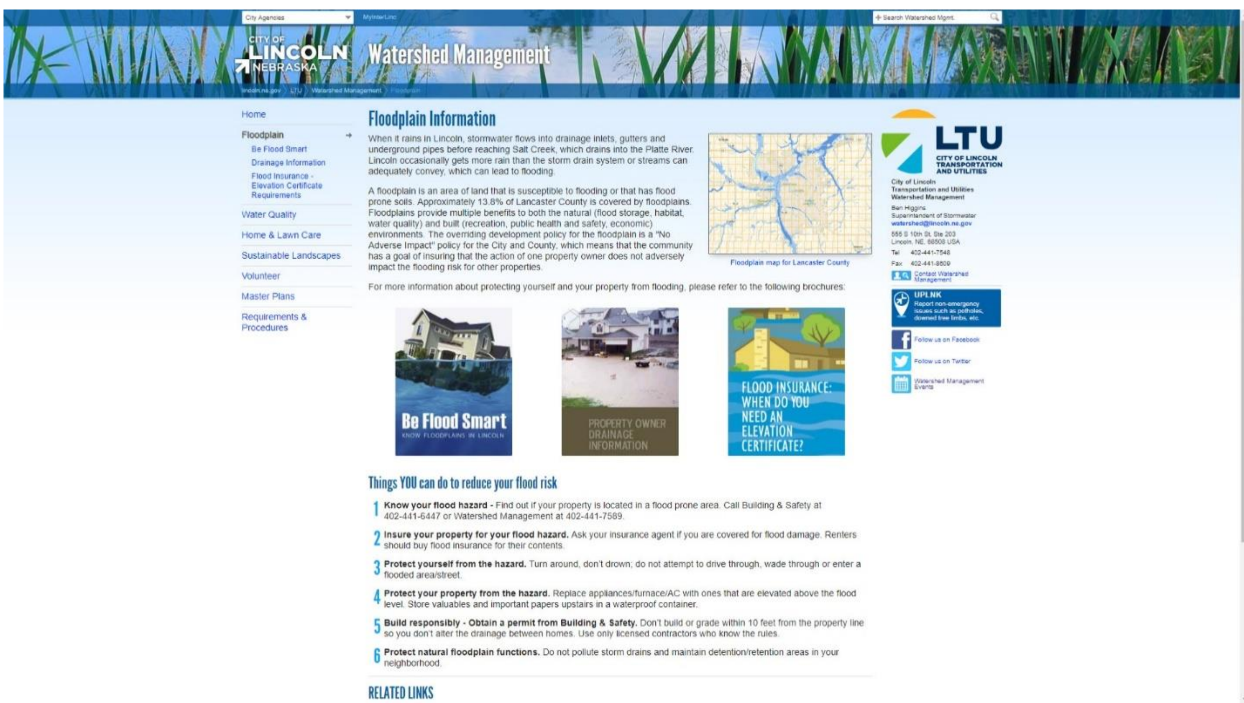


Figure 2. Website from Watershed Management – City of Lincoln, Nebraska.

- Festivals and Events – The City of Lincoln and the LPSNRD partner to put on or participate in several events that focus on floodplain and stormwater management, including the Earth Wellness Festival every March. Events like this provide people with the opportunity to learn about floodplains and stormwater management through lessons and interactive activities.

- Flood Warning Systems – The City of Lincoln and the LPSNRD provide flood warning information on their websites and to local radio and television stations. The City of Lincoln and the LPSNRD have many spotters who monitor potential flooding during severe weather conditions. The spotters also monitor the Salt Creek Flood Risk Reduction project (Salt Creek levees). A warning system is in place to provide texts and voicemail messages to residents in the event of flooding or road closures. The city and the NRD also keep in contact with the NWS to monitor weather conditions and stay aware of weather alerts.

- Public Meetings – The City of Lincoln and the LPSNRD typically hold public meetings on a project basis. The City of Lincoln and LPSNRD, often in coordination with the consultant for the project, provide more than just project-specific flood information. Public meetings create an opportunity to provide residents information about floodplain management in Lincoln and within the LPSNRD's boundary. Past projects like the Antelope Valley project, the drainage basin master plan projects, the Salt Creek floodplain map update, the levee projects, and many others included significant education and outreach efforts on floodplain and stormwater management in Lincoln.

Pros: The City of Lincoln and the LPSNRD provide a range of resources for the public and have very good floodplain education and outreach programs.

Cons: Preparing for flooding is not the top priority for many people until a flood event occurs. When flooding occurs, the primary focus must shift from education and prevention of flood damage to recovering from flood damage.

Policies

The City of Lincoln has a robust set of policies and standards for managing floodplains. These policies include management practices for three distinct regions of the city. The required practices for floodplain management in new growth areas (which are areas outside the corporate limits of the City of Lincoln and zoned AG or AGR as of May 10, 2004) exceed the minimum standards set forth by FEMA and the State of Nebraska minimum standards for floodplain management programs. The new growth area standards protect existing development by minimizing the adverse impacts that could be caused by future development. City of Lincoln floodplain standards also exceed FEMA and state standards in the designated Salt Creek flood storage areas (SCFSA), located on the landward side of the Salt Creek Flood Risk Reduction project (Salt Creek levees). The SCFSA each have limits on allowable floodplain fill for the properties within the SCFSA. These limits cap future floodplain creep and allow the floodway to remain confined to the Salt Creek levees. Elsewhere in Lincoln, state and federal minimum standards apply.

The City of Lincoln has experienced continued population and area growth since before the inception of the NFIP. This continued growth has often led to flooding issues for properties downstream of the developed areas. Increased downstream flooding prompted the completion of large flood management projects to mitigate the impacts of upstream development. The Antelope Valley project is one example of a large flood management project that was undertaken to counter the impacts of development in the watershed. Retrofitting large flood management projects in the developed urban environment is extremely expensive, presents many challenges, and often conflicts with existing infrastructure. To limit the potential for future development to adversely affect existing development, floodplain management practices – in the form of new growth area standards – were created.

No Adverse Impact (NAI) in New Growth Areas

The new growth area standards govern development in future urban areas around the perimeter of the existing city. The standards are based on the overriding NAI philosophy, which is an integral theme of many modern floodplain management strategies. The Mayor's Floodplain Task Force originally recommended incorporation of NAI philosophy into the floodplain regulations for the City of Lincoln.

No Net Rise and Compensatory Storage

The intent of the no net rise policy is to preserve flood conveyance along streams and drainageways. The concepts associated with the no net rise policy are shown in **Figure 3**. The policy requires that development within the floodplain or flood-prone area (area identified by the City of Lincoln as potentially flooded during a 1 percent annual chance flood event but outside the regulatory floodplain identified by FEMA) will not cause a rise in the 1 percent annual chance flood event water surface elevation of more than 0.05 foot. The 0.05-foot limit is sometimes referred to as the "de minimis" (meaning minimal, or insignificant) no rise limit standard for fill.

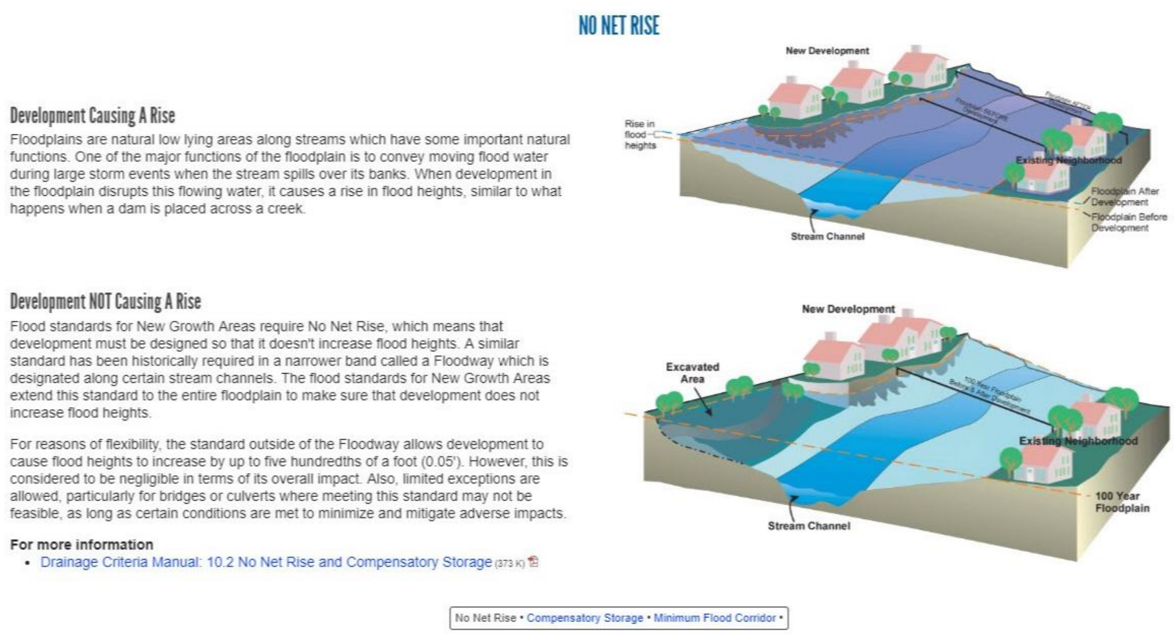


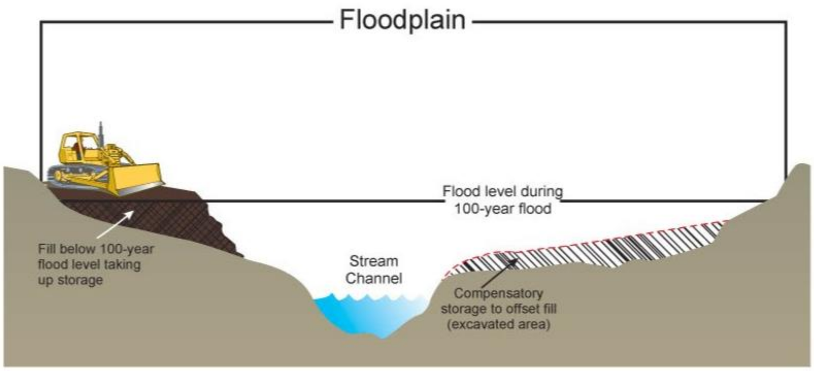
Figure 3. No Net Rise.
(City of Lincoln – Watershed Management)

The compensatory storage, or no net fill, policy is intended to conserve the volume of flood storage available within the floodplain. The conservation of storage is demonstrated by providing hydrologic modeling that shows the post-grading 50 percent, 10 percent, and 1 percent annual chance flow rates do not increase downstream of the affected reach. In the absence of hydrologic modeling, flood storage calculations can be used to demonstrate no net fill.

Exceptions exist for the no net rise and compensatory storage requirements for stream crossings, dams and other stormwater storage structures, and other minor projects. Within the regulatory floodway, the de minimis no net rise standard for fill or encroachment is superseded by the FEMA no rise standard, which requires the post-project elevation to be lower than or equal to the pre-project flood elevation (equal to the hundredths place, or 0.00 feet difference). Stream crossings of the floodplain or flood-prone area must undergo a sequencing process to avoid, minimize, and mitigate impacts, in that order of priority. The sequencing process seeks to identify an acceptable alternative for the crossing that minimizes increases in upstream flood heights. **Figure 4** illustrates the concept of compensatory storage.

COMPENSATORY STORAGE

Another major function of the floodplain is to store flood water that floods outside of the stream banks and is temporarily slowed down in the floodplain outside of the creek. One way to think about storage vs. conveyance of flood water is to relate it to traffic at rush hour. If water in a floodplain from a big storm were a bunch of cars heading in the same direction on a freeway at rush hour, the water being conveyed would be the cars still moving on the freeway in the faster inner lanes, and the water being stored would be the cars in the slower outer lanes.



Another analogy is helpful when you think about what happens when development impacts the floodplain's ability to store flood water. Imagine that the floodplain during a large storm is like a bathtub filled to the brim with water. If you put a big brick in the tub, it will displace the water, which will spill onto the floor. The same thing can happen with development in the floodplain. Fill or other structures in the floodplain displace flood water just like a brick displaces water in a tub, and the displaced water moves onto another property.

Compensatory Storage is a standard for New Growth Areas which preserves the ability of the floodplain to store water. Compensatory storage means that loss of flood storage due to buildings or fill dirt in the floodplain is compensated for by providing an equal volume of storage to replace what is lost. In other words, if you bring one bucket in you need to take one bucket out. Limited exceptions are allowed as described in the section on 'No Net Rise.'

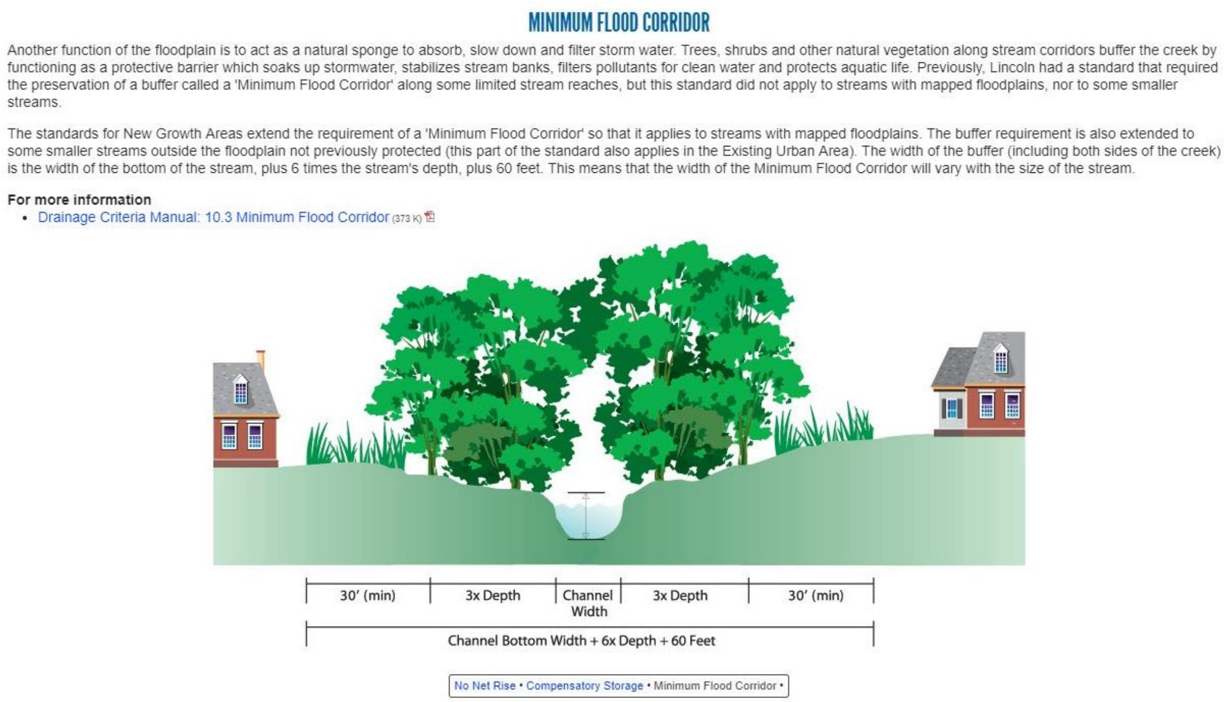
For more information
- Drainage Criteria Manual: 10.2 No Net Rise and Compensatory Storage (373 K)

No Net Rise • Compensatory Storage • Minimum Flood Corridor •

Figure 4. Compensatory Storage.
(City of Lincoln – Watershed Management)

Minimum Corridor

The minimum corridor policy is included in the new growth area standards to preserve the stream corridor and to minimize impacts to the stream channel and the vegetation. The minimum corridor policy protects a width, generally centered along the streamline, of 60 feet, plus the channel bottom width, plus six times the channel depth, as shown in **Figure 5**. Within this corridor, encroachments are only allowed for certain purposes (stream channel stabilization and enhancement, roadway or trail crossings, utilities or utility crossings, stormwater storage facilities). Impacts to the channel or vegetation must be mitigated, as prescribed in Chapter 10 of the City of Lincoln Drainage Criteria Manual (City of Lincoln Public Works and Utilities Department 2004).



MINIMUM FLOOD CORRIDOR

Another function of the floodplain is to act as a natural sponge to absorb, slow down and filter storm water. Trees, shrubs and other natural vegetation along stream corridors buffer the creek by functioning as a protective barrier which soaks up stormwater, stabilizes stream banks, filters pollutants for clean water and protects aquatic life. Previously, Lincoln had a standard that required the preservation of a buffer called a 'Minimum Flood Corridor' along some limited stream reaches, but this standard did not apply to streams with mapped floodplains, nor to some smaller streams.

The standards for New Growth Areas extend the requirement of a 'Minimum Flood Corridor' so that it applies to streams with mapped floodplains. The buffer requirement is also extended to some smaller streams outside the floodplain not previously protected (this part of the standard also applies in the Existing Urban Area). The width of the buffer (including both sides of the creek) is the width of the bottom of the stream, plus 6 times the stream's depth, plus 60 feet. This means that the width of the Minimum Flood Corridor will vary with the size of the stream.

For more information
- Drainage Criteria Manual: 10.3 Minimum Flood Corridor (373 K)

Figure 5. Minimum Flood Corridor.
(City of Lincoln – Watershed Management)

Prior to encroachment in the minimum corridor, and as with stream crossings, a sequencing process must be followed for minimum corridor encroachments to demonstrate the encroachment is necessary and that the impacts to the stream channel were avoided, where possible, and were minimized and mitigated elsewhere. The sequencing process is like the process the USACE uses for impacts to waters of the United States under Section 404 of the Clean Water Act (EPA 2020).

The new growth area standards also include recommended (nonmandatory) practices, such as developing clusters of conservation easements, constructing wetlands, installing filter strips, implementing grassed swales, using porous pavement, and creating stream buffers. Guidelines are provided in the standards for development and building construction practices and stream stability criteria (City of Lincoln Public Works and Utilities Department 2004). These practices help with floodplain management, and they can provide significant water quality benefits by limiting erosion from development sites.

Pros: The new growth area policies preserve the natural and beneficial function of the floodplains while maintaining flexibility in grading the floodplain to provide flood storage and conveyance. The minimum corridor standards protect and preserve the channel and riparian corridor from adverse impacts. The policies satisfy the NAI philosophy.

Cons: Even with no net rise and compensatory storage, floodplain regrading can lead to changes in floodplain extents. These changes can be difficult to track over time and may create a requirement for frequent letter of map change (LOMC) submittals. Over time, it may be difficult to determine the current regulatory floodplain and floodway boundaries, as multiple LOMCs may have been granted for the same stream reach.

Local Detention Requirements

The City of Lincoln requires proposed developments to detain peak runoff rates from the site for the 50-percent, 10-percent, and 1 percent annual chance flood events to predevelopment runoff rates. The detention requirements prevent increased discharges, flood elevations, and floodplain extents for downstream floodplains and flood-prone areas. Requiring detention for the range of events, especially when combined with water quality practices, helps maintain the hydrologic flow regimes of downstream water bodies. The range of flows remains consistent as development occurs.

Pros: City of Lincoln detention requirements prevent increases to downstream flood risk and flood damages by preventing increased runoff from new development. The City of Lincoln requirements help maintain the predevelopment hydrologic regime.

Cons: Detention cells must be properly maintained to function as intended. Typically, the private property owner or homeowner's association is responsible for the maintenance and upkeep of the detention cell. The City of Lincoln is responsible for inspecting the large number of detention cells within the city. Inspection and enforcement of maintenance requirements can be time-consuming and difficult.

Post-construction Stormwater BMPs

The City of Lincoln (with assistance from the LPSNRD and others) has implemented a robust set of regulations for managing stormwater runoff from development sites. The standards require all new development and all redevelopment sites to provide stormwater management practices on the sites that treat runoff from water quality events (City of Lincoln Public Works and Utilities Department 2014). The primary intent of the stormwater management practices is to remove pollutants from site runoff and to improve water quality of receiving streams. Disconnecting the impervious areas in a development, providing vegetated water quality features for retention and infiltration or evapotranspiration of runoff, and slowing runoff down all help diminish potential flooding downstream.

Pros: Stormwater BMPs reduce pollutants from site runoff and help improve water quality in downstream ponds, lakes, and streams.

Cons: Stormwater BMPs require maintenance and upkeep for proper function. Typically, the maintenance and upkeep are the responsibility of the private property owner or homeowner's association. The City of Lincoln is responsible for inspecting stormwater BMPs in Lincoln. Inspection and enforcement of maintenance requirements can be time-consuming and difficult.

Salt Creek Flood Storage Areas (SCFSA)

The City of Lincoln, in coordination with the LPSNRD and the Nebraska Department of Natural Resources (NeDNR), developed a detailed flood routing model for Salt Creek that includes the reach of Salt Creek from the upper to lower limits of detailed study. The model includes dynamic routing of runoff hydrographs from Salt Creek tributaries and drainage areas. The model includes detailed analysis of the flood storage areas landward of the Salt Creek Flood Risk Reduction project, or Salt Creek levees. The levees stretch from Calvert Street at the upstream end to Superior Street at the downstream end and provide protection from Salt Creek flooding through a mostly urbanized area of Lincoln. FEMA does not accredit or recognize the levees as providing protection from the 1 percent annual chance flood event. The flood storage areas landward of the levees are identified as SCFSAs.

The SCFSAs were developed to limit fill in the floodplain, on the landward side of the Salt Creek levees. The limits on floodplain fill help preserve flood storage and limit floodplain creep. The limits on floodplain fill differ by storage area and were determined using the detailed flood routing model. Reductions to floodplain storage lead to reductions in the ability of the Salt Creek floodplain to attenuate flood flows along Salt Creek. The resulting increases in Salt Creek flows lead to higher surcharges within the regulatory floodway. The floodplain fill limits were set so that the floodway encroachment limits can be kept at the Salt Creek levees, and the Salt Creek flows will remain low enough that floodway surcharge will not rise more than 1 foot.

Pros: The results of the detailed Salt Creek models correlated well with the runoff hydrographs from the U.S. Geological Survey (USGS) stream gages for historical events, including the May 2015 event (USGS 2020). Precipitation gage records from Lincoln and from Lancaster County generally indicated the storm event was close to a 1 percent annual chance flood event. The USGS Salt Creek Gage 06803500 at 27th Street recorded a peak flow of 34,800 cubic feet per second (cfs). The peak flow in the model for the 1 percent annual chance flood event is 34,070 cfs. The hydrograph shape and duration also seemed to be reasonably similar between the model and the gage data. The Salt Creek model predicts the flows will be mostly contained by the Salt Creek levees during the 1 percent annual chance flood event. The USGS gages and the anecdotal evidence suggest the 2015 flood was mostly contained within the levees. Because the model results are consistent with observed conditions and gage data, we have confidence the Salt Creek model provides realistic results. This means we can have confidence in the established flood storage limits of the SCFSA. It also means we can confidently use the Salt Creek models as predictive tools for future storms.

Cons: Floodplain fill in the SCFSAs must be tracked over time. Large projects, which include both floodplain fill and flood storage mitigation, can become complicated. Floodplain storage calculations will often have to be coordinated across multiple properties or parcels. Allowable fill differs from SCFSA to SCFSA, and some owners may be more limited in how much floodplain fill they can place, when compared with other owners.

Freeboard Requirements

The City of Lincoln requires residential development in or adjacent to the FEMA floodplain to have the lowest finished floor elevated at least 1 foot above the BFE. Nonresidential development must be elevated or floodproofed to 1 foot above the flood elevation. In most cases, the city requires a letter of map revision (LOMR) prior to issuing a building permit. The City of Lincoln requires an executed building restriction agreement before the city approves the LOMR application. The building restriction agreement requires any future building on the site to be constructed in accordance with the floodplain regulations, even if the area is removed from the floodplain by the LOMR. The City of Lincoln also requires that proposed lots adjacent to the floodplain have the lowest finished floor elevations set 1 foot above the BFE. New development in an area where the FEMA floodplain or flood-prone areas have not been identified must be designed so the lowest opening elevation of adjacent buildings is protected to 1 foot above the calculated 1 percent annual chance flood profile. The building restriction agreement and low opening requirements both exceed state and federal minimum standards and provide additional protection for new development.

Pros: Standards for City of Lincoln extend beyond the limits of the FEMA floodplain and include minimum elevations for areas upstream of the FEMA mapping or areas where FEMA mapping has not occurred.

Cons: Local drainage can also be a source of flooding for buildings and other structures. It is not practicable to set minimum finished floor or minimum opening elevations for every property.

FEMA Community Rating System (CRS)

The City of Lincoln voluntarily participates in the CRS and is rated as a Class 5 community. The CRS rating is the result of the policies, projects, and actions that the City of Lincoln and the LPSNRD have worked on together for decades to implement. Because Lincoln is a Class 5 community, property owners within an SFHA in Lincoln are eligible for a 25 percent discount on their flood insurance premiums. Property owners outside the SFHA can obtain a 10 percent discount on their preferred risk flood insurance premiums.

Pros: Nearly all the practices described in this study contribute to the Class 5 CRS rating for the City of Lincoln, which entitles residents to a 25 percent reduction in their flood insurance premiums. Lincoln is the highest-rated community in the State of Nebraska.

Cons: Although flood insurance premiums are reduced, only a few of the practices described herein directly remove properties from the regulatory floodplain: buyouts and/or relocations, and flood management or flood risk reduction projects. Elevating or floodproofing can provide complete protection from the regulatory flood, but elevated or floodproofed structures are still considered to be "in the floodplain" for flood insurance purposes.

Floodplain Preservation

The City of Lincoln and the LPSNRD both incorporate open space preservation in their floodplain management strategies. Open space preservation is more difficult to implement in developed areas, but it continues to be an extremely effective best practice for floodplain management in Lincoln, because it keeps infrastructure away from flood risk and uses the natural flood-mitigating properties of floodplains (flow attenuation, infiltration, etc.). The City of Lincoln has done an excellent job implementing open space preservation and receives over 40 percent of its CRS points from open space preservation efforts. In many locations throughout the city, the City of Lincoln and the LPSNRD have gone beyond preservation and have enhanced open spaces by constructing wetlands and water quality measures within the open spaces. Enhancement of these open space areas to increase flood storage helps attenuate flood flows in Lincoln and reduce flood extents along Salt Creek.

Open space preservation is a key component of the city's floodplain management strategy. As part of its CRS efforts, the city has purchased or obtained nine parcels of land since 2013. Many large open spaces within the floodplains of Lincoln are already floodplain preservation sites. Local examples of these include:

- Seacrest Range area along Middle Creek
- Wilderness Park (shown in **Figure 6**), Sawyer Snell Park, Hayward Park, Boosalis Park, and Warner Wetlands along Salt Creek
- Tierra/Briarhurst and Pine Lake Park along Beal Slough
- Antelope Park along Antelope Creek
- Oak Creek Dog Run and airport properties along Oak Creek
- Roper Park along Lynn Creek
- Shoemaker Marsh, Arbor Lake, and King Saline Wetlands along Little Salt Creek

Preserving floodplain storage in the above open spaces is relatively inexpensive compared to acquiring new open space. The above open spaces are publicly owned areas that already provide the natural and beneficial function of a floodplain. New open spaces must be acquired through purchase and, in largely developed urban areas, often involve the loss of economic development potential and property tax revenue. Finding the site with the greatest flood storage potential with the lowest cost requires a careful examination of topography, existing development patterns, and flood elevations.

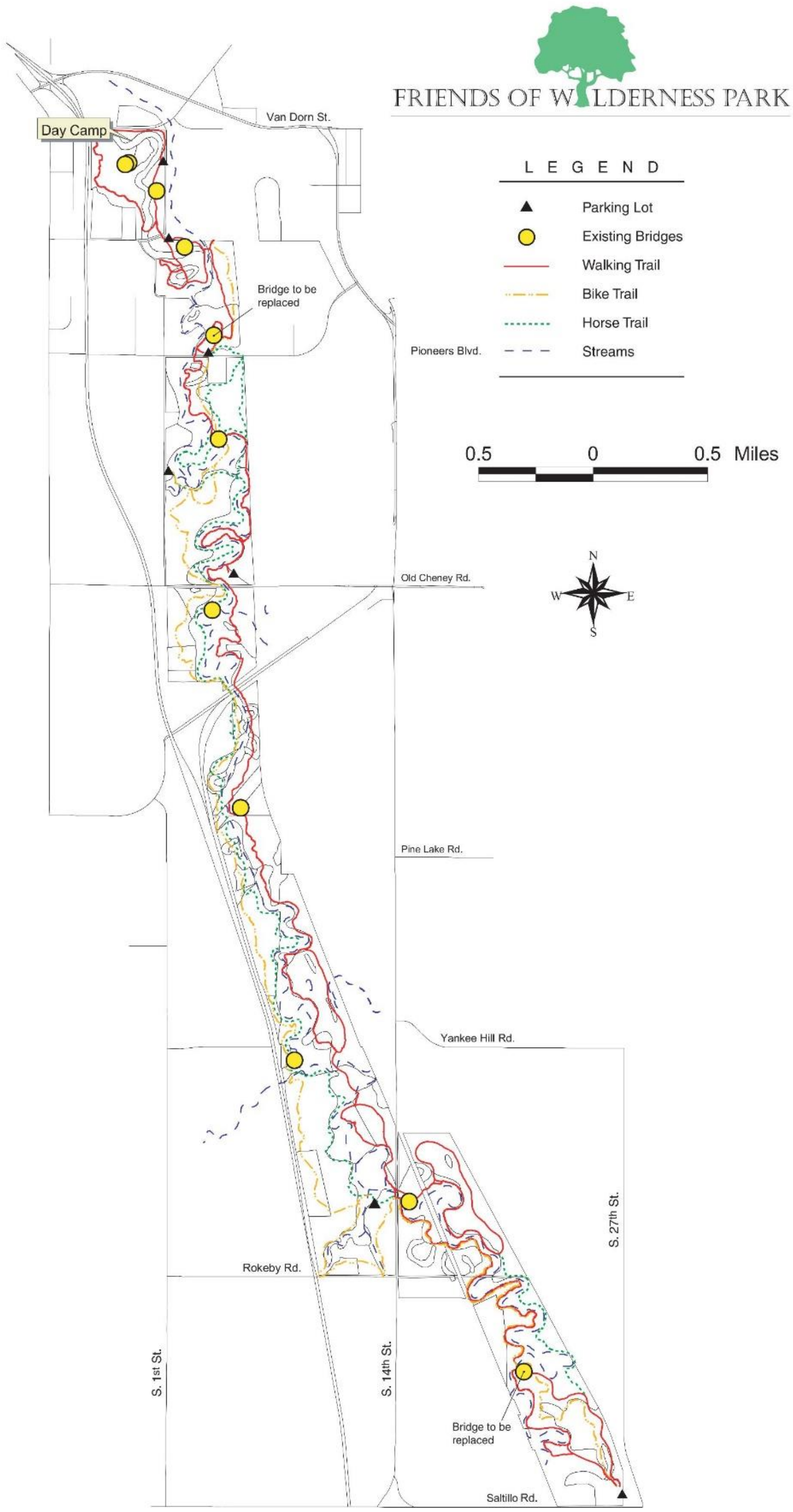


Figure 6. Wilderness Park – An Example of Open Space Preservation.
(Friends of Wilderness Park)

The LPSNRD has been a partner in many of the above areas and owns areas like the Whitehead Saline Wetland along Little Salt Creek, Lincoln Saline Wetlands Nature Center near Capitol Beach Lake, and the Marsh Wren Saline Wetland Community Management Area along Salt Creek.

Pros: The City of Lincoln and the LPSNRD work together to provide excellent open space preservation in the Salt Creek watershed and the tributary watersheds.

Cons: Opportunities for additional open space preservation in the Salt Creek floodplain, in Lincoln, are limited. Enhancing the existing open spaces to increase flood storage may be a more viable, or beneficial, option. It may also be beneficial to focus on potential Salt Creek flood storage conservation areas outside the city limits, where larger tracts of floodplain conservation area can be obtained.

Flood Protection and Buyouts

Past flood protection and buyouts in Lincoln have typically been project specific. The Antelope Valley project included buyout of 46 homes and businesses. Two of the houses were historical structures. Those houses were relocated and elevated for compliance with floodplain regulations. The Beal Slough Flood Reduction project included the construction of flood protection berms to protect two critical facilities within the Beal Slough floodplain. The Central Utility Plant at the Nebraska State Penitentiary (NSP) is protected by a berm that surrounds the facility. Upstream, several businesses, including a large cold food storage facility, are also protected by a berm that prevents Beal Slough overflows from flowing to the north and inundating the buildings.

Pros: Buyouts and/or relocations eliminate a structure from the regulatory floodplain. Flood protection, or floodproofing, can provide complete protection from the regulatory flood. Targeted buyout programs, focusing on structures that are most likely to flood or are most likely to experience significant damage during a flood, can be cost-effective tools for reducing potential flood damages.

Cons: Larger scale buyouts and/or relocations can be prohibitively expensive. As noted, for flood insurance purposes, floodproofing doesn’t remove structures from the regulatory floodplain, and it can be expensive. Often, it can only be justified for high-value or critical structures.

Flood Risk Reduction Projects

Regional Detention

The Salt Creek watershed has 10 large flood management dams, built by the USACE, and 66 smaller dams, controlled by the LPSNRD. Branched Oak Lake and its dam, shown in **Figure 7**, is the largest flood management reservoir in the basin. According to the NeDNR database, there are 79 NRCS dams (74 are regulated) in the portion of the Salt Creek watershed that contribute runoff to the Salt Creek levee system (Upper Salt Creek, Cardwell Branch, Haines Branch, Middle Branch, Oaks Creek, Southeast Upper Salt Creek, Beal Slough, Antelope Creek, and Deadmans Run). The NRCS and the LPSNRD installed these projects from the 1960s through the 1980s. The LPSNRD constructed 10 additional structures in the Steven’s Creek watershed, which has its confluence with Salt Creek downstream of the Salt Creek levee system.

The dams reduce peak flows along Salt Creek through Lincoln by controlling their respective contributing drainage areas and limiting peak runoff rates from those areas. The dams, most of which were constructed in the 1960s, control a significant portion of the Salt Creek watershed. The confluences of South Salt Creek (including the Hickman Tributary to Salt Creek), Southeast Upper Salt Creek, and Cardwell Branch are all upstream of the Salt Creek levees. The confluences of Haines Branch, Middle Creek, and Oak Creek are all located in the leveed reach of Salt Creek. The existing dams in these tributaries control approximately 282 square miles, or

44 percent of the 610-square-mile total drainage area from the tributaries. The dams reduce peak flows on Salt Creek significantly; however, more than half of the total Salt Creek drainage area upstream of the confluence Oak Creek remains uncontrolled.

Large, high-hazard dams provide most of the flood management on the tributaries. Branched Oak, Pawnee, Wagon Train, Stagecoach, Conestoga, Yankee Hill, Twin Lakes, Olive Creek, and Bluestem are all large, high-hazard dams, designed by USACE. Together, they control runoff from approximately 214 square miles, or 35 percent of the approximately 610 square miles of the tributaries to Salt Creek. The remaining 9 percent of the tributary drainage areas are controlled by smaller dams.

Figure 7. Branched Oak Lake – One of 10 Large Flood Management Dams Built by the U.S. Army Corps of Engineers (USACE).

Levees

As described above, the Salt Creek Flood Risk Reduction project (Salt Creek levees) as shown in **Figure 8**, extends from Calvert Street at the upstream end to Superior Street at the downstream end. The project was also constructed in the 1960s and includes seven separate levee systems with a total length of approximately 13.5 miles. The LPSNRD is the sponsor of the levees and is responsible for maintenance and upkeep. As reflected in the FIRMs for the City of Lincoln, the Salt Creek floodplain is not confined to the levees. FEMA does not accredit the levees as providing protection from the 1 percent chance annual chance flood event. The levees do not have the necessary freeboard to meet FEMA standards for accreditation. But the levees do provide substantial flood protection benefits to the City of Lincoln. Since construction, the levees have prevented approximately $99 million in property damages. In the flood event of early May 2015, the flood flows were largely contained within the levees. The Salt Creek flood records indicate the flood stage of Salt Creek in May 2015 was the highest since 1908, more than one century earlier (Hicks 2015).

Figure 8. Salt Creek Flood Risk Reduction Project.

Urban Flood Management Projects

Space is limited in the urban environment. So, large flood management projects within the City of Lincoln have been primarily focused on increasing conveyance by constructing channel improvements and larger culverts/bridges. Some of the larger flood management projects in Lincoln are summarized below.

Antelope Valley

The Antelope Valley Flood Risk Reduction project provides flood management and transportation and urban renewal benefits to the area along the east end of downtown Lincoln. The flood management portion of the project involved constructing an overflow diversion channel to convey overflows from the existing closed drainage system through the project area. The overflow channel, combined with the existing drainage system, has the capacity to convey the 1 percent annual chance flood event without inundating areas outside the overflow channel.

The project removed more than 400 acres and 835 structures from the floodplain. The project area has been transformed with a linear park (Union Plaza, shown in **Figure 9**) along the overflow channel, better connectivity for pedestrian and vehicle traffic, and urban renewal in the form of new business and housing within the project area. The combination of flood management benefits with transportation and economic development benefits led to an overall benefit-to-cost ratio of greater than 3 to 1.

Figure 9. Union Plaza.

Upper Antelope Creek

This project was a follow-up to the Antelope Valley project and was designed to eliminate flooding in the fully developed watershed upstream of Antelope Valley. Numerous alternatives for flood risk reduction were analyzed throughout the project reach, including offline storage, channel improvements, and replacement of existing bridge structures. Working with the LPSNRD, the City of Lincoln, watershed residents, and other stakeholders, plans were developed for the alternative deemed the most cost-effective.

The resulting project included the construction of channel improvements along Antelope Creek from "A" Street downstream to 27th Street, improvements to the hydraulic capacity of the "A" Street bridge opening, and construction of detention storage on a tributary to Antelope Creek.

The constructed solutions provided flood reduction benefits to hundreds of home and property owners. The project confined the floodplain to within the channel banks through most of the project reach. The project also included improvements to the area's trails and to the adjacent Lincoln Children's Zoo.

Beal Slough

Several alternatives were evaluated to reduce flood elevations and floodplain extents along Beal Slough near the NSP. The project also resulted in protection of commercial and industrial facilities upstream of the NSP. The City of Lincoln, the LPSNRD, and the project's partners worked together to develop a preferred alternative for flood risk reduction and flood protection for these critical facilities. The preferred alternative was incorporated into a FEMA HMGP application. An HMGP grant was obtained, and the grant funded 75 percent of the $5.3 million project. The project involved removing an existing railroad bridge, removing and replacing an access road bridge on the NSP property, removing and replacing the 14th Street bridge over Beal Slough, and constructing flood protection berms to protect the NSP Central Utility Plant and the commercial and industrial facilities upstream of the NSP. The flood risk reduction project and the flood protection berms help protect more than $100 million in property and keep critical facilities free from flooding during the base flood.

Deadmans Run Flood Risk Reduction Project

The City of Lincoln and the LPSNRD (local sponsors) partnered with the USACE on a study to evaluate possible flood risk management solutions along Deadmans Run (USACE 2018). Flooding in the Deadmans Run basin can cause widespread residential and commercial property damage in northeast Lincoln. The study evaluated several alternatives for flood risk reduction and a preferred alternative was selected (see **Figure 10**). It included widening the channel and completing improvements to the channel from Cornhusker Highway upstream to just east of 48th Street (approximately 1.4 miles), replacing existing concrete mat and gabions with riprap sized to mitigate streambed erosion, and constructing a flume under the BNSF Railroad bridges. The selected project cost was $14.2 million, of which the USACE will pay approximately $9.2 million and the local sponsors will pay the remainder. The project will reduce risks for 487 structures in the Deadmans Run 1 percent annual chance floodplain, resulting in a net annual benefit of nearly $900,000 and a benefit-to-cost ratio of 2.69 to 1. In addition to the USACE project, the local sponsors (with the University of Nebraska-Lincoln) are removing and replacing the 33rd Street, 38th Street, and 48th Street bridges over Deadmans Run and constructing a detention cell for a tributary to Deadmans Run. The new bridges will span the improved channel, constructed by the USACE. The cost of the additional, local project work is approximately $10 million. The local project work is not included in the benefit-cost ratio for the federal project.

Figure 10. Deadmans Run Flood Risk Reduction Project.

The projects described above demonstrate the ability of flood risk reduction projects (structural measures) to successfully reduce flooding in the Salt Creek watershed. The existing dams reduce peak runoff rates in Salt Creek. The levees provide protection for the areas landward of the Salt Creek levee system. Listed below are some pros and cons of flood management / flood risk reduction projects.

Pros: Flood management, or risk reduction, projects can remove large numbers of structures or properties from the regulatory floodplain. These projects can substantially reduce risk for structures or properties, even if they are not removed from the regulatory floodplain. Other benefits, such as those for water quality, wildlife habitat, recreation, streamflow augmentation, and emergency water supply can be incorporated into flood management projects.

Cons: Flood management projects can be expensive, particularly when retrofitted into built, urban environments. These projects also have a high potential for conflicts with other infrastructure. Again, the risk of conflict is higher in the urban environment. Flood management projects in rural areas upstream from Lincoln will most likely require the acquisition of property rights for large areas to provide flood storage and attenuation. When incorporating other benefits into flood management projects, the requirements for those benefits may conflict with the requirements of the flood management project.

3.2 Summary

The City of Lincoln’s floodplain management practices include a blend of both non-structural and structural measures. The city’s floodplain regulations provide a framework for protecting future development and minimizing potential flood impacts to the built environment. The regulations were built upon state and federal minimum standards, and additional measures have been added that have their roots in the NAI philosophy. The NAI practices conserve the beneficial functions of the floodplains but still allow flexibility regarding the configuration of the post-development floodplain. Practices such as buyouts, flood protection, and structural flood management measures are typically implemented on a project basis. The combined efforts of the City of Lincoln and the LPSNRD have garnered the City of Lincoln the highest CRS rating (Class 5) in the State of Nebraska.

SECTION 4 – SUMMARY OF NATIONAL AND LOCAL FLOOD HISTORY

A Brief History of Levees in the United States

Levees play an important role in flood risk reduction in many communities across the United States. Historically, development focused near and around waterways to take advantage of the natural resource whether it be for agriculture, industrial, transportation, or infrastructure uses. This desire to be close to the very versatile resource in the past has now placed communities in flood-prone locations. The need to protect against flooding was recognized early on and has been an ongoing issue with the first levee in the United States being built by the French around New Orleans between 1717 and 1727 (Mohr and Powell 2007). A brief history of levee construction and regulation over the last century is described below.

- Initial federal legislation was designed to reduce flood damage along the Mississippi, Ohio, and Sacramento rivers (Ransdell-Humphreys Flood Control Act of 1917). This act directed local communities to contribute half of the cost to construct levee projects, and it required the communities to maintain the levees upon completion, which unfortunately created many unregulated and poorly constructed levees.
- The next major law increased public awareness and advanced flood control theory (Flood Control Act of 1928). It also authorized the USACE to design and construct flood control projects, with communities retaining the post-construction operation and maintenance of the flood control projects. A key provision was that the federal government could not be held liable for flood damages.
- Subsequently, congress recognized flood control as a national priority and authorized the USACE and other government agencies to construct flood control structures (Flood Control Act of 1936). It also committed the federal government to protecting people and property.
- In 1986, FEMA established detailed requirements to guide the evaluation of levee systems and to map areas landward of the levee systems on FIRMs (NFIP 1986).
- More recently, congress sought the collection and documentation of basic information relative to federal levees (National Levee Safety Act of 2007). This documentation included an inventory of federal levees, inspection reports, and assessments.
- In 2011, FEMA revised its approach to precisely reflect the impact of nonaccredited levees on flood hazards and their associated risks (FEMA 2011a). This removed the mapped flood protection from levees that have not demonstrated that they will provide protection for at least the 1 percent annual chance flood.

4.1 Review of Past Studies

Salt Creek Levee History

Salt Creek was channelized in sections between Lincoln and Ashland dating from approximately 1917 to 1942, with most of the work occurring in the 1930s. Over time, the channelization of Salt Creek created large spoil piles of excavated and dredged material along the banks of Salt Creek. From 1964 through1968, the USACE constructed the Salt Valley project, which consisted of a system of levees along Salt Creek and dams on the tributaries. The levees along Salt Creek were approximately 13.5 miles long. The levees were established by reshaping the spoil piles of excavated and dredged material that were already present along a large portion of Salt Creek and excavating additional material from within the channel area to establish the desired width and depth.

As part of the Salt Valley project, 10 dams were built: Branched Oak, Pawnee, Twin Lakes, Conestoga, Holmes, Yankee Hill, Bluestem, Stagecoach, Wagon Train, and Olive Creek.

Levees were originally designed to contain the 1 percent annual chance rainfall event with 2 feet of freeboard; however, a later study of the area used revised data and deemed that levees did not meet the minimum freeboard requirements.

The flood records for Salt Creek extend all the way back to the founding of the City of Lincoln. There have been more than 100 flood events recorded on Salt Creek over the past 120 years, including 17 major events and two events that were considered catastrophic (USACE 1983).

Studies of Salt Creek

A 1954 comprehensive plan for water management in the Salt Creek watershed led to the congressional authorization of the Salt Creek and Tributaries Flood Control project in Nebraska (Flood Control Act of 1958; USACE 1994). The project included construction of the reservoirs and a levee system along Salt Creek as described above.

1967 – Floodplain Information: Metropolitan Region, Lincoln, Nebraska; Volume III, Summary Report, Little Salt Creek, Oak, Salt, and Stevens Creek, Salt Creek Basin, September 1967, USACE – Omaha District (USACE 1967)

Floodplain information was developed for the Salt Creek basin and included hydrology, hydraulics, and floodplain mapping for the 1 percent annual chance flood. The floodplain information showed that the existing flood management project protected Lincoln from the 1 percent annual chance flood. The only area not shown as being protected from the 1 percent annual chance flood was the area between Superior Street and Calvert Street along the left bank of Salt Creek from its confluence with Oak Creek to “O” Street.

1983 – Salt Creek at Lincoln, Nebraska; Section 216 Study, November 1983, USACE – Omaha District (USACE 1983)

The purpose of this study was to reevaluate the flood problems along Salt Creek; evaluate the dispersive clays problem; formulate potential measures that would reduce flood damages or improve the level of flood protection provided by the existing project; and evaluate the economic feasibility of and federal interest in such measures. Several alternative measures were considered including channel improvements and bridge replacements to determine potential flood risk reduction benefits. None were found to be economically feasible, and most were infeasible by a very wide margin. Consequently, no federal action was recommended.

1983 – Flood Insurance Study for Lincoln, Nebraska; and Subsequent Revisions, 1983 – 2013, Federal Emergency Management Agency – National Flood Insurance Program (FEMA 1983-2013)

The flood insurance study (FIS) is the compilation and presentation of flood risk data for Salt Creek. There have been five revisions to the FIS, with the latest revision in April 2013.

1985 – Treatment of Dispersive Clay Erosion, Salt Creek and Tributaries, Lincoln, Nebraska; October 30, 1985, USACE – Omaha District (USACE 1985)

In 1980, to test treatment of the dispersive clay at Salt Creek, the USACE Omaha district used two principle tests for identification of dispersiveness: the Soil Conservation Service’s pin hole test and the pore water chemistry test. The principle treatments included various additives being mixed into the soil surface including alum, kiln dust, lime, fly ash, and green manure. All the treatments used, except for the green manure, showed some signs of reducing the dispersiveness of the clay at the test section. The recommended treatment measures from the 1985 report included the use of kiln dust for surface treatment on the levees and berms and a 2 percent lime-treated soil mixture to form a cut-off trench at the badly eroded channel banks. Alum was the most effective treatment but at the time was considered too expensive to use for large-scale remediation. Although not tested for the report, untreated nondispersive clay was recommended to fill in small dispersive holes. A nondispersive clay cap was not tested as part of this analysis.

1987 – Salt Creek at Lincoln, Nebraska; Section 216 Study, December 1987, USACE – Omaha District (USACE 1987)

A follow-up study to the 1983 Section 216 Study was conducted and included evaluation of flood damage reduction measures (mostly raising existing levee segments) and levee stability measures. This study also included a resurvey of the Salt Creek levee system using ground-penetrating radar to identify dispersive clay void distribution in the levees. This study did not find feasible solutions to restore 1 percent annual chance flood event level protection with the required 3 feet of freeboard throughout the levee system. However, it did find several incremental solutions that were economically feasible, and it recommended them for further study.

1990 – Salt Creek Levees at Lincoln, Nebraska; Section 205 Study, October 1990, USACE – Omaha District (USACE 1990)

This report presented the results of a reconnaissance-level study of the flood and erosion problems along Salt Creek and described and evaluated potential solutions to those problems. The recommended plan would provide incremental levels of protection with 3 feet of freeboard along four specific reaches of the existing Salt Creek levee and would provide channel improvements.

The plan recommended placing a 2.5-foot-thick lining of compacted nondispersive clay on the riverward slope of the levee system. The design would also include berm and toe protection to a width of 10 feet. The existing levee would be stripped of vegetation and ripped to a depth of about 1.5 feet and recompacted prior to placement of the clay lining material. The principle was to protect the dispersive clay in the levee embankment from continuing dispersive action by placing an impervious layer of clay over the riverward side and crown of the levee.

1993 – Engineering Division Technical Report, Hydrologic Analysis, Salt Creek at Lincoln, Nebraska; Feasibility Study, Final Draft, October 1993, USACE – Omaha District (USACE 1993a)

The original discharge-frequency relationships used in the design and analysis of the Salt Creek Flood Control project were based on regional frequency parameters. A lack of sound hydrologic definition of the flooding characteristics of the basin resulted in an inadequate design. The original hydrologic design had two deficiencies that caused flood flows and, consequently, flood stages to be underestimated. The original regional frequency analysis was based on nine stream gages that had an average flow record length of 30.6 years. The study was repeated in 1987, and the same nine gages were reanalyzed and had a new record length of 50 years and an approximate 20 percent increase in peak flows.

The analysis measured existing conditions peak flow rates using the UNET model (a software program that routes runoff hydrographs along open channel drainageways) and the most recent inflow hydrology for Salt Creek and its tributaries. Various levee failure scenarios were not addressed. The UNET model was calibrated to the 1 percent annual chance flood event.

1993 – Salt Creek Existing Conditions Hydraulic Analysis, Section 205 Feasibility Study, December 1993, USACE – Omaha District (USACE 1993b)

The USACE developed a software program called HEC-2 to model flood elevations and the flood flows along open channel drainageways. A confined-condition HEC-2 model (confined-condition, meaning flows were confined to the Salt Creek levees) was developed. The revised model used new cross-sections from the latest topographic surveys when available. Revised topographic surveys used 1986 information and did not include Oak Creek or any bridge sections. The hydraulic analysis used the peak flow rates measured by the UNET model to compute water surface profiles for the confined condition and to identify initial overtopping stage and frequency within each of the 11 economic reaches of Salt Creek.

1994 – Salt Creek, Lincoln, Nebraska; Section 205 Feasibility Study, March 1994, USACE – Omaha District (USACE 1994)

The feasibility phase study included a more detailed evaluation of the economically feasible alternatives previously studied for the Section 216 and reconnaissance phases. This included the evaluation of a detention storage site on Oak Creek upstream from Interstate 80 (I-80).

The flood management alternatives consisted of the following:

- Restore structural stability to the existing levees and berms.
- Reconstruct the levee using compacted nondispersive clay cap on the riverward levee side slope.
- Reconstruct berm with toe protection to a width of 10 feet.
- Construct new levees from Salt Creek to Oak Creek to protect the Westgate Industrial Properties and the Capital Beach Lake areas.
- Develop detention storage on Oak Creek upstream from I-80.
- Design a detention storage structure to capture peak flows of the Oak Creek hydrograph.
- Design detention storage to reduce flood stages along Oak Creek and Salt Creek.
- Design a detention site to enhance wetland development.

1995 –Salt Creek Detention Ponds Middle Creek, MC2, Public Works City of Lincoln (LTU 1995)

A preliminary analysis of detention ponds from the Salt Creek Section 205 Feasibility Study, along with the preliminary cost estimate, was combined with the results of the detention pond evaluation and the levee repair evaluations and a report was written.

The detention sites selected were Middle Creek 2, Oak Creek 2, and possibly Oak Creek 1. Hydrology was taken from the hydrology section of USACE (1993a). All sites primarily used excavation with low-rise berms to create storage volume and therefore created a groundwater concern with total attainable storage volume.

1995 – Salt Creek Feasibility Study Problem Identification Phase, Section 22 – Planning Assistance to States Study, November 1995, USACE – Omaha District (USACE 1995)

This study evaluated Salt Creek within Lincoln. The feasibility study included hydrologic modeling on Salt Creek downstream from the Haines Branch confluence.

1996 – Salt Creek, Lincoln, Nebraska; Section 205 Feasibility Study, 1996, USACE – Omaha District (USACE 1996)

The USACE evaluated offline flood storage locations on Middle Creek and Beal Slough. The USACE found a benefit-cost ratio of 0.08 to 1 for the facilities. The study appears to be a follow-up study to USACE (1994).

1996 – Middle Creek and Oak Creek Flood Storage Detention Area Pre-feasibility Study, January 1996, HWS Consulting & Lower Platte South Natural Resources District (LPSNRD 1996)

This study concentrated on hydrologic issues, specifically geology with respect to groundwater occurrences, location of the groundwater table, and likely water table fluctuations over time. The two sites identified were Middle Creek 1 (MC1) and Oak Creek 2 (OC2). Both sites consisted of farmland situated on alluvial bottomland. Preliminary water levels suggested that site OC2 will not encounter groundwater; however, there will be standing water in the MC1 site if excavated. According to the 1995 City of Lincoln report, long-term monitoring was recommended to understand the full seasonal range of groundwater fluctuations in the site areas.

1999 – Salt Creek at Wilderness Park Hydrologic Study, Section 22 – Planning Assistance to States Study, June 1999, USACE – Omaha District (USACE 1999)

The purpose of this study was to perform a rigorous evaluation of several alternatives that could affect peak flows and stages along Salt Creek through Wilderness Park and downstream within Lincoln. A total of 17 different alternatives were examined for four different storm recurrence intervals. The analysis determined that significant peak discharge/stage reduction would be limited for most of the alternatives that were examined; however, significant increases would be possible for some alternatives.

2000-2018 – Watershed Master Plans, City of Lincoln, Nebraska; and Lower Platte South Natural Resources District (LTU 2000-2018)

Individual watershed master plans have been completed for 14 basins as part of an effort to develop a comprehensive watershed master plan for the city and its future growth areas. Adopted watershed master plans include those for Antelope Creek, Beal Slough, Cardwell Branch, Deadmans Run, Haines Branch, Little Salt Creek, Lynn Creek, Middle Creek, Oak Creek, North Salt Creek, South Salt Creek, Southeast Upper Salt Creek, Stevens Creek, and Upper Wagon Train basins.

2003 – Deadmans Run, Beal Slough, and Salt Creek at Lincoln, Nebraska – Floodplain Analyses, Section 22 – Planning Assistance to States Study, August 2003, USACE – Omaha District (USACE 2003)

The goals of this study were to identify options for obtaining credits toward the CRS of FEMA's NFIP and to determine successful floodplain management strategies used by other communities throughout the United States.

2006 – Salt Creek Floodplain Mapping Update – Floodway Approach Summary, City of Lincoln, Nebraska (LTU 2006a)

As part of the floodplain map update process for Salt Creek, the SCFSA were evaluated. The storage areas were modeled to determine the percentage of flood storage volume in each SCFSA that can be filled or displaced without increasing the 1 percent annual chance flood height more than 1 foot. The designation of the "percentage of allowable fill" for the SCFSA preserves a portion of the flood storage volume in each SCFSA. The protection of the flood storage in the SCFSA allows the City of Lincoln to keep the regulatory floodway boundaries at the levees. Without the SCFSA, the regulatory floodway would extend beyond the levees. Existing homes and businesses would be placed in the regulatory floodway, which would place much more restrictive regulations on the properties.

2009 – Evaluation of Storage Areas in the Salt Creek Watershed, March 2009, City of Lincoln, Nebraska; and Lower Platte South Natural Resources District (LTU 2009)

This study evaluated potential flood risk reduction measures and developed a preferred alternative that included seven offline storage facilities on two tributaries to Salt Creek, Oak Creek, and Middle Creek. The evaluated offline storage areas had footprints that covered a total area of 248 acres (average footprint was 35 acres) and provided a total flood storage of 1,957 acre-feet

(1,400 acre-feet on Oak Creek and 557 acre-feet on Middle Creek), with an average depth of approximately 8 feet. The total cost of the structures was $39,200,000, and the total benefit was $17,300,000 (reduced average annual flood damage from $7,180,000 to $6,250,000), for a benefit-to-cost ratio of 0.44 to 1. The study also looked at creating additional flood storage in Wilderness Park but concluded that constructing flood risk reduction measures there would adversely affect the mature riparian vegetation. Therefore, Wilderness Park flood risk reduction measures were not included in the preferred alternative.

2014 – Understanding and Assessing Climate Change, Implications for Nebraska, 2014, University of Nebraska-Lincoln (Bathke et al. 2014)

This study evaluated the potential impacts of climate change and trends in climate variables. The overarching conclusion was that annual precipitation will increase in eastern Nebraska and the increase will largely be caused by increases in frequency and magnitude of large or extreme precipitation events. The findings of this report are supported by the recent update of the Atlas 14 (NOAA 2013) documents that provide rainfall amounts for various frequencies across the United States. In Lincoln, the traditional 1 percent annual chance design precipitation amount is 6.7 inches, which is derived from Technical Paper 40 (TP40; U.S. Department of Commerce 1961). The updated NOAA Atlas 14 documents indicate the 1 percent annual chance design precipitation event should be 7.3 inches. Based on an additional 40 to 50 years of precipitation gage data, the estimate of the 1 percent annual chance design precipitation has increased more than 10 percent.

2016 – Salt Creek Levee Systemwide Improvement Framework (SWIF), Lincoln, Nebraska; October 2016, Lower Platte South Natural Resources District (LPSNRD 2016)

A SWIF has been developed for the Salt Creek Levee System. This framework addresses maintenance needs and deficiencies identified during USACE inspections. A priority list of future projects to address the maintenance needs and deficiencies has been developed. The SWIF allows the Salt Creek levee system sponsor to remain eligible for USACE emergency readiness and response programs.

4.2 Summary

We know from past studies that raising the Salt Creek levees is not a feasible option for Salt Creek flood protection. We also know that singular approaches to flood management are not effective. USACE (1994) demonstrated that effective flood management cannot be achieved by only using offline storage. Past studies have also demonstrated that flood management measures will not be effective if they are not implemented in a comprehensive and systematic manner. LTU 2009 demonstrated that flood management measures implemented on only a few tributaries did not provide adequate flood risk reduction benefits to justify the costs. However, those studies did not include all the tributaries. Section 6 of this report will discuss non-structural flood risk reduction measures and the potential evaluation of structural flood management options.

SECTION 5 – LOCAL CLIMATE EVALUATIONS AND RESILIENCY STANDARDS

Optimal resiliency planning requires a forward-looking approach: Planners must consider not just events and hazards that may occur in the present day, but they must also account for future hazards and how those hazards may evolve over time. Therefore, this study evaluated local historical and existing precipitation patterns, developed probable future storm magnitudes, and developed future flood discharges that can be used for future conditions flood hazard analysis. The results presented in this study were obtained using reliable engineering methods and reasonable judgement, but do not in any way constitute approved levels of future discharges and/or flood elevations.

Throughout this section, Section 6, and Section 8 of the report, specific terminology will be used to differentiate the individual conditions being analyzed.

Existing conditions (in bold text throughout the remainder of the report - **existing conditions**) refers to conditions when precipitation values used came from the U.S. Weather Bureau's Technical Paper No. 40 and the associated discharges (U.S. Department of Commerce 1961).

Updated conditions (in bold text throughout the remainder of the report - **updated conditions**) refers to conditions when precipitation values used came from the Atlas 14 and the associated discharges (NOAA 2013).

Future conditions (in bold text throughout the remainder of the report - **future conditions**) refers to conditions when precipitation values used come from climate modeling and future land use changes and the associated discharges.

5.1 Historical Precipitation and Existing Conditions Hazards

Peak discharges in Salt Creek are calculated using HEC-HMS models specific to local subbasins across the larger Salt Creek watershed. (The HEC-HMS model is USACE's Hydrologic Engineering Center's Hydrologic Modeling System software, which is designed to simulate the complete hydrologic processes of dendritic watershed systems.) There are 12 subbasins in the Salt Creek watershed. HEC-HMS models for seven of the subbasins were obtained for the purposes of this analysis. A summary of the 12 subbasins is provided in **Table 31**, and a map depicting these subbasins is provided as **Figure 11**. Hydrographs from each of these models are combined and routed in a single HEC-RAS model for Salt Creek. (The HEC-RAS is USACE's Hydrologic Engineering Center's River Analysis System software, which is designed to perform one-dimensional steady flow and one and two-dimensional unsteady flow calculations.) The HEC-RAS model is unsteady and thus accounts for storage in the Salt Creek floodplain.

Table 31. Subbasin HEC-HMS Model Summary.

Subbasin	Drainage Area (square miles)	HEC-HMS Model Obtained and Analyzed
Antelope Creek	13.1	✓
Beal Slough	13.5	
Cardwell Branch	16.5	✓
Deadmans Run	9.6	
Haines Branch	68.1	
Little Salt Creek	43.4	✓
Middle Creek	100.2	✓
North Salt Creek	40.8	
Oak Creek	258.7	✓
Southeast Upper Salt Creek	9.7	✓
South Salt Creek	200.9	✓
Stevens Creek	52.7	

The existing HEC-HMS models for Salt Creek are based on precipitation data from the U.S. Weather Bureau’s TP40, which dates from 1961. These models were created prior to the publication of NOAA Atlas 14 (Volume 8), which was created for the State of Nebraska in 2013 (NOAA 2013). NOAA Atlas 14 provides precipitation frequency estimates for various storm durations at average recurrence intervals of 1 percent through 0.01 percent annual chance precipitation events. Atlas 14 analysis was performed on precipitation measurements through December 2012 and thus contains the most up-to-date precipitation analysis for Nebraska. Therefore, the flood hazard information for Salt Creek is not based on the most up-to-date precipitation data. Additionally, the computed flow rates reported in this study for the **existing conditions** are based on HEC-HMS 4.2, an updated version of the HEC-HMS model. Thus, the existing conditions flow rates may be different from the flow rates from the FIS, even when the same rainfall amounts are used.

To determine the extent to which **updated conditions** flood hazards may differ from the existing conditions flood hazards, an updated conditions flood hazard analysis was performed.

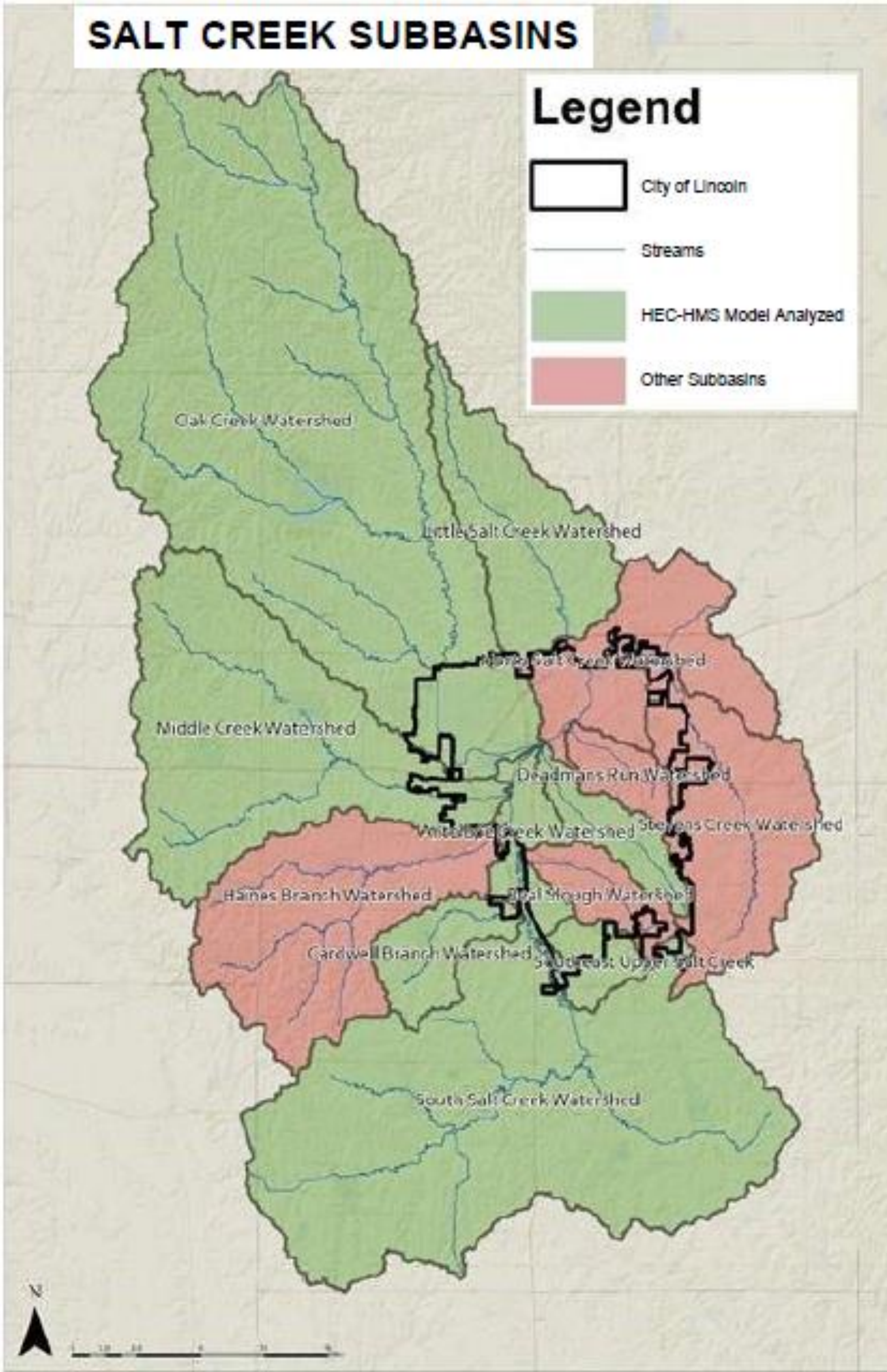


Figure 11. Salt Creek Subbasins.

5.1.1 Updated Conditions Precipitation Estimates

To create an **updated conditions** analysis, precipitation frequency estimates were extracted from NOAA Atlas 14 for each of the seven different Salt Creek subbasins. The estimates were extracted at the centroids of the collected HEC-HMS models. A comparison of these precipitation frequency estimates and the **existing conditions** precipitation estimates from the analyzed HEC-HMS models is provided in **Table 32.** A more detailed table can be found in Appendix A.

Table 32. Comparison of Existing Conditions Precipitation Estimates to Atlas 14 Precipitation Estimates.

Subbasin	Modeled Storm Duration (hours)	10% Annual Chance Precipitation (inches)		2% Annual Chance Precipitation (inches)		1% Annual Chance Precipitation (inches)		0.2% Annual Chance Precipitation (inches)	
		Existing	Updated	Existing	Updated	Existing	Updated	Existing	Updated
Antelope Creek	6	3.50	3.65	4.60	5.15	5.10	5.86	6.00	7.66
Cardwell Branch	24	4.69	4.44	6.00	7.89	6.68	7.33	8.20	9.86
Little Salt Creek	24	4.69	4.53	6.00	6.49	6.68	7.44	8.18	9.95
Middle Creek	48	5.08	4.86	6.55	6.89	7.31	7.81	8.81	10.50
Oak Creek	48	5.08	4.79	6.55	6.74	7.31	7.70	8.81	10.30
Southeast Upper Salt Creek	24	4.70	4.55	6.00	6.50	6.70	7.46	8.40	9.94
South Salt Creek	48	5.08	5.07	6.55	7.17	7.31	8.19	8.81	10.80

The **updated conditions** (NOAA 2013) precipitation data clearly indicates that a longer period of record for collection of precipitation data does affect the precipitation frequency estimates, particularly for larger, less frequent precipitation events. NOAA Atlas 14, which is based on much more recent and extensive precipitation data, is more representative of the current conditions. Generally, this data shows that **existing conditions** precipitation frequency estimates for the 10 percent annual chance event are *higher* than the **updated conditions** precipitation frequency estimates (as determined using NOAA Atlas 14), and **existing conditions** precipitation frequency estimates for the 2 percent , 1 percent , and 0.2 percent annual chance events are *lower* than the **updated conditions** precipitation frequency estimates.

> ➢ **KEY TAKEAWAY**
> **The existing conditions hydrologic models do not use up-to-date precipitation frequency estimates.**

5.1.2 Updated Conditions Discharge Estimates

To determine how the discharges from each of these subbasins would change using **updated conditions** precipitation frequency estimates, **updated conditions** hydrologic models were created for each of the seven subbasins by modifying the respective HEC-HMS models. **Existing conditions** precipitation values were replaced with NOAA Atlas 14 values to create the **updated conditions** models. Discharge results at the mouth of each of these subbasins are provided in **Table 33**. The percentage of change between **existing conditions** and **updated conditions** discharges for each subbasin and each recurrence interval is given in **Table 34**.

Table 33. Comparison of Existing Conditions Discharge Estimates to Updated Conditions Discharge Estimates.

Subbasin	10% Annual Chance Discharge (cfs)		2% Annual Chance Discharge (cfs)		1% Annual Chance Discharge (cfs)		0.2% Annual Chance Discharge (cfs)	
	Existing	Updated	Existing	Updated	Existing	Updated	Existing	Updated
Antelope Creek	5,050	5,150	9,710	10,700	12,100	13,400	15,300	20,600
Cardwell Branch	1,530	1,440	2,060	2,220	2,350	2,630	3,100	4,010
Little Salt Creek	7,570	6,900	12,000	13,700	14,300	17,100	19,900	29,400
Middle Creek	5,770	5,240	9,080	9,940	11,000	12,500	14,800	19,700
Oak Creek	7,810	6,910	12,900	13,500	15,600	17,100	21,300	27,600
Southeast Upper Salt Creek	4,300	4,060	6,720	7,720	8,130	9,700	11,700	15,200
South Salt Creek	8,000	7,860	12,200	13,900	14,400	17,000	18,900	25,400

*cfs (cubic feet per second)

Table 34. Percentage of Change in Discharge Between Existing Conditions and Updated Conditions Models.

Subbasin	10% Annual Chance Discharge (% change)	2% Annual Chance Discharge (% change)	1% Annual Chance Discharge (% change)	0.2% Annual Chance Discharge (% change)
Antelope Creek	2	10	11	34
Cardwell Branch	-6	8	12	29
Little Salt Creek	-9	14	19	47
Middle Creek	-9	9	14	33
Oak Creek	-12	5	10	30
Southeast Upper Salt Creek	-6	15	19	31
South Salt Creek	-2	14	18	34
AVERAGE	**-6**	**11**	**15**	**34**

The discharge data at the subbasin level is consistent with the changes made to the precipitation depth in the HEC-HMS models. The lower **updated conditions** precipitation depth in the 10 percent annual chance model runs have resulted in lower discharges, while the higher **updated conditions** precipitation depths in the 2 percent, 1 percent, and 0.2 percent annual chance model runs resulted in higher discharges. On average, the **updated conditions** discharges are approximately 15 percent higher than the **existing conditions** discharges for the 1 percent annual chance flood event, and 34 percent higher for the 0.2 percent annual chance flood event.

Next, the changes in peak discharge at the subbasin level were applied to the input hydrographs in the **existing conditions** HEC-RAS model. To address inconsistencies between the **existing conditions** HEC-HMS models and the **existing conditions** HEC-RAS models in terms of storm timing and time step, the input hydrographs were multiplied by the percentage of change in peak discharge, which is summarized in Table 34. This approach is consistent with unit hydrograph theory. For all input hydrographs in the HEC-RAS model outside of the subbasins listed in Table 34, the average percentage of change in peak discharge across the Salt Creek watershed was used as the multiplier. Therefore, **updated conditions** hydraulic models were created for the 10 percent, 2 percent, 1 percent, and 0.2 percent annual chance flood events for comparison to the same events in the **existing conditions** hydraulic model on Salt Creek. The data is summarized in **Table 35.** All results presented are averages across all cross-sections on Salt Creek.

Table 35. Comparison of Updated Conditions Flood Hazards (Discharge and Water Surface Elevation) to Existing Conditions Flood Hazards (Discharge and Water Surface Elevation).

	10% Annual Chance Event	2% Annual Chance Event	1% Annual Chance Event	0.2% Annual Chance Event
Average Increase in Discharge	-600 cfs	+1,700 cfs	+2,400 cfs	+7,000 cfs
Increase in Discharge	-3%	+11%	+12%	+27%
Average Increase in Water Surface Elevation	-0.4 feet	+0.6 feet	+0.8 feet	+2.2 feet

These results are consistent with changes to precipitation values observed in NOAA Atlas 14 data when compared to the TP40 precipitation values in the **existing conditions** HEC-HMS models. The results clearly indicate that the **existing conditions** flood hazard information on Salt Creek underestimates the existing risk. This is especially true for the 1 percent annual chance event and the 0.2 percent annual chance events, where the average water surface elevation has increased by approximately 0.8 foot and 2.2 feet, respectively.

> ➢ **KEY TAKEAWAY**
> **The existing conditions flood hazard data on Salt Creek underestimates the updated conditions flood hazards in the City of Lincoln.**

5.2 Probable Future Storm Magnitudes

While it is critical to understand **updated conditions** flood hazards, it is also critical to understand that flood hazards will change in the future. There are two important mechanisms by which flood hazards will likely change: precipitation changes caused by global climate change, and land use changes that drive changing runoff patterns. The impact of global climate change specifically on future rainfall has been discussed in several recent studies including Understanding and Assessing Climate Change, Implications for Nebraska (Bathke et al. 2014), as well as the Fourth National Climate Assessment (U.S. Global Change Research Program 2018). To analyze how flood hazards may change over time in the City of Lincoln specifically, a detailed analysis was performed of probable future storm magnitudes in the Salt Creek watershed.

Greenhouse gases have a direct influence on climatic variables, including precipitation. Around the world, different teams of scientists have created different climate models to project future climate conditions for the next century. These models are known as global climate models or general circulation models (GCMs) and are recognized as the best available tools to understand the climatic response to different greenhouse gas concentration scenarios. These models are based on well-documented physical processes and simulate the transfer of energy and materials through the ocean, atmosphere, and land. **Figure 12** shows some of the concepts that are modeled in the GCMs. GCM models are tested against historic and observed climate and weather conditions. They are used to forecast climatic changes going forward – typically to the year 2100.

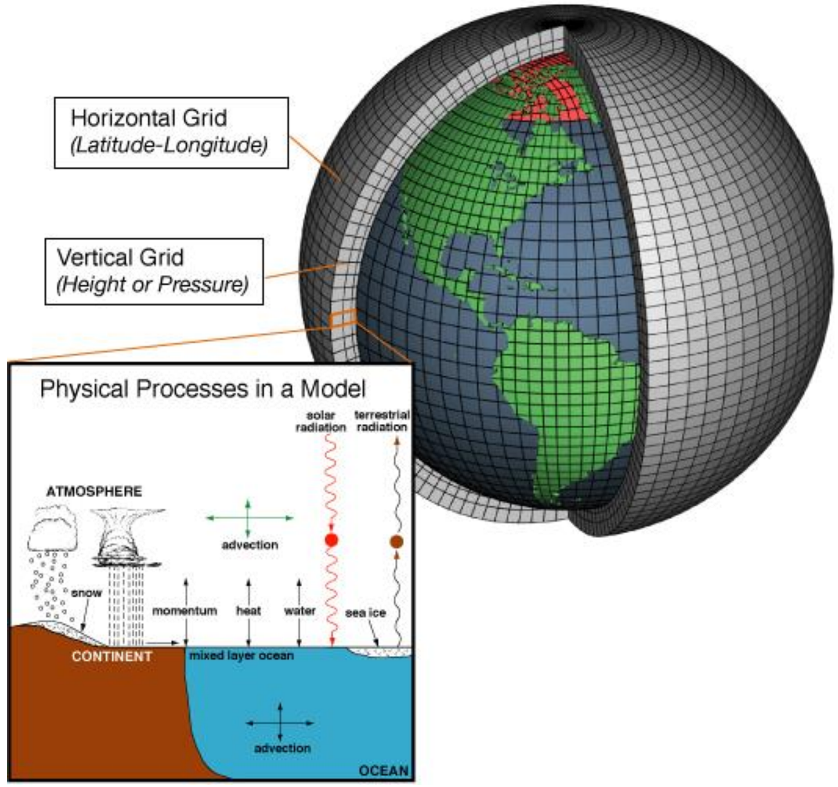


Figure 12. Atmospheric Model Schematic (image source: National Oceanic and Atmospheric Administration [NOAA]).

The resolution of these GCMs are typically too coarse to draw conclusions at a local scale. To address this problem, downscaling methods have been developed to increase the resolution of the model projections. A new method of downscaling has been developed called localized constructed analogs (LOCA). LOCA can develop higher resolution predictions by using historical local weather patterns. LOCA provides predictions of future climatic conditions at a resolution of 3.7-mile by 3.7-mile grid cells. By using a high-resolution dataset of historical weather patterns, LOCA provides clear improvement on past downscaling methods and more accurate forecasts for future climate scenarios. According to the Scripps Institution of Oceanography (Pierce and Cayan 2017), "…[LOCA] better preserves extreme hot days and heavy rain events than the previous generation of downscaling approaches. Extreme events such as heat waves or heavy precipitation have some of the biggest economic and societal impacts, even though they can last just a few days." For this reason, LOCA-downscaled GCMs were chosen to analyze probable future storm magnitudes in the City of Lincoln.

Downscaled projected climate data (LOCA-CMIP5 Climate Daily) is available from the Lawrence Livermore National Laboratory's Climate and Hydrology Projections website (Archive Collaborators 2016). Precipitation data was downloaded for a broad time period for full analysis: January 1950 through December 2099. The data was downloaded at the grid-cell level resolution for the entirety of the Salt Creek watershed (a total of 256 3.7-mile by 3.7-mile grid cells).

Data from the following seven separate climate models was downloaded for the Salt Creek watershed:

- bcc-csm1-1.1
- csiro-mk3-6-0.1
- gfdl-cm3.1
- giss-e2-h.2
- hadgem2-ao.1
- miroc5.1
- mri-cgcm3.1

These models were selected because they are well-tested, span the three climate sensitivity groups, and are relatively independent from each other in terms of algorithms.

For each of the seven climate models, data from two representative concentration pathways (RCPs), were accessed: RCP4.5 and RCP8.5. These pathways represent potential greenhouse gas concentration trajectories in the future – standard pathways adopted by the Intergovernmental Panel on Climate Change (IPCC). RCP4.5 is considered to be a moderate-low pathway, where greenhouse gas emissions continue to rise until 2040, after which time they stabilize and moderately decline, such that the greenhouse gas concentration in the atmosphere continues to increase, but more slowly. This would be indicative of a future where society takes significant action to reduce greenhouse gas emissions in the next 20 years. RCP8.5 is known as the “business-as-usual” scenario. RCP8.5 is characterized by increasing greenhouse gas emissions over time, continuing until at least the year 2100. Charts produced by the IPCC showing greenhouse gas concentration over time are provided in **Figure 13.**

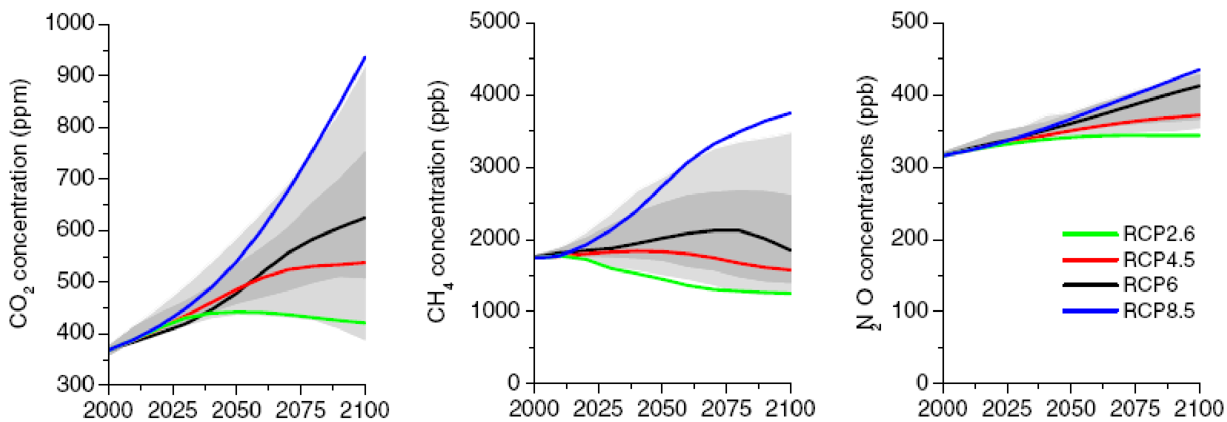


Figure 13. Greenhouse Gas Concentrations of Representative Concentration Pathways (RCPs) (image source: Intergovernmental Panel on Climate Change [IPCC]).

5.2.1 Ratio of Future Precipitation to Historic Precipitation

Data for each model and RCP was extracted and processed using a set of custom scripts to ensure reproducibility of the analysis. Using these scripts, daily precipitation data from 1950-2099 was extracted for each model, RCP, and the 3.7-mile by 3.7-mile grid cells.

Three time periods were analyzed: 1950-2005 (representing the historical period for the LOCA data set), 2006-2050 (representing future data for 2050), and 2051-2099 (representing future data for 2100).

A weighted average of daily precipitation across all grid cells was calculated for each of the 12 subbasins within the Salt Creek watershed, for each of the seven GCMs. The annual maximum daily precipitation was determined for each year. Then, Log-Pearson Type III analysis was performed on the annual maximum data for the three time periods to determine various annual chance exceedance levels. Finally, ratios of future GCM daily precipitation (2051-2099) to present day GCM daily precipitation (1950-2005) were calculated for various annual chance exceedance levels. A ratio of greater than 1.00 indicates that peak precipitation is modeled to increase in the future, while a ratio of less than 1.00 indicates that peak precipitation is modeled to decrease in the future. A ratio of 1.00 indicates “no change” in future precipitation.

For the RCP4.5 scenario models, the seven GCMs produced varying ratios of future (year 2100) to present-day rainfall across the Salt Creek watershed. For the 1 percent annual chance event, these ratios ranged from 0.86 to 1.10 with an average of 0.99 – essentially a "no change" outcome. In other words, under the RCP4.5 modeling scenario, the average outcome between the seven GCMs analyzed showed that rainfall in the future would remain approximately the same as the that in the present day. The differences between the seven models indicates the uncertainty in this forecast. The ratios of the 1 percent annual chance event between the year 2100 and present day are shown in **Table 36.** Other percent annual chance exceedances and time periods (i.e., projections for the year 2050) showed similar results – with some uncertainty, future precipitation patterns are not expected to change much under the RCP4.5 scenario.

> ➢ **KEY TAKEAWAY**
> **If society takes significant actions to reduce greenhouse gas emissions in the next 20 years, precipitation patterns in the Salt Creek watershed are NOT expected to change much by the year 2100.**

Table 36. RCP4.5 Modeled Ratios of Future to Present-day Daily Precipitation.

General Circulation Model (GCM)	Ratio of Future GCM daily precipitation (year 2100) to present daily precipitation (1% annual chance event)
bcc-csm 1-1.1	0.87
csiro-mk3-6-0.1	1.06
gfdl-cm3.1	0.92
giss-e2-8.2	1.10
hadgem-ao.1	0.86
miroc5.1	1.05
mri-cgcm3.1	1.08
AVERAGE	**0.99**

Analysis of the RCP8.5 scenario showed very different results. All seven models indicated that peak annual daily precipitation would increase in the future (year 2100) for most percent annual chance exceedances compared to the present-day period. The degree of increase varies across percent annual chance exceedances and across the 12 subbasins in the Salt Creek watershed. However, the general trend is clear. Under the RCP8.5 scenario, peak precipitation will increase by nearly 10 percent by the year 2100 in the Salt Creek watershed. These trends in increased peak precipitation are consistent with the general findings of both Bathke et al. (2014) and U.S. Global Research Program (2018). The ratios of peak precipitation for various percent annual chance exceedances between the year 2100 and the present day are shown in **Table 37.**

> ➢ **KEY TAKEAWAY**
> **In the "business-as-usual" global greenhouse gas emissions scenario, precipitation events causing flooding are forecasted to increase by nearly 10 percent by the year 2100 in the Salt Creek watershed.**

Table 37. RCP8.5 Modeled Ratios of Future to Present-day Daily Precipitation.

General Circulation Model (GCM)	Ratio of Future GCM daily precipitation (year 2100) to present daily precipitation			
	10% annual chance event	2% annual chance event	1% annual chance event	0.2% annual chance event
bcc-csm 1-1.1	1.13	1.19	1.22	1.29
csiro-mk3-6-0.1	1.09	1.11	1.11	1.11
gfdl-cm3.1	1.05	1.08	1.10	1.15
giss-e2-8.2	1.03	1.06	1.08	1.12
hadgem-ao.1	1.07	1.03	1.00	0.95
miroc5.1	1.07	1.03	1.01	0.96
mri-cgcm3.1	1.11	1.12	1.12	1.14
AVERAGE	**1.08**	**1.09**	**1.09**	**1.10**

As would be expected, the seven GCMs showed more variation in ratios for the more extreme events. For example, the range of ratios for the 10 percent annual chance event by GCM is a very narrow 1.03 to 1.13, while the range of ratios for the 0.2 percent annual chance events is a much wider 0.95 to 1.29. This is indicative of greater future uncertainty for the more extreme events compared to the more common events.

The ratios shown in Table 36 and Table 37 are averages for the entire Salt Creek watershed. The models also show a degree of variance in ratios across individual subbasins in the watershed. Generally, the higher ratios (and hence greater magnitude increases in future precipitation events) occur in the northern and eastern parts of the watershed – specifically in the Oak Creek subbasin, the Little Salt Creek subbasin, the North Salt Creek subbasin, and the Deadmans Run subbasin. Ratios in other subbasins are all above 1.00, but to a lesser degree. A map showing the ratio of 1 percent annual chance **future conditions** (year 2100) to **updated conditions** peak precipitation by subbasin is provided in **Figure 14.**

The ratios shown in Table 37 were applied to the **updated conditions** precipitation frequency estimates to determine **future conditions** precipitation frequency estimates. Average **future conditions** precipitation frequency estimates in the seven modeled subbasins are shown in **Table 38**.

Table 38. Comparison of Updated Conditions and Future Conditions Precipitation Frequency Estimates.

Subbasin	Modeled Storm Duration (hours)	10% Annual Chance Precipitation (inches)		2% Annual Chance Precipitation (inches)		1% Annual Chance Precipitation (inches)		0.2% Annual Chance Precipitation (inches)	
		Updated (Atlas 14)	**Future** (RCP8.5)	**Updated** (Atlas 14)	**Future** (RCP8.5)	**Updated** (Atlas 14)	**Future** (RCP8.5)	**Updated** (Atlas 14)	**Future** (RCP8.5)
Antelope Creek	6	3.65	4.02	5.15	5.67	5.86	6.39	7.66	8.20
Cardwell Branch	24	4.44	4.84	7.89	8.60	7.33	8.06	9.86	10.94
Little Salt Creek	24	4.53	5.07	6.49	7.40	7.44	8.63	9.95	11.84
Middle Creek	48	4.86	5.20	6.89	7.30	7.81	8.28	10.50	11.13
Oak Creek	48	4.79	5.13	6.74	7.35	7.70	8.55	10.30	11.64
Southeast Upper Salt Creek	24	4.55	4.82	6.50	6.89	7.46	7.91	9.94	10.54
South Salt Creek	48	5.07	5.42	7.17	7.67	8.19	8.76	10.80	11.56

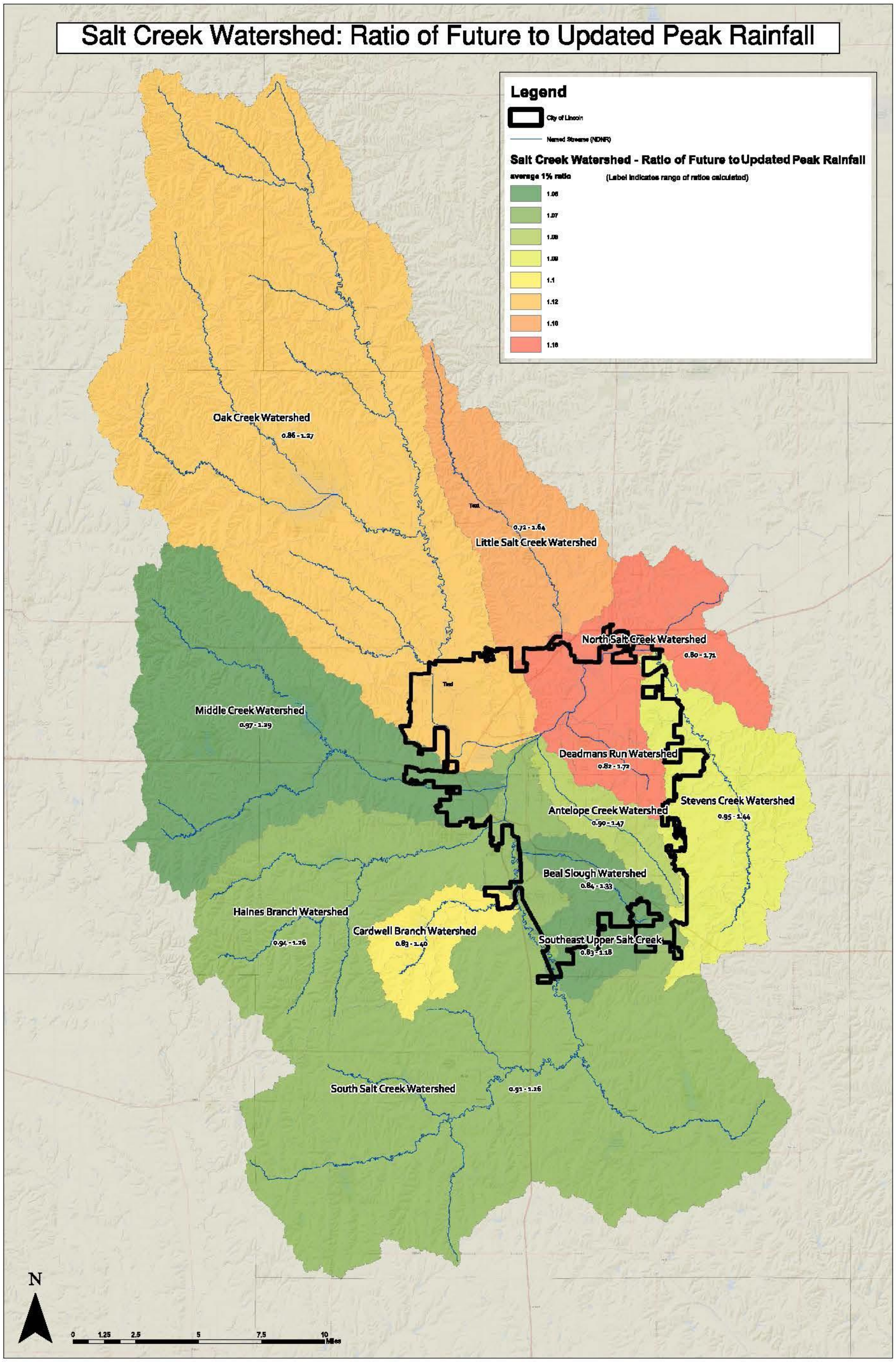


Figure 14. Ratio of 1 Percent Annual Chance (2100) Future Conditions to Updated Conditions Peak Precipitation by Subbasin.

Table 39 provides a comparison of precipitation values from the Drainage Criteria Manual and TP40, NOAA Atlas 14, and **future conditions** (RCP8.5) for the 50, 10, 2, 1, and 0.2 percent annual chance precipitation events.

Table 39. Comparison of Corresponding 24-hour Point Precipitation Values from Different Sources.

Probability (percent annual chance)	Common Event Name	Total Precipitation DCM*/TP40 (inches)	Total Precipitation NOAA Atlas 14 (inches)	Total Precipitation Future Conditions RCP8.5 (inches)
50	2-year	3.00	3.03	3.21
10	10-year	4.69	4.47	4.83
2	50-year	6.00	6.37	6.94
1	100-year	6.68	7.31	7.97
0.2	500-year	8.18	9.75	10.73

**DCM – City of Lincoln Drainage Criteria Manual (City of Lincoln Public Works and Utilities Department 2004)*

5.3 Flood Hazards in the Year 2100

There are two important mechanisms by which flood hazards may change by the year 2100: precipitation changes caused by climate change, and land use changes that drive changes to runoff patterns. These two mechanisms were both combined into **future conditions** models for Salt Creek, as well as for the individual subbasins within Salt Creek.

5.3.1 Flood Increases Because of Land Use Changes

Land use changes typically cause increases in runoff by reducing the amount of precipitation absorbed into the soil. When native land and vegetation are replaced with buildings and impervious surfaces, a higher percentage of precipitation runs off, creating a higher potential for downstream flooding.

Growth and development are expected to continue to occur in the City of Lincoln and the Salt Creek watershed. As a part of the Lincoln-Lancaster County 2040 Comprehensive Plan (Comprehensive Plan; Lincoln-Lancaster County Planning Department 2016), areas around Lincoln were identified as areas where future development is planned. These areas are divided into tiers, which reflect the time period when the proposed development is likely to take place: Tier 1A (currently developing), Tier 1B (development by 2025), Tier 1C (development by 2040), Tier II (development by 2060), and Tier III (possible development after 2060). Some infill development is also anticipated in currently developed areas of Lincoln. A map from the comprehensive plan, showing developed areas and the growth tiers around Lincoln, is provided as **Figure 15.**

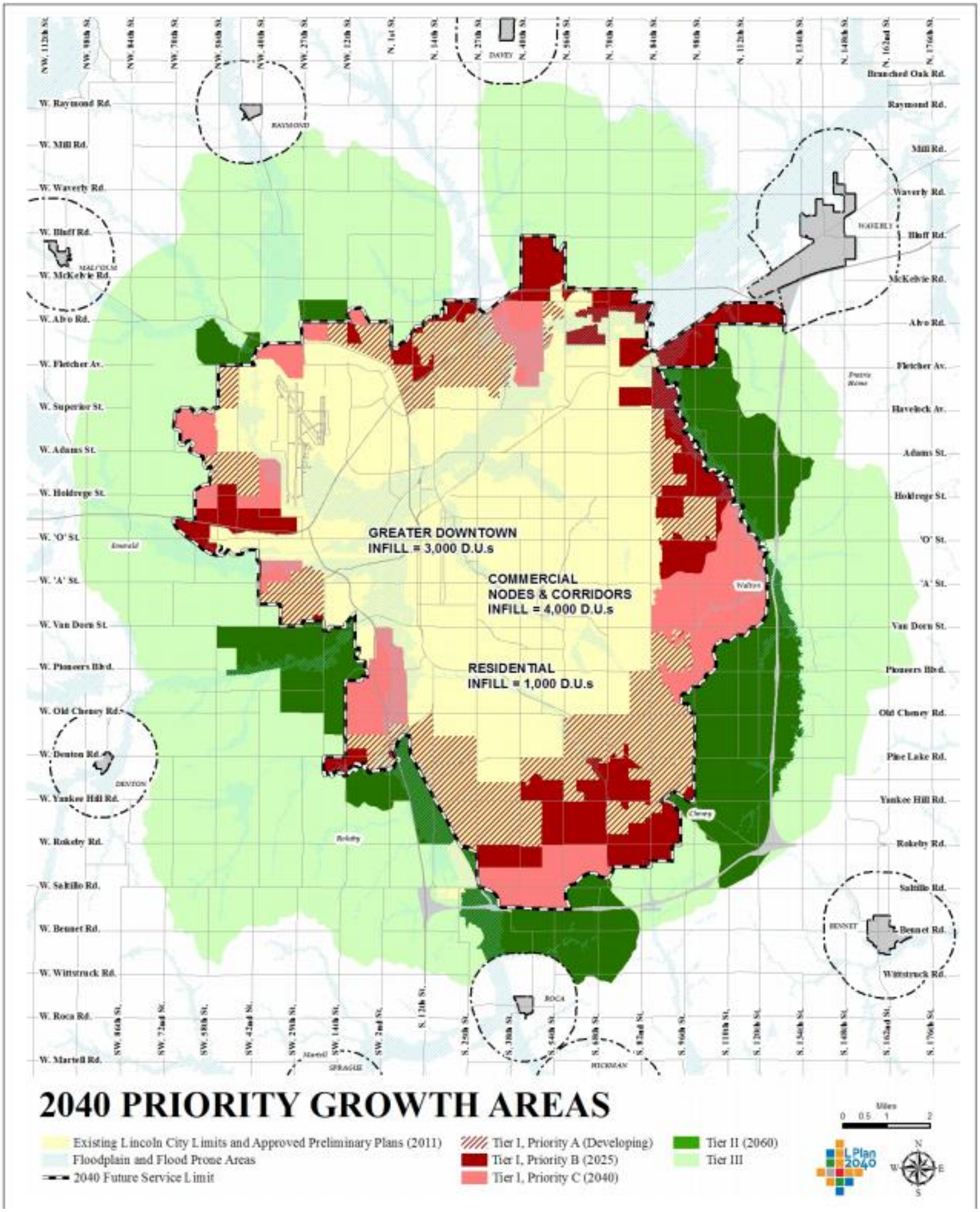


Figure 15. City of Lincoln Growth Tiers.
(Lincoln-Lancaster County Planning Department 2016)

To calculate how much the projected development will affect discharges, the **updated conditions** hydrologic and hydraulic models were revised to reflect this potential development. For the seven **updated conditions** HEC-HMS models, curve numbers and initial and constant loss values were revised. All existing HEC-HMS models used an imperviousness value of zero, with elevated curve numbers to account for imperviousness – this precedent was followed in the creation of **future conditions** models. For some subbasins, "built-out" curve numbers were available in the subbasin master plans and were used for this purpose. For other areas, curve numbers were estimated on a subbasin level. For tiers I and II, this was done by adjusting curve numbers to be equal to adjacent developed areas. Smaller curve number adjustments were made in already developed areas (to account for infill) and to the Tier III areas (to account for possible, but not certain, development by the year 2100). A detailed table with curve numbers used is included in **Appendix B**. The HEC-HMS models were run with these adjusted curve numbers, with discharges compared at the mouth of each subbasin. These results are presented in **Table 40.**

Table 40. Projected Increase in Flood Discharges Caused by Projected Development (Modeled).

Subbasin	Index Percent of Subbasin to be Developed*	10% Annual Chance Discharge (% change)	2% Annual Chance Discharge (% change)	1% Annual Chance Discharge (% change)	0.2% Annual Chance Discharge (% change)
Antelope Creek	17%	2.3%	1.6%	1.3%	0.8%
Cardwell Branch	41%	5.2%	4.1%	3.1%	1.5%
Little Salt Creek	12%	3.0%	1.2%	0.6%	0.2%
Middle Creek	8%	0.6%	0.4%	0.3%	0.3%
Oak Creek	6%	0.1%	0.1%	0.1%	0.0%
Southeast Upper Salt Creek	88%	11.6%	8.0%	6.6%	5.0%
South Salt Creek	9%	0.4%	0.3%	0.3%	0.2%
AVERAGE	**10%****	**3.3%**	**2.2%**	**1.8%**	**1.1%**

*Index was calculated as .05 times the percent area already developed (to account for infill) plus the percent area in tiers I and II (to account for planned high likelihood of development) plus 0.33 times the percent area in Tier III (to account for potential, yet not certain development by 2100).
**This value is the percentage to be developed for the entire Salt Creek watershed.

As can be seen in this data, the overall average impact of projected development on the flood discharges at the mouths of individual subbasins ranges from close to zero where a limited amount of development is expected, to over 6 percent for the 1 percent annual chance flood event for subbasins with greater potential development. It is critical to note that the discharge increases in Table 40 are taken at the mouth of each subbasin, where large amounts of flow accumulate, including from areas not subject to projected development. However, increases to discharges can be much more extreme on a localized basis. A property's detention and water quality control design elements, and development can lead to significant negative impacts to downstream properties in terms of flood discharge, erosion, and environmental degradation.

> ➢ **KEY TAKEAWAY**
> **Increases to flood discharges because of development can be extreme at a localized level. Property detention and water quality control features are critical to reduce the negative impacts of development.**

To determine relative increases in flood discharges for the five subbasins that were not modeled, a relationship was developed between the index percentage of each modeled subbasin to be developed, and the percentage of increase in discharge for each percent annual chance exceedance. This relationship was determined to be very strong and linear. Therefore, the projected increase in flood discharges caused by development can easily be extrapolated to the five subbasins that were not modeled. This relationship is shown in **Appendix C**. These extrapolated projected increases are summarized in **Table 41.**

Table 41. Projected Increase in Flood Discharges Caused by Projected Development (Extrapolated).

Subbasin	Index Percentage (%) of Subbasin to be Developed	10% Annual Chance Discharge (% change)	2% Annual Chance Discharge (% change)	1% Annual Chance Discharge (% change)	0.2% Annual Chance Discharge (% change)
Beal Slough	39	5.0	3.5	2.8	2.0
Deadmans Run	5	0.7	0.5	0.4	0.3
Haines Branch	13	1.6	1.2	0.9	0.7
North Salt Creek	25	3.2	2.2	1.8	1.3
Stevens Creek	71	9.2	6.5	5.2	3.7

5.3.2 Flood Increases Caused by Climate Change

To determine how flood hazards may increase over time because of climate change, the precipitation ratios calculated in Section 5.2.1 were applied to the seven available HEC-HMS models. These precipitation ratios were applied to the precipitation depths in the models with land use adjusted for **future conditions** to create **future conditions** hydrologic models. Detailed hydrologic modeling was performed for all four annual chance exceedances and for three of the seven GCMs: bcc, csiro, and hadgem (these GCMs generally represent the high, middle, and low ratio for the average subbasin). From model runs with these three GCMs, a relationship was determined between the precipitation ratio for each subbasin and the future discharge ratio for each subbasin. These relationships were used to calculate approximate discharges for all other subbasins; GCMs and are shown in **Appendix D**. **Table 42** shows the 1 percent annual chance discharges calculated in seven subbasins for the **future conditions** (median GCM for each subbasin for the RCP8.5 scenario) compared to **existing** and **updated conditions** discharges.

Table 42. 1 Percent Annual Chance Existing, Updated, and Future Conditions Discharges by Subbasin (Median General Circulation Model [GCM] and RCP8.5).

Subbasin	Existing HMS Model Discharge (cfs)	Updated Conditions Discharge (cfs)	Future Conditions Discharge – Median GCM (cfs)
Antelope Creek	12,100	13,400	15,700
Cardwell Branch	2,350	2,630	2,950
Little Salt Creek	14,300	17,100	21,100
Middle Creek	11,000	12,500	13,700
Oak Creek	15,600	17,100	20,700
Southeast Upper Salt Creek	8,130	9,700	11,300
South Salt Creek	14,400	17,000	19,300

As this data shows, the median climate model of the seven subbasins analyzed leads to substantial increases in discharge compared to both the **existing conditions** analysis and the **updated conditions** analysis – an average across these seven subbasins of approximately 31 percent compared to **existing conditions**, and approximately 15 percent compared to **updated conditions**. There is some variability in the increases between the different subbasins. This variability is correlated to the degree of increase in precipitation between the **existing conditions** analysis and the **updated conditions** analysis, as well as the precipitation ratio calculated in the **future conditions** analysis.

To determine how these results, at the level of the individual subbasins, would affect conditions on Salt Creek, separate HEC-RAS hydraulic models were created for each annual chance exceedance and for each GCM. In **Table 43**, the increases caused by the median GCM **future conditions** model for the RCP8.5 scenario are compared to the **existing conditions** hydraulic model on Salt Creek. All results presented in this table are averages across all cross-sections on Salt Creek.

Table 43. Comparison of Future Conditions Flood Hazards (Discharge and Water Surface Elevation) to Existing Conditions Flood Hazards (Discharge and Water Surface Elevation) for Median GCM and RCP8.5.

	10% Annual Chance Event	2% Annual Chance Event	1% Annual Chance Event	0.2% Annual Chance Event
Average Increase in Discharge	+1,100 cfs	+4,400 cfs	+6,500 cfs	+12,600 cfs
Increase in Discharge	+8%	+21%	+28%	+45%
Average Increase in Water Surface Elevation	+0.6 ft	+1.5 ft	+2.2 ft	+4.5 ft

This data shows that flood hazards will increase significantly in **future conditions**, compared to the **existing conditions** data. Some of this increase is because of improved **updated conditions** precipitation data, some of this increase is because of changes in future land use, and some of this increase is because of changes in **future conditions** precipitation caused by climate change. Overall, these three factors combine to greatly increase the flood risk in the City of Lincoln by the year 2100.

> ➢ **KEY TAKEAWAY**
> **In the "business-as-usual" global greenhouse gas emissions scenario, flood hazards will INCREASE SIGNIFICANTLY in magnitude in the Salt Creek watershed by the year 2100, compared to existing flood hazards.**

Generally, flooding during the most extreme events will increase by the greatest amount. The increase in flood hazards during the 10 percent annual chance flood event in the year 2100 is not expected to be as extreme as other events – an average 8 percent increase in discharge, and an average 0.6-foot rise in water surface elevation. The more extreme events will incur larger increases in discharge and water surface elevation. The water surface elevations for the 1 percent annual chance flood event and 0.2 percent annual chance flood event are expected to increase by 2.2 feet and 4.5 feet, respectively, by the year 2100.

5.4 Uncertainty in Future Flood Hazard Projections

As is the case with all future projections that plan as far ahead as the year 2100, there is a great deal of uncertainty in this forecast of **future conditions** flood hazards. Some of the key sources of uncertainty in projecting future conditions flood hazards are as follows:

- *Uncertainty in **updated conditions** precipitation frequency estimates* – NOAA Atlas 14 (NOAA 2013) is the best source for **updated conditions** precipitation frequency estimates; however, the estimates it provides have a relatively wide margin of error. For example, the 24-hour, 1 percent annual chance precipitation event estimate for the City of Lincoln has a depth of 7.27 inches from NOAA Atlas 14. However, the 90 percent confidence interval of this estimate is 5.68 to 9.16 inches – a very large spread that adds uncertainty to any hydrologic and hydraulic model.

- *Uncertainty in future land use changes* – The Lincoln-Lancaster County 2040 Comprehensive Plan has mapped out specific areas of future growth; however, these planned areas become more and more uncertain the further into the future they are projected. Proper planning and implementation of future stormwater controls could help mitigate the effects of future development. This is not accounted for in the analysis.

- *Uncertainty in the human response to climate change* – In this analysis, two potential future rates of global carbon emissions were examined – RCP4.5 and RCP8.5. If moderate steps to curb emissions are taken on a global scale (RCP4.5), the impact of climate change on Salt Creek flood hazards are expected to be minor. However, under the "business-as-usual" carbon emissions scenario (RCP8.5), the impacts of climate change on Salt Creek flood hazards would be substantial. These are just two in a wide range of possible human responses to climate change. In the future, carbon emissions could be lower than both of these RCPs, in between, or higher than both. The degree to which the global community reduces or fails to reduce carbon emissions is highly uncertain.

> ➢ **KEY TAKEAWAY**
> **There is a high degree of uncertainty in future conditions flood hazard analysis. When planning for future resiliency, it is critical to account for this uncertainty.**

- *Uncertainty in climate modeling* – In this analysis, seven different GCMs were examined. The median model result, as shown in Table 43, depicts substantial increases in flood hazards. However, the models vary in how they predict flood risk changing for the Salt Creek watershed. **Table 44** shows the low, median, and high future conditions GCM projections compared to existing conditions flood hazards. In general, the uncertainty is higher for more extreme events. Note that these low, median, and high results depict the uncertainty in the GCM (RCP8.5 scenario) climate modeling only and do not include the other sources of uncertainty.

Table 44. Low, Median, and High Future Conditions Flood Hazards on Salt Creek Compared to Existing Conditions Flood Hazards (RCP8.5).

	Low 1% Annual Chance Event Projection	Median 1% Annual Chance Event Projection	High 1% Annual Chance Event Projection
Average Increase in Discharge (cfs)	+2,800	+6,500	+8,500
Percent Increase in Discharge (%)	+9	+28	+37
Average Increase in Water Surface Elevation (ft)	+1.2	+2.2	+3.1

5.5 Summary - Future Flood Resiliency

In the City of Lincoln, flood hazards on Salt Creek and its tributaries can be expected to increase in the future. The degree of increase is uncertain, but generally Lincoln should expect floodwater surface elevations multiple feet higher than the existing conditions flood hazard data. When considering resiliency and potential flood hazard risk reduction measures, it is critical to allow for these increases.

SECTION 6 – POTENTIAL FLOOD RISK REDUCTION MEASURES

A resilient flood management plan requires a comprehensive flood risk reduction strategy that includes both structural and non-structural measures. The foundation of a flood management plan includes robust non-structural measures, such as floodplain management policy, buyouts, relocations, floodproofing, and preservation of open space. These non-structural measures are complemented by structural flood risk reduction measures. The proposed measures must be designed to manage the events and hazards that may occur in the present day, but they also must account for future hazards and how those hazards may evolve over time.

6.1 Nonstructural Flood Risk Reduction Measures

Based on information analyzed in this study including revised flood data, national BMPs, and the BMPs from comparable communities, we recommend six non-structural flood resiliency measures to the city and LPSNRD for further consideration. The non-structural measures that are described in the following sections include the following:

- Cluster subdivision regulations
- Overlay zoning
- Voluntary buyout program
- Setbacks and riparian preservation
- LID regulations
- Higher floodplain management standards

The measures selected were evaluated based on conversations with the project team, the review of comparative regulatory levels from other communities, feedback from the stakeholder group, and anticipated benefits associated with implementation of the measures. For example, several communities identified in the BMP section of this study offer consistent funding sources for buyout programs, which is a more formalized process than has been implemented in Lincoln. These communities have seen impressive returns on investment based on the modest local funding requirements and successful removal of structures from the floodplain. This programmatic revision is identified as having a high potential impact on reducing risk, while still having a feasible financial path to implementation.

Each recommendation should be considered complementary to other recommendations, a building block in the strategy for risk reduction. These recommendations further expand upon BMPs and provide next steps for implementation. Each recommendation includes:

- A reference to the BMP in which it was first identified
- A description of the recommendation
- An overview of why it is beneficial to the Salt Creek watershed
- An evaluation of potential CRS points
- Identified next steps

The CRS points are based on the 19 different activities laid out in the four series in the CRS program (FEMA 2017). The point levels are estimations, and a more refined understanding of points will be based on the specifics of implementation for any given recommendation. Also see Section 3.1 FEMA Community Rating System (CRS).

6.1.1 Cluster Subdivision

BMP of Reference: NOAA

Cluster subdivision regulations protect open space or environmentally sensitive lands, including hazard-prone areas. Clustering development means grouping or directing new development to relatively less-sensitive areas within a subdivision. This strategy does not increase the overall density of a development, but rather allows dwellings to be grouped (or “clustered”) on smaller lots that are out of the floodplain or flood hazard area. An additional benefit is retaining greenspace as an amenity for the community.

This regulation would be implemented through the subdivision regulations in the jurisdiction with land use control – either the City of Lincoln and/or Lancaster County. This tool can be mandatory in areas of mapped flooding or an optional incentive in combination with other tools. The City of Omaha has implemented cluster subdivisions in section 53-11 of their code of ordinances (City of Omaha 2020). The code states that this tool allows for greater flexibility in design and development to produce more innovative environments, provides for more efficient use of land, protects topographical features, permits common open space, and permits private pedestrian and vehicular access. As noted in Omaha’s regulation, the open space that is maintained through this process must also include a plan for the permanent maintenance of all proposed open space and common facilities.

Benefits to the Salt Creek Watershed

Currently, Lincoln does not use cluster subdivision regulations. The Drainage Criteria Manual (City of Lincoln Public Works and Utilities Department 2014) and the Comprehensive Plan (Lincoln-Lancaster County Planning Department 2016) both include recommendations for cluster development; but formal requirements or incentives can help. Incentive examples include waivers to block lengths, rear yard setbacks, and development density. Infill development should be restricted in the floodplains and minimum flood corridors.

As Lincoln and Lancaster County continue to develop, new development can retain value while keeping structures out of harm’s way by placing them on the portions of a platted subdivision that are low risk for flooding, which greatly increases safety and reduces risks to life, health, and property in the community. Clustered subdivisions will retain a community asset with green space, reduce insurance costs for residents, reduce impacts downstream, and reduce risk to new development. Additionally, the open space maintenance will be accounted for through the subdivision process and will not put additional burden on the city or county.

Potential CRS Points

In addition to the critical task of protecting life, health, and property from flood risks, CRS points can also be obtained. CRS Activity 420 (FEMA 2017) includes open space preservation, which is a benefit of cluster subdivisions. The CRS points available for open space preservation are shown in **Table 45**.

Table 45. 420 Open Space Preservation Points Schedule (Applicable Categories).

Activity	Maximum Points	Description
Open space preservation	1,450	Keeping land vacant through ownership or regulations
Deed restrictions	50	Extra credit for legal restrictions that ensure that parcels credited for open space preservation will never be developed
Natural functions open space	350	Extra credit for preservation or restoration of open space preservation parcels
Open space incentives	250	Extra credit for local requirements that keep flood-prone portions of new development open
Source: CRS Coordination Manual (FEMA 2017)		

Clustered subdivision regulation is discussed on page 420-23 of the CRS Coordinator's Manual (FEMA 2017).

Next Steps

Conversations with communities, such as Omaha, who have enacted cluster subdivisions could help answer questions regarding how to communicate the benefits of this tool, how implementation has played out, and lessons learned. Implementing cluster subdivision regulations must be a coordinated effort with Lincoln and with the Lancaster County Planning Department to craft cluster subdivision regulations for new development. The entities must also determine the regulatory standard of the regulation and areas of applicability.

6.1.2 Overlay Zoning

BMP of Reference: NOAA

An overlay zone (or district) is an additional layer on top of a base zone district that provides additional guidance or restrictions for development. A key benefit to implementation is that a jurisdiction can address the area of concern without amending all other relevant sections of the code.

An overlay zone does have similarities to the NAI standards in new growth areas already established in Lincoln's unincorporated planning area. However, overlay districts may also include guidance on building standards to protect occupants from flood hazards, restrictions on uses, requirements for water and sanitation infrastructure, and site design guidance to ensure that improvements on the land are located out of harm's way.

The new growth areas can provide a boundary for an overlay district; however, given the revised data and continuing growth, these boundaries should be evaluated. The key elements of overlay zone language include the purpose, applicability, overlay zone map, development standards, and review procedures. In addition to the standards established through no net rise, additional regulations and guidance for substantial improvements and development in other areas of the community and with other regulatory tools could be included in an overlay district.

Higher standards for floodplain management, such as a prohibiting development in the 0.2 percent annual chance floodplain, can be simple to implement as an overlay zone. The 0.2

percent annual chance floodplain is already depicted on the existing FEMA flood maps and is also an easy concept to convey and understand.

Benefits to the Salt Creek Watershed

An overlay district can go beyond the new growth areas, offering additional regulation in established areas and areas beyond the mapped floodplain to reduce flood risks and protect lives and investments.

Potential CRS Points

Available CRS points will vary depending on the amount of area in an overlay zoning district and the specific regulations outlined in the overlay language. Activities that are potentially applicable to this strategy are shown in **Table 46**.

Table 46. Potential Applicable Community Rating System (CRS) Activities for Overlay Zoning.

Activity	Description
420 Preserving Open Space	Keeping land vacant through ownership or regulations
430 Higher Regulatory Standards	Development limitations, freeboard, foundation protection, local drainage protections, special flood-related hazards regulations, and other higher standards could all potentially be reflected in the language of an overlay district
Source: CRS Coordination Manual (FEMA 2017)	

Next Steps

To determine whether there are areas beyond the new growth boundaries that should have additional regulations and zoning restrictions, an analysis of the best available data for risk should be completed to see what parcels fall outside of the new growth area and would benefit from an overlay zone. Once the gaps are identified, the type of risk should be analyzed and then paired with effective zoning or building code regulations to mitigate the risk. This must happen in coordination with the planning and zoning department.

6.1.3 Voluntary Buyout Program

BMP of Reference: Papio-Missouri River Natural Resources District and Papillion, Nebraska, Mecklenburg County, North Carolina, and Beatrice, Nebraska

Lincoln has a history of completing voluntary buyouts on an individual project basis. A voluntary buyout program that is sustained through local funds that use federal dollars, will allow the city and LPSNRD to have a standing program available to property owners when they are ready to sell on a voluntary basis.

As noted in the reference BMP, the city or LPSNRD can serve as an overarching entity to:

1. Draft program strategy that identifies parcels for buyout, establish a system for the voluntary buyout process, and provide educational materials to eligible property owners.
2. Identify a standing funding source to sustain the program at the local and watershed level. These funds should build until there are adequate matching funds for federal grant requests.

3. Track, gather, and share data on program benefits. These should include both the losses avoided by moving people and property out of harm's way and realizing a public benefit from public and passive use of the land. Passive land uses allow for access to public land, but not to put in improvements on the land, such as building or infrastructure.

As part of a voluntary buyout program, "right of first refusal" is recommended as an additional tool that can strengthen the possibility of purchase. Right of first refusal is a contractual obligation for a property owner to offer sale to an identified entity, such as the city and LPSNRD, prior to making the property available to the general market for purchase. This ensures that the entity is notified of the opportunity for purchase and given an opportunity to purchase prior to the competing market. This would require an available funding stream and a program with adequate capacity to act within the designated time frame. Another version of this, which offers more flexibility to the property owner, is the right of first offer (or negotiation). In the case of right of first refusal, the owner must determine a price for sale. In the case of right of first offer, the two entities can negotiate a price. The latter option offers more flexibility for the homeowner and purchaser through the price negotiation process.

Benefits to the Salt Creek Watershed

To date, the city and LPSNRD have completed acquisitions on a project-by-project basis. An established and consistent funding stream and program would allow the entities to purchase properties as owners are ready to sell, giving property owners an option.

This is particularly useful in the case of repetitive-loss or nonconforming properties. If a property cannot be substantially improved, if flood insurance rates are very high, or there have been multiple claims on the property, owners might find themselves in a position where it is difficult to sell or maintain the property. At the same time, this property represents their investment. Often, these owners will continue to live on a property that repeatedly floods because they do not have an option out. Voluntary buyouts offer a way for property owners to retain some value, while also walking away from a high-hazard investment.

An acquisition program also benefits the Salt Creek watershed because it is a more comprehensive and holistic mitigation solution than other alternatives, such as elevating the structure in place. Structural elevation programs carry limitations on their benefit. The elevated structure is still subject to the broader infrastructure and impacts to the area during flooding. For example, while the structure is protected by elevation, the road network may be inundated and impassable, still creating a threat to life and safety if residents remain in the home. Buyouts remove people from the floodplain, eliminating flood risks to life, health, and property.

Potential Funding Strategy

It is strongly recommended that a voluntary buyout program have a consistent and sustained local funding source. Examples include a $.05 sale tax (City of Austin, Minnesota), a stormwater utility fee based on impervious acreage (Charlotte-Mecklenburg County, North Carolina), or an additional mil levee on property (King County, Washington). These funds are then matched with other local, state, and federal funds to create an ongoing program that has capacity to sustain buyouts when properties become available.

Potential CRS Points

Points available for this type of program fall under CRS Activity 520 (FEMA 2017), Acquisition and Relocation. The maximum credit available for this category is 2,250 points. Points applicable to this work are awarded for buildings acquired and relocated, focusing on buildings on the repetitive-loss list and severe repetitive-loss properties and critical facilities.

Next Steps

The City of Lincoln has already learned lessons through prior project-specific buyout initiatives. What has worked well and should be carried on, and what must change, should be noted. Learning the lessons from nearby communities regarding the operations, funding mechanisms, timelines, and key staff will be critical to increasing the success and efficiency of the program from the onset.

A consistent funding source must be identified, and if a new tax or fee is involved, it must be approved through local processes. Outreach and communication should be conducted to reach the owners of potential voluntary buyout properties. The property owners should be aware of the option, the benefits, and the timelines for purchase.

Identifying priority buyout properties, based on data that shows higher risk, repetitive-loss, or critical use types (i.e., multiple housing units in a structure or critical facilities) can help guide investments in engagement and prioritize properties if interest exceeds funding capacity for purchases.

Once acquired, the properties must be owned and maintained as passive open space. The program administrators should identify that entity, or those entities, that will own and maintain land and enter into an agreement prior to purchase.

6.1.4 Setbacks and Riparian Preservation

BMP of Reference: Shawnee, Kansas

Setbacks beyond the minimum corridor and riparian preservation strategies are tools to address fluvial hazards and/or erosion zones. The current minimum setback in Lincoln addresses the current conditions of the river but offers limited protection in the event of changing conditions, such as stream migration or riverine erosion. To determine setbacks that account for changing conditions, Lincoln must understand the combined impacts of possible channel degradation, migration, and bank erosion. The setbacks developed based on evaluation of these factors are often incorporated into fluvial hazard mapping for the streams in the community. Development within these areas should be restricted or prohibited. Some communities restrict development to noninhabitable structures or to those with a small footprint.

Benefits to the Salt Creek Watershed

We know that flood hazards are increasing and that river corridors are changing. This study also demonstrates that discharges are expected to increase. Setbacks and riparian preservation offer a larger buffer to protect life and property from risk and reduce the impacts. Given the uncertainty of climate conditions in the future, more conservative setbacks also add an additional layer of protection for anticipated conditions in a “business-as-usual” (RCP8.5) greenhouse gas emission scenario.

Potential CRS Points

The potential point areas are shown in **Table 47**. The full points would be dependent on the amount of land preserved for open space, the specific planning activities used for developing the regulatory standard, and the specifics of setback and development regulations.

Table 47. Potential Applicable CRS Activities for Setback and Riparian Preservation.

Activity	Description
420 Preserving Open Space	Streamside buffers and setback regulations (provided that they prohibit buildings and filling), greenway, and setback rules for floodplain preservation
510 Floodplain Management Planning	Natural floodplain functions planning may be a relevant initial step for this recommendation
430 Higher Regulatory Standards	Development or redevelopment limitations around riparian areas, such as maintaining the flood-attenuating benefits of natural areas, and the “other higher standards” categories are applicable for this recommendation
450 Stormwater Management	Watershed master planning may be a relevant first step for this recommendation
Source: CRS Coordination Manual (FEMA 2017)	

Next Steps

The City of Lincoln should conduct a study to understand a setback envelope based on possible channel degradation, migration, and bank erosion for both a “business-as-usual” (RCP8.5) model and also a model for “significant action greenhouse gas emissions reduction in the next 20 years” (RCP4.5). This data can be the foundation for determining a boundary for waterways that provides a more conservative level of setbacks and riparian preservation boundaries to protect lives and investment.

6.1.5 Low-impact Development Regulations

BMP of Reference: Fort Collins, Colorado

Lincoln has invested in developing LID recommendations specific to the climate and geography of the area. The city has noted this best practice in the “Alternative Stormwater Best Management Practices Guidelines” document (City of Lincoln and the LPSNRD April 2006), which provides guidance on specific strategies and vegetation. Currently, these are not mandatory on any parcel. Lincoln should consider making LID regulations mandatory to reduce water runoff and to improve water quality. The regulatory standards for LID vary greatly from community to community.

Fort Collins requires that:

- 50 percent of new impervious surface area must be treated by a LID-type device or technology (e.g., bio-retention cell, bio-swale).
- At least 20 percent of new parking areas must be designed to be pervious.
- A design alternative that provides equal or better treatment than the previous requirements must be implemented.

The Mile High Flood District in the Denver metro region has developed a tool to identify which LID practices to implement through the site design process. This is a spreadsheet tool that includes a tab titled BMP Selection Tool. The tool can be found on the district’s website (Mile High Flood District 2018). By stepping through several questions about the development site in question (for example, “To identify potential BMPs, what best describes that type of site?”), the user is guided through a decision-making process that identifies effective and feasible LID regulations.

Benefits to the Salt Creek Watershed

The City of Lincoln currently has water quality standards for new development and redevelopment, which require the implementation of water quality management practices. The primary benefits of LID improvements are improving water quality by filtering pollutants, reducing the rate of runoff, and diminishing the overall impacts of impervious surfaces. Implementation can also have a small impact on the number and severity of flooding events, improve groundwater recharge, enhance property value, reduce irrigation and energy demands, enhance neighborhood aesthetics, and reduce the impact of heat islands.

Next Steps

The burden of mandatory LID regulations falls generally on developers and property owners. The City of Lincoln can provide a match or incentives to engage in LID practices. The USEPA has completed a cost-benefit analysis of LID practices. The case studies note that "savings of tens to hundreds of thousands of dollars in site work and infrastructure costs with the application of LID/BMPs…[so] in most cases, savings more than offset costs associated with the systems development fees" (EPA 2013). The city should meet with stakeholders, including those who have completed projects that include LID and those who are concerned about the impacts on development, to understand what regulatory standard may be appropriate for the city and what support the community needs for successful implementation.

Potential CRS Points

LID requirements fall under CRS Activity 450 Stormwater Management, and details can be found on page 450-8 of the CRS Coordinator's Manual (FEMA 2017). The maximum number of points for LID is 25, and the total number of points are awarded when a community requires LID for all new development and for redevelopment. Partial points are awarded to communities that require LID for development of a certain size.

6.1.6 Higher Floodplain Management Standards

BMP of Reference: Cedar Falls, Iowa

The City of Lincoln can benefit from increasing regulatory standards for freeboard and restricting allowable uses within flood-prone areas. Approximately 20-25 percent of all flood claims occur outside of FEMA's mapped Special Flood Hazard Areas (EPA, 2013).

Following the establishment of a Mayor's Floodplain Ordinance Task Force, Cedar Falls reviewed and revised its floodplain development regulations to include higher standards than those outlined by FEMA. During Cedar Falls' update major consideration was given to the flood losses associated with flooding events that exceeded the 1 percent annual chance flood elevations, flooding outside of the city's mapped 1 percent annual chance floodplain, and the amount of growth occurring throughout the community. The city addressed these challenges by focusing on freeboard and use requirements.

Cedar Falls now exceeds the minimum NFIP standard for lowest floor elevation requirements by requiring buildings to be elevated or floodproofed (depending on building category) to a minimum of 1 foot above the 0.2 percent annual chance flood elevation. Other communities have chosen to regulate using a similar strategy, but with different reference elevations.

Similar outcomes can be achieved by basing regulations on a future conditions flood elevation, a more conservative return period flood elevation, or by using additional freeboard above the existing conditions 1 percent annual chance flood elevation. There are communities in the NFIP that regulate using freeboard greater than 1 foot above the 1 percent annual chance flood elevation. At sample locations in and around Lincoln, the difference in elevation between the 1 percent and 0.2 percent annual chance flood event is approximately 2 feet. Thus, applying a freeboard requirement like that of Cedar Falls (1 foot above the 0.2 percent annual chance flood elevation) would generally equate to elevating (or floodproofing) structures approximately 3 feet above the 1 percent annual chance flood elevation.

Higher freeboard requirements can also be applied to infrastructure, including on-site wastewater treatment systems (septic systems). These systems must be protected from flooding up to the freeboard elevation, and these requirements typically apply across the system design to include tanks, ports and access, soil treatment areas, and building connections. In Boulder County, Colorado, tanks are required to be anchored to resist the effects of buoyancy because of static flood forces, even in the 0.2 percent annual chance floodplain where groundwater elevations may be affected during floods of lesser magnitudes.

Another opportunity for higher regulatory standards that is recommended is prohibiting development in the 1 percent annual chance and the 0.2 percent annual chance floodplains (as discussed in Section 6.1.2). At a minimum, critical facilities should be prohibited in the 0.2 percent annual chance floodplain. Applying these prohibitions to schools, hospitals, and other care facilities and to emergency and essential services and communication infrastructure helps reduce the flooding exposure of large, gathered, and vulnerable populations, and it ensures public safety during and following a disaster.

Benefits to the Salt Creek Watershed

Higher regulatory standards, as recommended above, will improve the resilience of development, reduce structural damage, protect real estate and infrastructure investments, keep critical facilities out of harm’s way, and ensure continuity of services and operations. These improvements translate to the paramount benefit of a safer community with decreased risks to life, health, and property. These higher standards should be implemented strategically across identified new growth areas as well as in areas of existing development where maintenance, repairs, improvements, and reconstruction take precedence.

Potential CRS Points

CRS Activity 430, Higher Regulatory Standards, offers a broad mix of eligible activities. The total eligible points will vary depending on the standards implemented. While not anticipated that all eligible activities would be implemented, the total available points for higher regulatory standards elements is 2,462.

Next Steps

The city and LPSNRD should evaluate where data indicate a standard would mitigate known risk. For example, in new and existing development, an assessment of elevation differences between the 1 percent annual chance and the 0.2 percent annual chance elevations throughout the county will guide the best freeboard method to appropriately mitigate risk. Depth-damage curves can provide the city and LPSNRD with an understanding of the potential losses, and the potential savings, associated with different amounts of freeboard.

When it comes time for a regulation or policy language update, these assessments can be used to demonstrate to city and county officials, as well as the public, the benefits of adopting higher freeboard requirements for buildings and other development.

6.1.7 Summary of Nonstructural Flood Risk Reduction Measures

The study recommends the city and LPSNRD take into further consideration six non-structural flood risk reduction measures. The non-structural strategies include cluster subdivisions regulations; overlay zoning; voluntary buy program; setbacks and riparian preservation; LID regulations; and higher floodplain management standards.

The strategies selected were evaluated based on conversations with the project team, the review of comparative regulatory levels from other communities, and anticipated benefits associated with implementation of the strategies.

In addition to the six non-structural flood risk reduction measures recommended, the public can implement many other voluntary practices such as the installing rain gardens, installing green roofs, using pervious pavement, and amending soils to increase infiltration, reduce runoff, and improve water quality. These measures, along with many other measures are described in Alternate Stormwater Best Management Practices Guidelines, City of Lincoln, Nebraska and the Lower Platte South Natural Resources District, April 2006 (LTU 2006b).

6.2 Structural Flood Risk Reduction Measures

The performance of the proposed structural flood risk reduction measures for this study have been analyzed using the **existing conditions**, **updated conditions**, and **future conditions** precipitation and their associated discharge values developed in Section 5. Because of the limited scope of this investigation, the analysis focuses on the 1 percent annual chance flood event and the 0.2 percent annual chance flood event. The 10 percent annual chance flood event and the 2 percent annual chance flood event were not analyzed.

6.2.1 Existing Hydraulic Model

The existing flood elevations and floodplain extents are calculated using the unsteady-state HEC-RAS model of Salt Creek developed by the City of Lincoln in 2007. The subbasin hydrographs that are used as inputs for the hydraulic model are developed from the HEC-HMS models described in Section 5. The unsteady-state HEC-RAS model is used to route the runoff hydrographs along Salt Creek. The HEC-RAS model is unsteady and thus accounts for storage in the Salt Creek floodplain. In reaches where the levees are present, effective flow is contained within the levees. The reaches of the Salt Creek HEC-RAS model are described in **Table 48** and shown in **Figure 16.**

Table 48. Salt Creek HEC-RAS Model Summary.

Reach	Description
MC05	Downstream of confluence with Steven’s Creek, Cross-section 1.172 to 0.703
MC10	Reach from Little Salt Creek confluence to Steven’s Creek confluence, Cross-section 6.186 to 1.2215
MC50	Reach from confluence of Middle Creek to confluence of Little Salt Creek, Cross-section 13.1181 to 6.548, includes downstream limit of Salt Creek levees at River Station 8.093, Superior Street
MC60	Reach from Haines Branch to Middle Creek, Cross-section 14.991 to 13.156
MC80	Reach from confluence of Cardwell Branch to confluence of Haines Branch, Cross-section 20.656 to 14.776, includes upstream limit of Salt Creek levees at 15.5273 (between Pioneers Boulevard and Van Dorn Street)
MC110	Reach upstream of confluence of Cardwell Branch, Cross-section 29.537 to 20.775, includes Saltillo Road and Warlick Boulevard

The existing model includes simulations of the 10, 2, 1, and 0.2 percent annual chance flood events. The hydrographs were developed based off the precipitation values provided in the City of Lincoln Drainage Criteria Manual. As discussed in Section 5, the Drainage Criteria Manual precipitation values are from TP40.

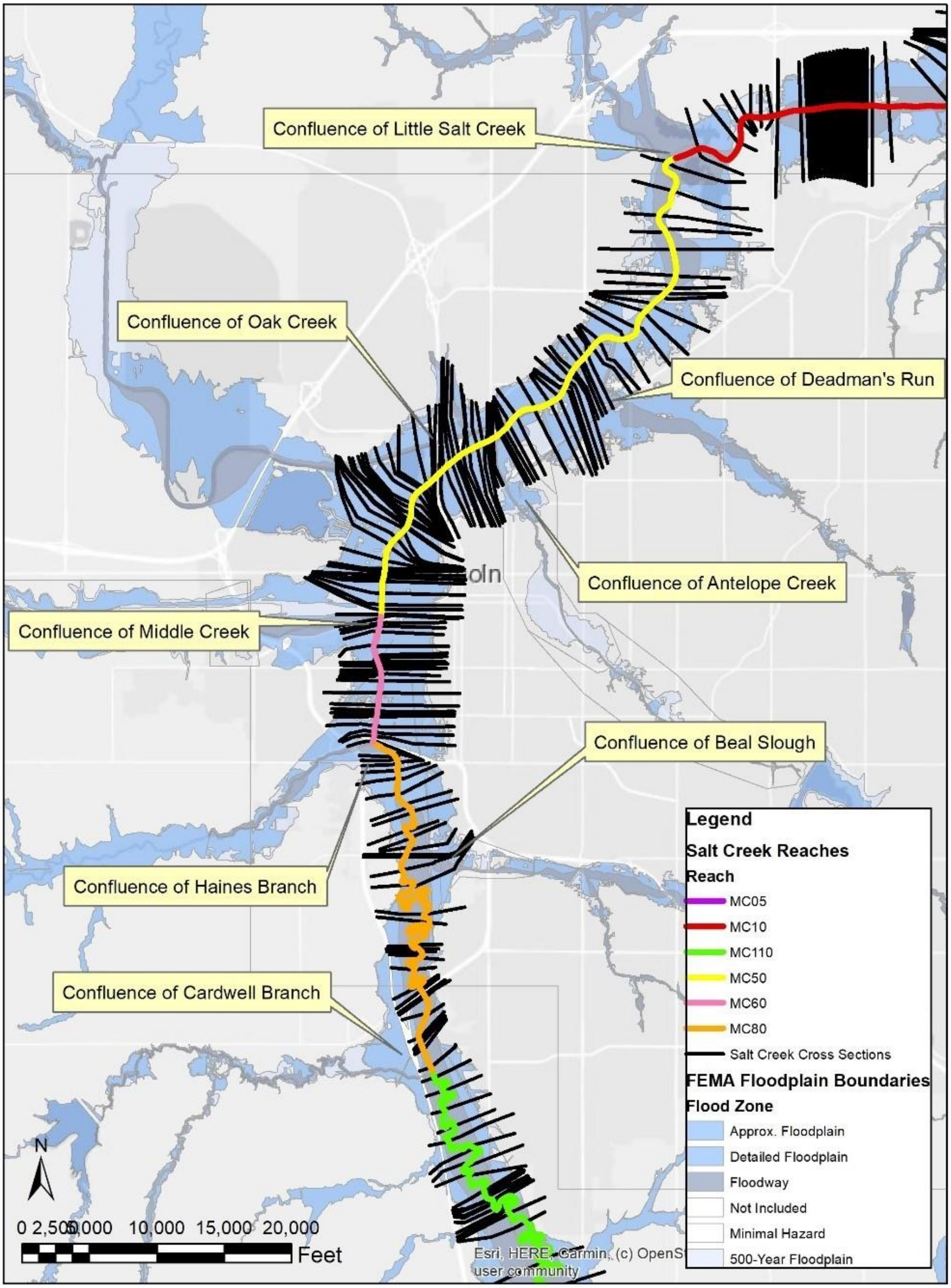


Figure 16. Salt Creek HEC-RAS Model – Reaches and Cross-sections.

6.2.2 Existing Conditions Flows

To create an **updated conditions** analysis, the runoff hydrographs from the **existing conditions** model were adjusted by the percentage increase values developed in Section 5 (see Table 34). These values are based on a comparison of runoff rates developed using NOAA Atlas 14 precipitation frequency estimates to runoff rates developed using the **existing conditions** (TP40) estimates. The percentage of change values were provided for each of the seven different Salt Creek subbasins modeled in HEC-HMS. Hydrographs for Salt Creek subbasins that were not modeled in HEC-HMS were adjusted by the average percentage of change for the HEC-HMS modeled subbasins. A comparison of the subbasin discharge rates generated using the NOAA Atlas 14 precipitation values to the runoff rates from the **existing conditions** model is provided in Section 5 (see Table 33). A comparison of the **updated conditions** flood hazards to **existing conditions** flood hazards is provided in Section 5 (see Table 35).

6.2.3 Future Conditions Flows

To determine how the discharges in the Salt Creek HEC-RAS model would change using **future conditions** precipitation frequency estimates, the runoff hydrographs from the **existing conditions** model were adjusted by the percentage of change values developed in Section 5 (shown in **Table 49**). The hydrologic models were created for each of the seven subbasins by modifying the respective HEC-HMS models. The percentage of change values for the seven modeled subbasins were taken directly from the HEC-HMS model results. For the other subbasins, the average percentage of change for the seven modeled subbasins was used to adjust the **future conditions** hydrograph.

Table 49. Percentage of change in Discharge Between Existing and Future Conditions (Median GCM and RCP8.5)

Subbasin	10% Annual Chance Flood Event Discharge (% change)	2% Annual Chance Flood Event Discharge (% change)	1% Annual Chance Flood Event Discharge (% change)	0.2% Annual Chance Flood Event Discharge (% change)
Antelope Creek	20	28	29	54
Cardwell Branch	3	16	22	41
Little Salt Creek	15	40	47	109
Middle Creek	3	18	24	47
Oak Creek	4	24	33	72
Southeast Upper Salt Creek	3	24	31	43
South Salt Creek	6	25	33	53
AVERAGE %	**8**	**25**	**31**	**59**

6.2.4 Existing, Updated, and Future Impacts

The 1-percent annual and 0.2 percent annual chance flood events were simulated using the existing HEC-RAS model geometry and the flow rates for each of the three conditions described above **(existing conditions** flow rates, **updated conditions** flow rates, and **future conditions** flow rates). The computed flood profiles for each of the three conditions, for the 1 percent and 0.2 percent annual chance flood events, are provided in **Figures 17 and 18**.

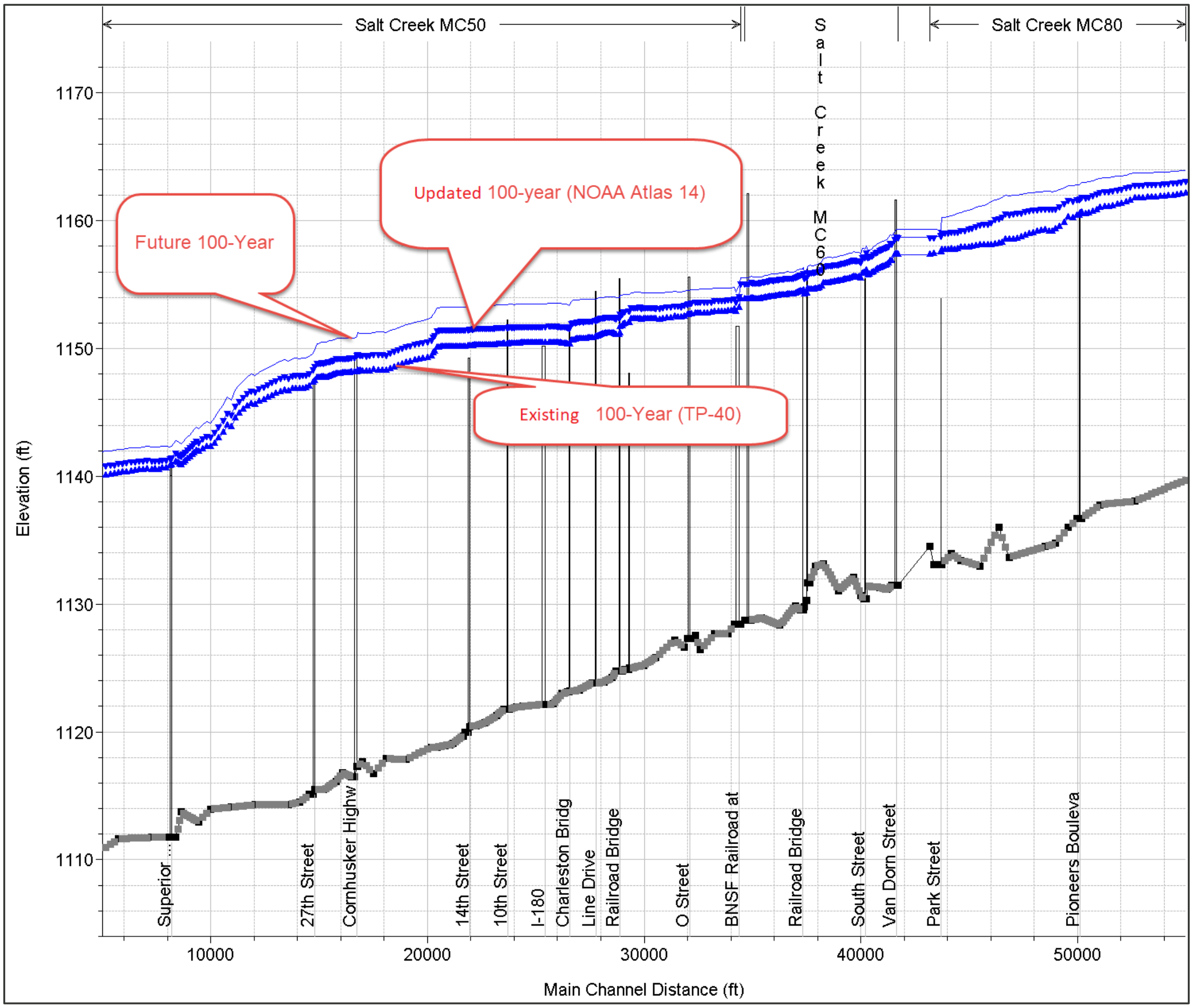


Figure 17. Existing Conditions (TP40), Updated Conditions (NOAA Atlas 14), and Future Conditions 1 Percent Annual Chance Flood Profiles Without Structural Flood Management Measures.

The leveed reach of Salt Creek is the segment of Salt Creek that is protected by the Salt Creek Flood Risk Reduction project, or the Salt Creek levees. The levees protect portions of the Salt Creek floodplain from Superior Street, at the downstream end, to Calvert Street, at the upstream end. According to the existing models, the levees provide a level of protection approximately equivalent to a 2 percent annual chance event. HEC-RAS model results indicate the average increase in flood elevations within the leveed reach of Salt Creek (HEC-RAS reaches MC50 and MC60) between the **existing conditions** model and the **updated conditions** model is approximately 1.3 feet for the 1 percent annual chance flood event and 4.1 feet for the 0.2 percent annual chance flood event. The HEC-RAS output indicates the **updated conditions** precipitation data results in higher flow rates and higher flood elevations, and consequently, larger floodplain extents for Salt Creek. The **existing conditions** models and data underestimate the current flood risks along Salt Creek and tributaries. The larger the storm event, the greater the difference between the peak flow rates and flood elevations for the **updated conditions** results compared to those from the existing model.

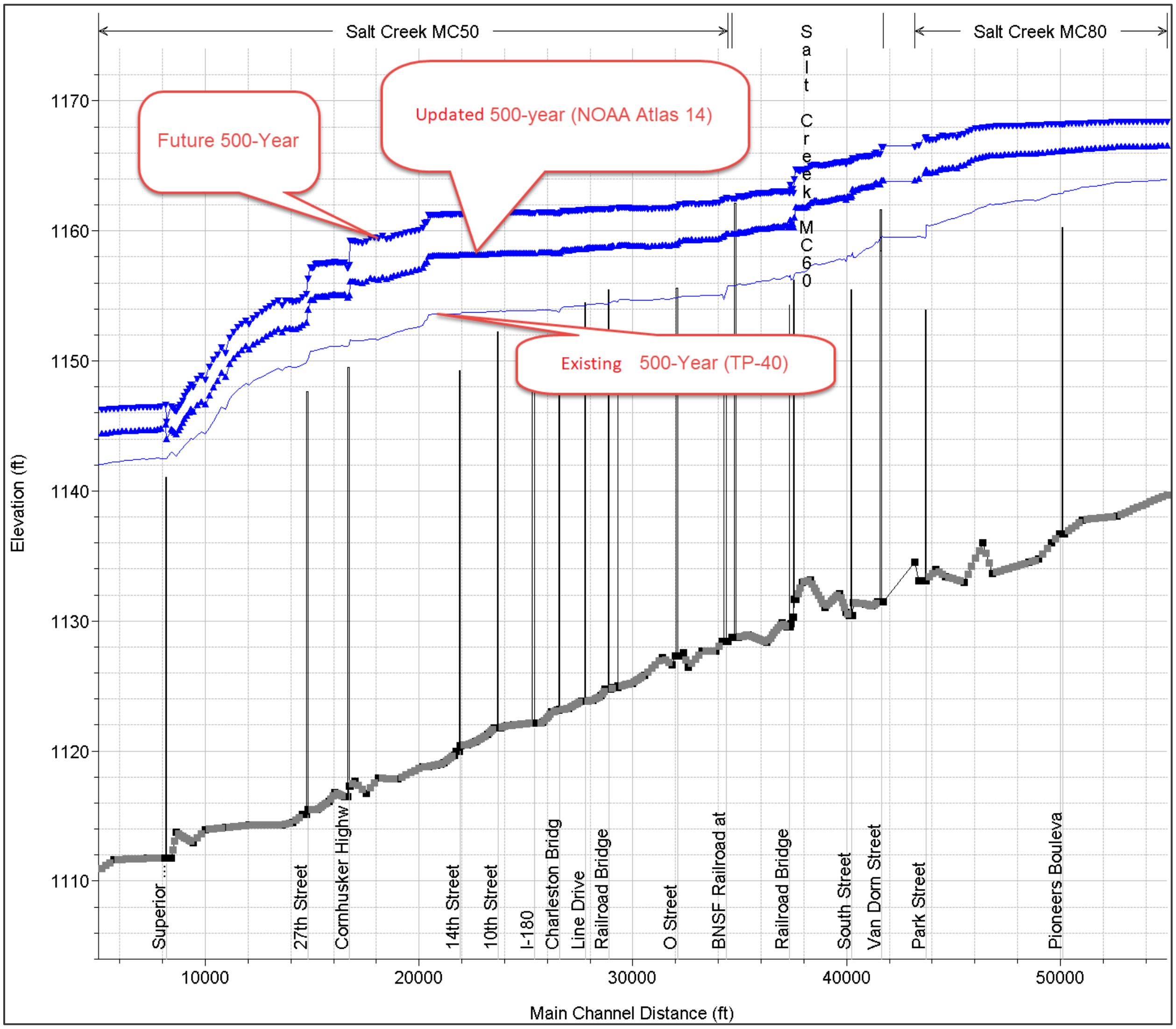


Figure 18. Existing Conditions (TP40), Updated Conditions (NOAA Atlas 14), and Future Conditions 0.2 Percent Annual Chance Flood Profiles Without Structural Flood Management Measures.

The average increase in flood elevations for the leveed reach of Salt Creek between the **existing conditions** model and the **future conditions** model is approximately 2.4 feet for the 1-percent annual chance flood event and 7.0 feet for the 0.2 percent annual chance flood event. The results indicate the **future conditions** precipitation data developed in Section 5 results in much higher flows and flood elevations than the **existing conditions** model.

The **existing conditions** HEC-RAS model for Salt Creek was developed assuming effective flows for the leveed reach only occurs between the levees. Floodwaters outside the levees count toward flood storage and flood flow attenuation; however, the floodwaters in the overbanks are assumed to be backwater areas, with no conveyance. When modeling higher flow rates, based on **updated conditions** or **future conditions** rainfall amounts, the flood elevations exceed the top of levee elevations, particularly for the 0.2 percent annual chance flood event. The higher modeled flows are still confined within the levees in the HEC-RAS model. Actual flood flows would overtop the levees and spread into the overbank. The flooded areas outside the levees would be directly connected to the flowing floodwater in the channel and would also flow freely. Confinement of the flows between the levees may not be an appropriate constraint for the **updated conditions** and

future conditions models. However, developing a new hydraulic model that includes free flow of floodwater outside the levees is outside the scope of this project. The net result of this modeling constraint is that the computed flood elevations for **updated** and **future conditions** overestimate flood elevations.

The results indicate that flood elevations developed using **updated conditions** precipitation amounts and **future conditions** precipitation amounts will increase and will overtop the levee for the 1 percent and the 0.2 percent annual chance flood events. The level of flood protection provided by the levees has decreased and will decrease further if design precipitation rates increase. The risk for flooding is much higher today than the existing models indicate. Potential flood risks and potential flood damages will also increase. The current regulatory floodplain for Salt Creek overlaps more than $1 billion in property and infrastructure. The **updated conditions** and **future conditions** floodplains will inundate larger areas and more property and infrastructure. Large-scale structural flood management measures would be necessary to mitigate increases in precipitation and to offset the increases in flood elevations and floodplain extents for Salt Creek.

6.2.5 Current Flood Management Measures

As described in Section 3, the portion of the Salt Creek watershed that contributes runoff to the levee system (Upper Salt Creek, Cardwell Branch, Haines Branch, Middle Branch, Oaks Creek, Southeast Upper Salt Creek, Beal Slough, Antelope Creek, and Deadmans Run) has 10 large flood management dams, built by the USACE, and 66 smaller dams, controlled by the LPSNRD. Branched Oak Lake and its dam is the largest flood management reservoir in the basin. According to the NeDNR database, there are 79 NRCS dams (74 are regulated) in the same portion of the Salt Creek watershed (NDNR 2020). Approximately 50 of these structures are PL-566 flood management structures, installed by the NRCS and the LPSNRD, from the 1960s through the 1980s. The LPSNRD constructed 10 additional structures in the Steven's Creek watershed, which has its confluence with Salt Creek downstream of the Salt Creek levee system.

The dams reduce peak flows along Salt Creek through Lincoln by controlling their respective contributing drainage areas and limiting peak runoff rates from those areas. Most of the dams were constructed in the 1960s. The dams manage a significant portion of the Salt Creek watershed. The confluences of South Salt Creek (including the Hickman Tributary to Salt Creek), Southeast Upper Salt Creek, and Cardwell Branch are all upstream of the Salt Creek levees. The confluences of Haines Branch, Middle Creek, and Oak Creek are all located in the leveed reach of Salt Creek. The existing dams in these tributaries control approximately 282 square miles, or 44 percent of the 610-square-mile total drainage area from the tributaries. The dams reduce peak flows on Salt Creek significantly; however, more than half of the total Salt Creek drainage area upstream of the confluence Oak Creek remains uncontrolled.

Large, high-hazard dams provide most of the flood management on the tributaries. Branched Oak, Pawnee, Wagon Train, Stagecoach, Conestoga, Yankee Hill, Twin Lakes, Olive Creek, and Bluestem are all large, high-hazard dams, designed by USACE. Together, they manage runoff from approximately 214 square miles, or 35 percent of the approximately 610 square miles of the tributaries to Salt Creek. The remaining 9 percent of the tributary drainage areas is controlled by smaller dams.

The existing flood management facilities are included in the hydrologic and hydraulic models used to develop the existing FEMA flood elevations and floodplain extents. For example, the hydrologic models for Oak Creek and Upper Salt Creek include the reservoirs in the model. For other tributary watersheds, which are not modeled in a detailed hydrologic model, like Middle Creek, the runoff hydrographs input into the Salt Creek HEC-RAS model are based on the runoff hydrographs, with the dams in place. The Salt Creek flow hydrographs and peak flood elevations were calibrated to the USGS stream gage data for gages along Salt Creek, in Lincoln. Thus, the models inherently reflect the impacts of the existing large and small flood management structures on Salt Creek runoff. The existing structures substantially reduce potential flooding of Salt Creek and provide protection to property and infrastructure along Salt Creek. However, the existing structures do not reduce Salt Creek flooding enough for the Salt Creek levees to contain the 1 percent annual chance floodplain on the stream side of the levees.

The potential flood elevations for **updated conditions** are higher than those computed by the existing model. If the "do nothing" scenario occurs and carbon dioxide levels continue to rise, future potential flooding could be worse. A comprehensive flood management plan is needed to minimize future flood damages and flood risks. Future risks must be presented to the community to set realistic expectations. A goal in a comprehensive flood management plan may include that future buildings/developments be protected to the **updated conditions** level of protection, as identified in this study, using non-structural measures.

6.2.6 Potential Flood Management Measures

Previous studies have included analyses of dams and offline storage facilities for flood management measures in the non-urbanized tributaries to Salt Creek. Previous studies for flood management structures were limited in the scope of the flood management measures employed and demonstrated limited benefits (see Section 4). This study focuses on a more comprehensive use of dams as flood management measures. Dams are used for several reasons, including these:

- Constructing a flood management dam is typically less expensive than an offline flood storage facility. All the flood storage for an offline facility is created by excavation. For every cubic yard of storage created, a cubic yard of earth must be excavated and removed.

- Reservoir levels behind dams can be more easily adjusted to provide seasonal water supply for baseflow augmentation, a water quality reservoir, and recreational use. Dams can provide a wider array of benefits.

- Dams are far more common than offline storage facilities. Funding sources for dams are also more common.

- Dams are typically capable of providing greater peak flow rate reductions for watershed runoff than offline storage facilities.

- Dams upstream from urban areas are typically designed to detain runoff from flood events larger than the 1 percent annual chance flood event. These dams typically detain the 0.2 percent annual chance flood event without flow overtopping the auxiliary spillway. Thus, dams are more likely to continue providing the intended level of flood risk reduction under future climate scenarios, with more frequent and larger extreme flood events.

The purpose of this analysis is to evaluate a conceptual system of flood management measures that reduce flood elevations for the 1 percent annual chance flood event for **existing conditions**, as shown in the FIS (NFIP 2013), to a level below the top of levee and low enough to provide the 3 feet of freeboard required to accredit a levee system, where possible.

Additionally, the conceptual system of flood management measures is intended to reduce the increased 1 percent annual chance flood elevations associated with **updated** and **future conditions** flood events to a level equal to or below the **existing conditions** flood elevations, as show in the FIS 2013, for a majority of the Salt Creek levee segments.

This analysis does not involve the development of recommendations for specific dam sites. Thus, the locations of the dams that were evaluated are not provided. Dams were evaluated for each of the unurbanized drainage areas that contribute runoff to the leveed reach of Salt Creek. The conceptual system of flood management measures was not optimized, and no alternative analyses were performed for locations or configurations of dams.

For the analysis, 16 dams were modeled in six subbasins. Dams were modeled in Upper Salt Creek (including Hickman Branch); in the three unnamed tributaries to Salt Creek; in Cardwell Branch; in Haines Branch; in Middle Creek; and in Oak Creek. A map showing the contributing drainage area controlled by the modeled dams is shown in **Figure 19**.

Conceptual design plans were developed for the dams in South (Upper) Salt Creek and Oak Creek to develop a preliminary opinion of probable cost for the analyzed structures. The conceptual designs provide cost opinions for a range of dam sizes. The conceptually designed dams were also modeled in HEC-HMS. Details from the conceptual design of seven dams are provided in **Table 50**.

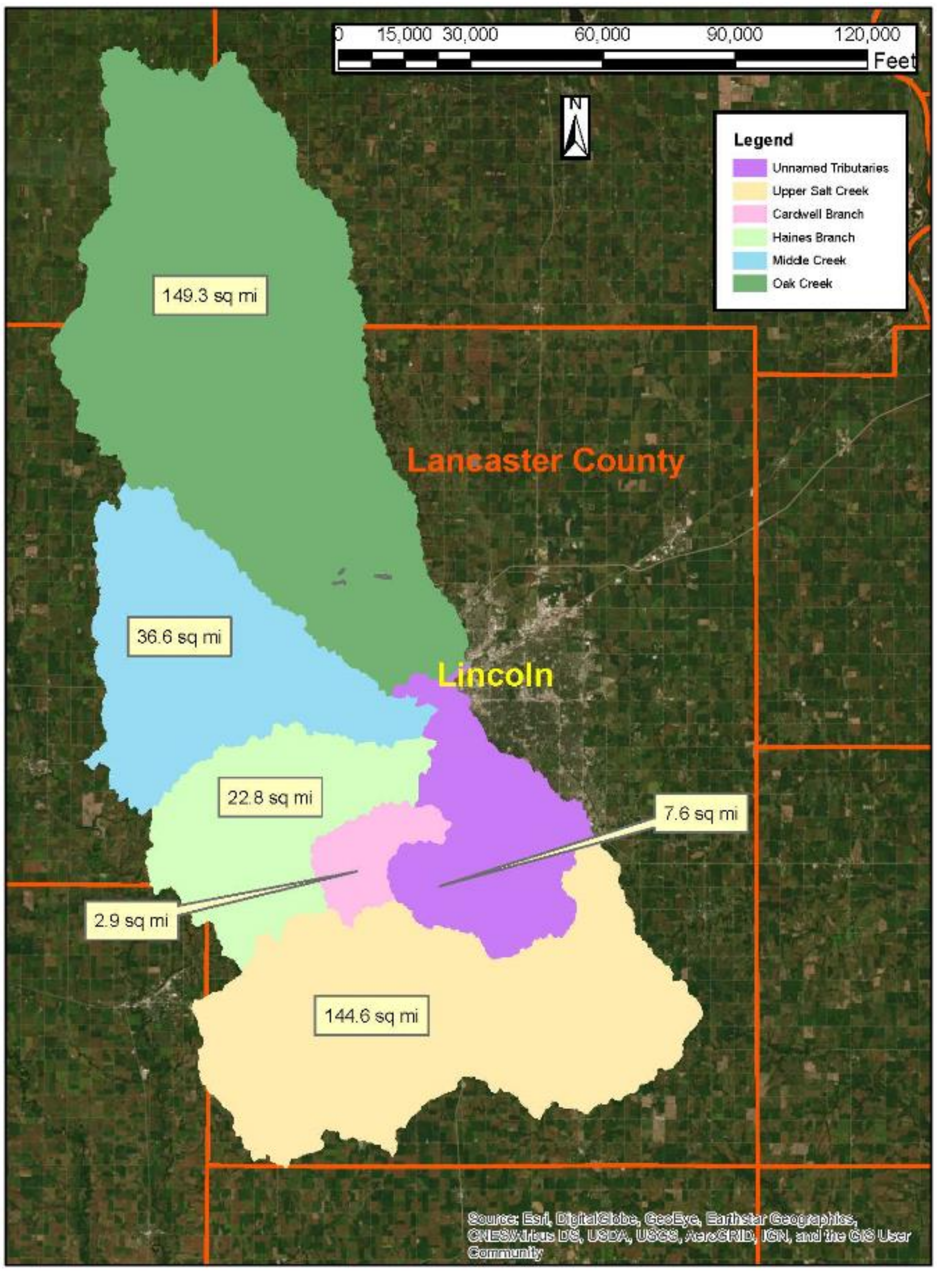


Figure 19. Contributing Drainage Areas Managed by the Modeled Dams.

Table 50. Details from Conceptual-Design of Seven Dams.

Subbasin	Height of Dam (feet)	Distance from Top to Auxiliary Spillway (feet)	Flood Pool Area at Auxiliary Spillway (acres)	Flood Pool Area at Top of Dam (acres)	Outfall Structure	Preliminary Opinion of Cost (Millions of $)
South (Upper) Salt Creek 1	35	5	696	985	3-10 ft by 8 ft CBC	13.5
South (Upper) Salt Creek 4	50	5	907	1,160	3-8 ft by 8 ft CBC	14.9
South (Upper) Salt Creek 2	50	5	309	391	48 in RCP	4.7
South (Upper) Salt Creek 3	40	5	234	330	48 in RCP	5.6
Oak Creek	50	10	1,620	2,880	3-10 ft by 8 ft CBC	30
West Oak Creek 1	40	5	295	332	60 in RCP	7.3
West Oak Creek 2	45	5	260	360	2-10 ft by 6 ft CBC	2.6

*CBC (Concrete box culvert) **RCP (Reinforced concrete pipe)

The preliminary opinions of probable cost for the dams that were not conceptually designed were manually estimated. **Appendix E** provides a detailed description of the manual method used.

The total preliminary opinion of probable cost for 16 potential dams is approximately $140 million. Details from the conceptually designed dams and manually estimated dams are provided in **Table 51**.

The remainder of the dams in the unnamed tributaries to Salt Creek, Cardwell Branch, Haines Branch, and Middle Creek watersheds were not modeled using HEC-HMS. Hydrologically, these dams were accounted for by adjusting the input hydrograph to the HEC-RAS model by a drainage area factor. Appendix F describes the method used for adjusting the input hydrograph to the HEC-RAS model.

Table 51. Details from All 16 Conceptually Designed Dams and Manually Estimated Dams.

	Subbasin	Contributing Drainage Area (sq mi)	Height of Dam (ft)	Distance from Top to Aux Spillway (ft)	Flood Pool Area at Aux Spillway (ac)	Flood Pool Area at Top of Dam (ac)	Outfall Structure	Preliminary Opinion of Cost (Millions of $)
Concept Design	South (Upper) Salt Creek 1	92	35	5	696	985	3-10'x8' CBC	13.5
	South (Upper) Salt Creek 4	42	50	5	907	1,160	3-8'x8' CBC	14.9
	South (Upper) Salt Creek 2	4.7	50	5	309	391	48" RCP	4.7
	South (Upper) Salt Creek 3	5.9	40	5	234	330	48" RCP	5.6
	Oak Creek	123	50	10	1,620	2,880	3-10'x8' CBC	30
	W Oak Creek 1	10.3	40	5	295	332	60" RCP	7.3
	W Oak Creek 2	16	45	5	260	360	2-10'x6' CBC	2.6
Estimated	Middle 1	34.3	45	5	800	1000	3-8'x6'	14
	Middle 2	2.3	35	5	250	300	48" RCP	5
	Haines 1	13.3	40	5	275	350	2 60" RCP	7.7
	Haines 2	7.1	40	5	240	340	60" RCP	6.5
	Haines 3	2.4	35	5	250	300	48" RCP	5
	Cardwell 1	2.9	40	5	275	330	48" RCP	5.5
	Un Trib 1	4.1	40	5	300	360	48" RCP	6
	Un Trib 2	1.5	30	5	240	270	48" RCP	5
	Un Trib 3	2	35	5	240	300	48" RCP	5
						Total Cost		**138.3**

6.2.7 Results with Structural Flood Management Measures

This study did not address detailed benefits and costs associated with any specific structural flood management measures, and a benefit-to-cost ratio cannot be determined at this time. Previous studies, identified in Section 4, demonstrated that raising the Salt Creek levees is not a feasible option for Salt Creek flood protection. We also know that singular approaches to flood management are not effective. USACE (1994) demonstrated that effective flood management cannot be achieved by only using offline storage. Past studies have also demonstrated that flood management measures will not be effective if they are not implemented in a comprehensive and systematic manner. LTU (2009) demonstrated that flood management measures implemented on only a few tributaries did not provide adequate flood risk reduction benefits to justify the costs. Those studies demonstrated flood risk reduction along Salt Creek of only a few inches, or less.

Any comprehensive evaluation of potential structural flood management measures will have to provide a detailed benefit-to-cost analysis to establish economic feasibility. Without a benefit-to-cost ratio greater than 1.0 for a proposed project, most federal and state funding sources will not be available.

Based on existing conditions, using TP40 rainfall, the 16 dams studied would altogether reduce the flood elevations along Salt Creek approximately 2.6 feet through the leveed reach for the 1 percent annual chance flood event. For updated conditions, using NOAA Atlas 14 rainfall data, the flood elevations would be lowered an average of 1.6 feet through the leveed reach for the 1 percent annual chance flood event.

Any future efforts to remap the floodplain of Salt Creek would be done using the NOAA Atlas 14 rainfall values (or possibly higher, future rainfall values). NOAA Atlas 14 rainfall data is the best available data and is currently the best national practice for floodplain modeling.

This study only evaluated large flood management measures on the tributaries that contribute runoff to Salt Creek within or upstream of the leveed reach of Salt Creek, because this reach of Salt Creek contains the vast majority of the homes, structures, and infrastructure within the Salt Creek floodplain in the City of Lincoln. Reducing flooding in the leveed reach provides the greatest reduction in risk to life, health, and property from Salt Creek flooding. Thus, the flood risk reduction benefits demonstrated only extend to the downstream end of the levee system at the Superior Street crossing of Salt Creek. Flood risk reduction benefits can be achieved downstream of Superior Street if additional flood management structures are implemented on Little Salt Creek and possibly Steven’s Creek. Alternatively, conveyance improvements to Salt Creek could be constructed to reduce flood elevations and flood risk. In that case, benefits could be extended to the downstream limits of the City of Lincoln. In the upstream direction, flood risk reduction benefits would be achieved along Salt Creek and the Hickman Branch to the towns of Roca, Denton, and Hickman.

The 1 percent annual chance flood event profiles with flood management measures for the **existing conditions** model (TP40), **updated conditions** model (NOAA Atlas 14), and **future conditions** model are shown in **Figure 20**. The 0.2 percent annual chance flood event profiles for the same simulations are shown in **Figure 21**.

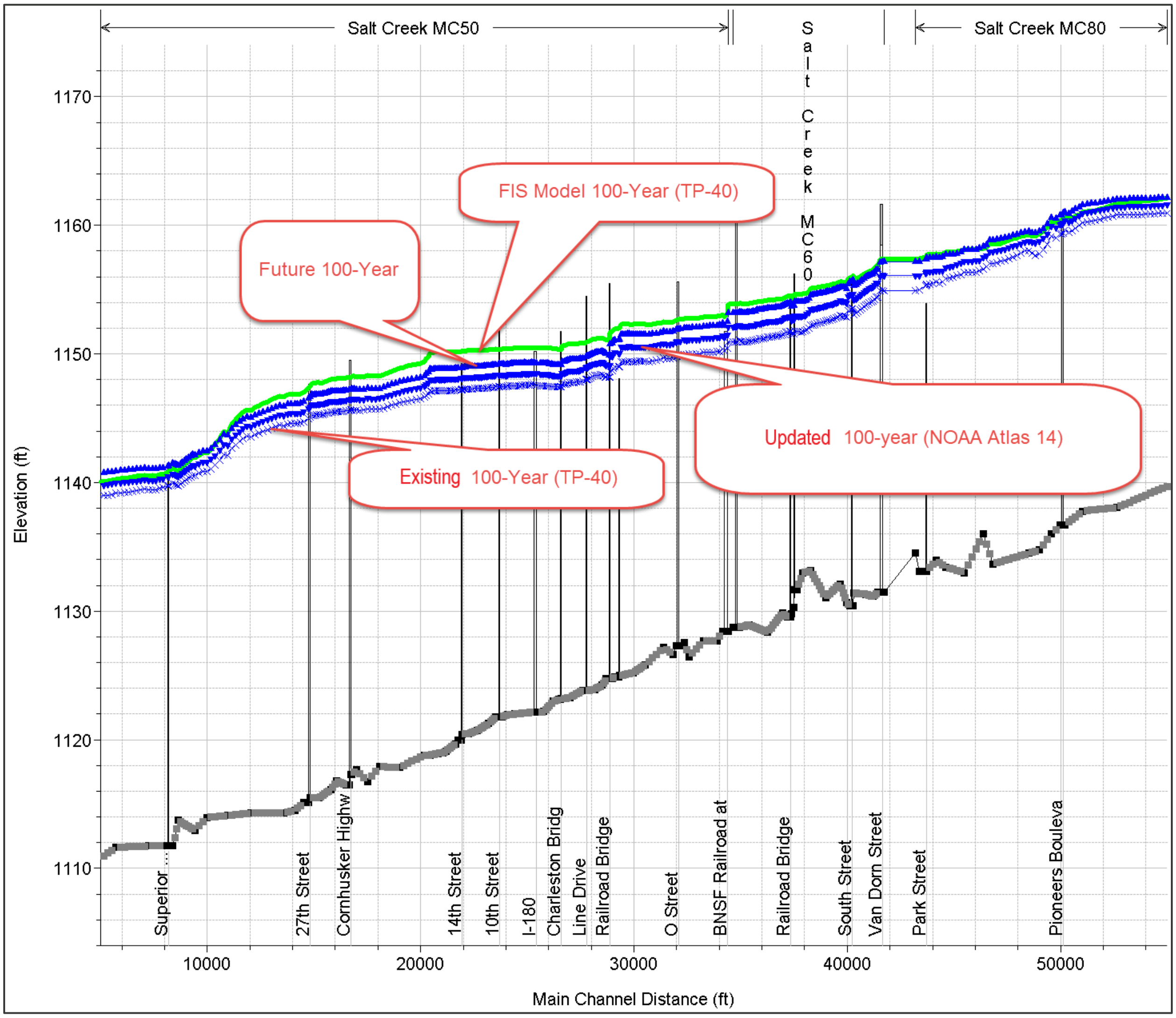


Figure 20. Existing (TP40), Updated (NOAA Atlas 14), and Future 1 Percent Annual Chance Flood Profiles with Structural Flood Management Measures.

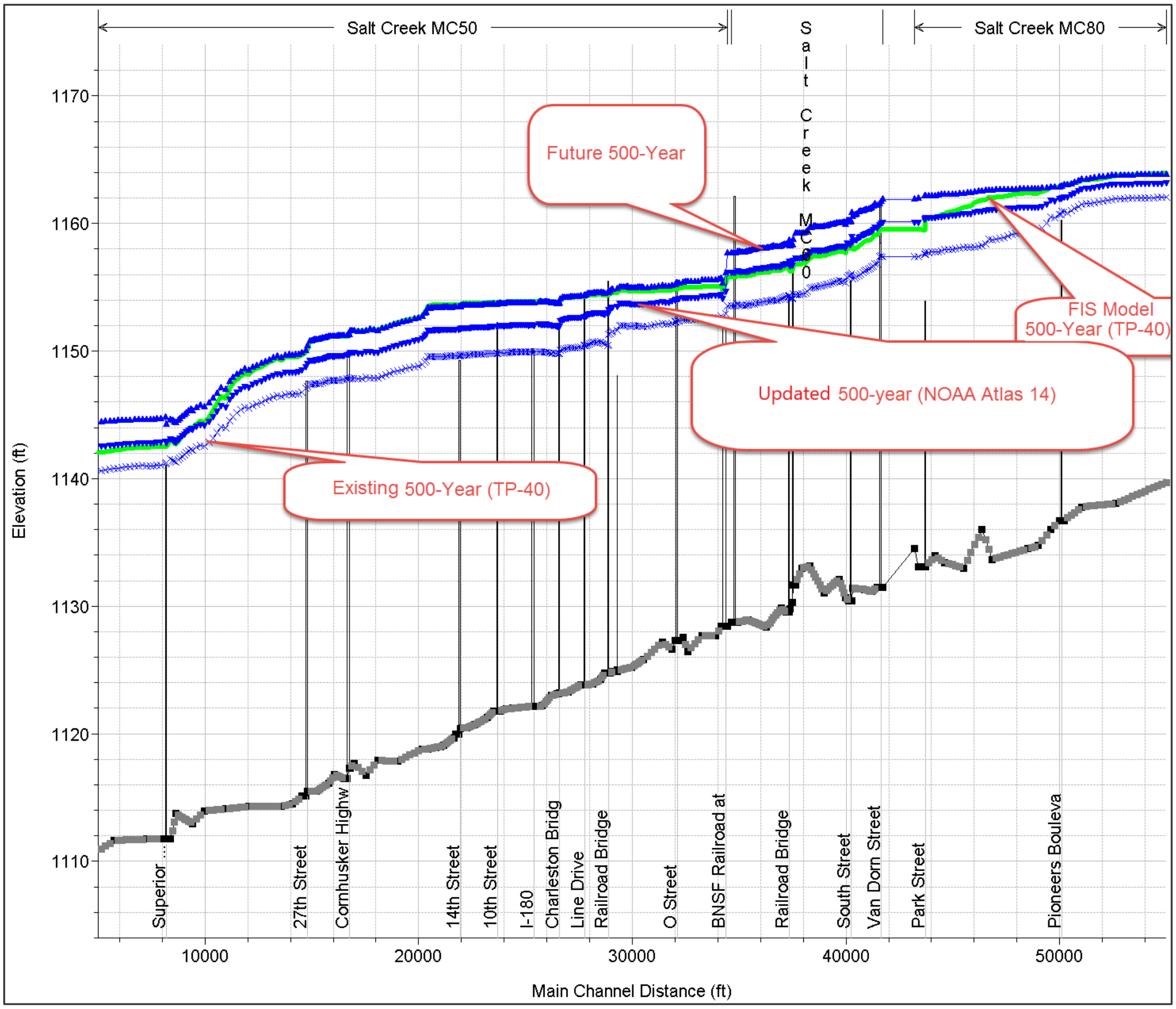


Figure 21. Existing (TP40), Updated (NOAA Atlas 14), and Future 0.2 Percent Annual Chance Flood Profiles with Structural Flood Management Measures.

6.3 Summary – Future Flood Resiliency

In the City of Lincoln, actual flood risks and potential flood damages are greater than depicted in the current regulatory models, maps, and public information. Flood hazards on Salt Creek and its tributaries can be expected to increase in the future. The degree of increase is uncertain, but generally, Lincoln should expect floodwater surface elevations multiple feet higher than the existing flood hazard data. When considering resiliency and potential flood hazard risk reduction measures, it is critical to allow for these increases.

For the non-structural flood risk reduction measures recommendations outlined, Lincoln, in partnership with LPSNRD should:

1. Identify the recommendations that are top priorities and chart a path to implementation. This includes identifying as a goal for future planning purposes that future building/developments be protected to the updated conditions level of protection as identified in this study.
2. Evaluate the cost to implement the identified recommendations.

3. Identify local funding sources that are sufficient to match potential federal funding sources.
4. Position projects for potential grant funding.

A comprehensive flood management plan, including structural flood management measures in the form of multiple dams within the Salt Creek tributary subbasins, may mitigate increased flood risks associated with **updated conditions** and **future conditions** floods. An analysis demonstrated that the conceptual system of flood management measures analyzed reduce flood elevations for the 1 percent annual chance flood event for the **updated** and **future conditions** to a level below **existing conditions** flood elevations (as shown in the FIS) throughout most of the Salt Creek levee system.

SECTION 7 – FUNDING SOURCE ANALYSIS

As described in Section 6.3, the actual flood risks and potential flood damages in Lincoln are greater than depicted in the current regulatory models, maps, and public information. And, as the climate models illustrate, the flood hazards on Salt Creek are expected to increase in the future. In this study, both structural and non-structural solutions to reduce the flood risks along Salt Creek and its tributaries are presented and most of these solutions are multimillion-dollar projects. In this section, several of the primary options for funding through federal, state, and local agencies are presented along with options to partner with private enterprises in public private partnerships. These funding sources, in general, can be used to address both structural and non-structural projects. As the preferred solution is selected, the appropriate funding strategy will be identified based on the details of the proposed project(s).

FEMA

FEMA has three specific programs that can provide grant and matching funds. Awards are granted through a competitive application process.

The Pre-disaster Mitigation (PDM) grant program provides funding for hazard mitigation plans and the implementation of mitigation projects prior to a disaster. Non-structural floodplain management activities such as property acquisition, structure relocation, and dry floodproofing are just a few of the eligible activities.

The Flood Mitigation Assistance Grant Program provides funding to implement measures that reduce or eliminate the long-term risk of flood damage to buildings insured under the NFIP. The Flood Mitigation Assistance Grant Program is focused on mitigating repetitive-loss structures.

The HMGP provides funding to implement long- term hazard mitigation measures after a major disaster declaration. HMGP funds may be used to fund projects that will reduce or eliminate the losses from future disasters.

In addition to existing federal funding sources in the FEMA HMGP, there are several new guidance documents and funding streams that should guide implementation of many of the non-structural recommendations.

Disaster Recovery Reform Act

FEMA has been increasing the available PDM grant program funding in recent years. The 2018 PDM appropriation was $135M, $2M higher than the prior year and communities will now have access to an additional funding stream, which comes out of the Disaster Recovery Reform Act. Key initiatives from the act that are driving the mitigation strategy and investment include:

The National Mitigation Investment Strategy and,

Building Resilient Infrastructure and Communities (BRIC)

These initiatives are described below:

National Mitigation Investment Strategy

FEMA's National Mitigation Investment Strategy was adopted August of 2019. The strategy lays out three high-level goals:

1. Show how mitigation investments reduce risk;
2. Coordinate mitigation investments to reduce risk; and
3. Make mitigation investment standard practice.

The strategy strongly encourages communities to coordinate mitigation efforts across departments and encourages the federal government to make funding for mitigation easier to access.

Building Resilient Infrastructure and Communities (BRIC)

BRIC funding from FEMA is a component of the new PDM grant program. BRIC is anticipated to be an annual program, with the initial notice of funding availability anticipated in March 2020. The focus of these funds is to provide monies for infrastructure projects before a disaster and for projects focused on hazard mitigation planning, building codes and enforcement, and risk informed funding.

U. S. Army Corps of Engineers (USACE)

USACE has three specific programs that can provide technical assistance for flood risk mitigation.

- Under the authority of the Flood Control Act of 1966, USACE Flood Plain Management Services provide technical assistance for effective floodplain management.
- The USACE Continuing Authorities Program provides study, design, and construction for small flood management projects.
- USACE Planning Assistance to States provides technical assistance for comprehensive plans for the development, utilization, and conservation of water and related land resources.

Natural Resources Conservation Service (NRCS)

NRCS's Watershed Protection and Flood Prevention Program provides funding and technical assistance for flood mitigation projects. The Watershed and Flood Prevention Operations Program works together with federal, state, local, and tribal agencies to:

- Prevent erosion
- Reduce floodwater and sediment damage
- Further the conservation development, use, and disposal of water
- Further the conservation and proper use of land in authorized watersheds

Awards are granted through a competitive application process.

Nebraska's Natural Resources Commission

This agency oversees eight state funds including the largest fund initiated in 2014 called the Water Sustainability Fund, which provides funding to eligible projects, programs, and activities that lead to the sustainability of Nebraska's water resources. Eligible types of projects include flood management, reducing threats to property damage, agricultural uses, municipal and industrial uses, recreational benefits, wildlife habitat, conservation, and preservation of water resources projects. Awards are granted through a competitive application process.

Nebraska Environmental Trust

This fund provides money for projects to preserve or restore lakes, waterways and groundwater from degradation or depletion; actions to research, design or foster best management practices; actions to conserve water and/or efficiently and effectively manage water use; actions to inform and educate. Awards are granted through a competitive application process.

Nebraska Department of Environment and Energy

This agency has a program that can provide low interest loans that support a variety of flood risk mitigation projects. The Revolving Loan Fund covers 100 percent of project costs and allows the borrower to spread out costs for improvements over twenty years, with low interest rates. The water quality loan fund can be used to also provide flood management benefits. Awards are granted through a competitive application process.

Tax Increment Financing

Tax Increment Financing is a method to capture and use a portion of new property tax revenues generated from new development in a blighted and substandard area for an improvement project. This public financing method is used to subsidize redevelopment, infrastructure, and other community improvement projects across the country. In Lincoln, tax increment financing projects are reviewed by the city, Planning Commission, and City Council at several points through the development process.

Public-private Partnerships (PPP)

There are several types of PPP that can be implemented to address flood risk mitigation. Each one requires an arrangement between, for example, private firms, investment groups, industry partners and one or more public agencies.

The first type of PPP is a lease purchase agreement. This is a contract in which a private entity funds the project, and the city makes scheduled lease payments until the lease is paid in full.

The second type of PPP is complete privatization of the flood management program. The private entity funds the design, construction, and operation of the facility, and the city pays for the private entity to provide flood management for the community.

Ultimately, the city and LPSNRD must identify the most appropriate source(s) of funding for the selected project based on the merits of the project, project timing, and other factors. Many of the funding options listed above will require cost-sharing and the city and LPSNRD require a dedicated source of funding to provide the cost-share. Sources of the cost-share may include bond measures, stormwater fees, and/or sales tax.

Lincoln has an excellent record of leveraging city funding for flood management projects through stormwater bonds. According to the city website, for more than 40 years, stormwater bonds have financed projects that:

- Improve the city's stormwater and drainage systems
- Protect personal health and property
- Remove residential and commercial properties from floodplains
- Open new land for development
- Stabilize banks of streams and creeks
- Attract federal, state and regional funding partners

Thirteen bonds have been passed by voters since 1983 totaling $95.3 million. Seven of these bonds have been retired. Four have been refinanced at lower interest rates to save property owners money. The most recent stormwater bond measure was passed in May 2019 for $9.9 million. Lincoln’s track record securing stormwater improvement bonds illustrates the community’s support for stormwater improvements that save Lincoln residents money by removing property from the floodplain and reducing flood insurance premiums.

As discussed in Section 6, any evaluation of potential flood management measures will have to provide a detailed benefit-to-cost analysis to establish economic feasibility. Without a benefit-to-cost ratio greater than 1.0 for a proposed project, most federal and state funding sources will not be available.

SECTION 8 – RECOMMENDATIONS

The City of Lincoln and the LPSNRD have partnered together to reduce flooding impacts and increase protection for the citizens of Lincoln from the hazards associated with flooding. The many successes of this partnership are the result of a blended approach to floodplain management. The approach is founded on non-structural practices such as education and outreach, public policy, floodplain preservation, flood protection, and property buyouts. The non-structural measures are complemented by structural measures, where necessary, in the form of flood management and flood impact reduction projects. Combined, the non-structural and structural measures have resulted in substantial impact reductions in flooding and associated flood damages for the city and the surrounding areas.

The city and LPSNRD are now focused on addressing resiliency in the Salt Creek floodplain. This requires a forward-looking approach: Planners must consider not just events and hazards that may occur in the present day, but they must also account for future hazards and how those hazards may evolve over time. Careful consideration of the key takeaways from the climate evaluation are critical in setting a path to future resiliency. These takeaways include:

- The **existing conditions** hydrologic models do not use up-to-date precipitation frequency estimates.
- The **existing conditions** flood hazard data on Salt Creek underestimates the **updated conditions** flood hazards.
- In the “business-as-usual” global greenhouse gas emissions scenario, precipitation events causing flooding are forecasted to increase by nearly 10 percent by the year 2100 in the Salt Creek watershed.
- In the “business-as-usual” global greenhouse gas emissions scenario, flood hazards will increase significantly in magnitude in the Salt Creek watershed by the year 2100, compared to **existing conditions** flood hazards.
- There is a high degree of uncertainty in **future conditions** flood hazard analysis. When planning for future resiliency, it is critical to account for this uncertainty.

Key Recommendations to Enhance the Resiliency of the Salt Creek Floodplain

1. The City of Lincoln should continue its active participation in the CRS program. The combined efforts of the city and the LPSNRD have garnered the city the highest CRS rating (Class 5) in the State of Nebraska. Continued floodplain management enhancements in non-structural and structural flood risk reduction measures will result in an improved CRS rating. The benefits of participating in the CRS program are documented throughout the report. Specifically, the CRS program is highlighted in Section 3.1 as one of the current practices that has resulted in flood risk reduction and flood insurance premium savings for the citizens of Lincoln. Additionally, for each of the six non-structural flood resiliency measures in Section 6.1 that are recommended for the city and LPSNRD’s further consideration, an evaluation of potential CRS points associated with each measure is provided.

2. Given the implications from the climate evaluation, the city should adopt higher floodplain regulatory standards for new construction and substantial improvements like Cedar Falls, Iowa, has done. One of the higher standards discussed in Section 2.4 that was adopted by Cedar Falls, and is recommended for adoption by Lincoln, was the 0.2 percent annual

chance floodplain delineation and associated flood elevations as the community's locally regulated flood information.

3. The city and LPSNRD should update the floodplain maps to incorporate NOAA Atlas 14 precipitation information. This effort could be initiated by the city and LPSNRD with the new maps used for the city's floodplain management program. This effort can also be done in cooperation with the FEMA mapping program to update the FIRMs. Recognizing that updating floodplain maps can take several years, the city should consider updating its Drainage Criterial Manual to incorporate NOAA Atlas 14 precipitation information to avoid building undersized drainage facilities in the future. Details associated with strategies and actions that will efficiently and effectively advance the identification, assessment, and management of flood hazards and risk are outlined in the information on the Technical Mapping Advisory Council in Section 1.5.

4. The city and LPSNRD should use the review of the national BMPs from FEMA, NOAA, Pew (Pew Charitable Trust), RNPN (Resilient Nation Partnership Network), TMAC (Technical Mapping Advisory Council), and the NAS (National Academy of Sciences) to guide a decision-making process for selecting strategic BMPs that align with their goal of making Lincoln more flood resilient. These national BMPs are discussed in Section 1 of the report.

5. In addition to the above recommendations, based on information analyzed in this study including updated flood data, national BMPs, and the BMPs from comparable communities, six non-structural flood resiliency strategies are also recommended for the city and LPSNRD to further consider. The non-structural strategies include:

   - Cluster subdivision regulations
   - Overlay zoning
   - Voluntary buyout program
   - Setbacks and riparian preservation
   - LID regulations
   - Higher floodplain management standards

   The strategies selected were evaluated based on conversations with the project team, the review of comparative regulatory levels from other communities, feedback from the stakeholder's group, and anticipated benefits associated with implementation of the strategies. The six strategies are discussed fully in Sections 6.1.1 through 6.1.6 of the report.

6. Given the potential for increased flooding in Salt Creek (as demonstrated in this study by updating precipitation data and using future climate predictions to establish updated flood discharges for various flood recurrence intervals) the city and LPSNRD should continue with the development of a comprehensive flood resiliency strategy for Salt Creek and the City of Lincoln.

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APPENDIX A

A Matrix of Community Best Management Practices

Table A-1. A Matrix of Community Best Management Practices.

Community	State	CRS Rating	Non-FIRM Locally adopted Floodplains?	Regulated water surface	Best Available Information allowed for determination of regulatory applicability	Freeboard above regulated water surface	Freeboard in Zone AO (above flood depth)	New Development – Floodplain – Residential/ Commercial	New Development – Floodplain – Other (Accessory, Agricultural, etc)	New Development – Floodway – Residential/Commercial	New Development – Floodway – Other (Accessory, Agricultural, etc)	Existing Development (Repairs/Improvements) – Floodplain	Existing Development (Repairs/Improvements) – Floodway	Critical Facilities	SI	SD	Fill/Compensatory Storage	Stream Setbacks/Buffers	OWTS/Sanitary systems	Stormwater Mgmt Program/Project Funding	Property Acquisition Program	# Properties Acquired	Local Grant Program	Other Higher Standards	Notes
City of Lincoln	NE	5	Yes	100-year	Yes	1 foot	1 foot	Allowed if no net rise	Allowed if no net rise	Prohibited	Prohibited, unless no rise and compensatory storage met, and no bike min corridor	NS: Allowed, must have one foot of freeboard	Prohibited unless no rise	Allowed, if elevated above 500-year and all other requirements met.	50% of market value	50% of pre-damage market value	New Growth Areas – compensatory storage must be provided, must not increase downstream 2-, 10-, 100-year flows, no net rise (0.05 ft max increase) in flood elevation. Existing developed areas – must comply with FEMA regs and/or previously approved plans	required in New Growth Areas; varies based on DA size	100-year protection, plus 1 foot freeboard	Yes, Bond Funded	Project Specific	46	LID Cost-shares		
City of Cedar Falls	IA	5	No	500-year	No	1 foot	Not Specified	Prohibited on lots subdivided/ recorded after 1/1/2010	allowed < 576 square feet	Prohibited	Prohibited	Allowed	Prohibited if SD; no additions	prohibited in 100-year and 500-year floodplains	50% market value or 25% increase in floor area (non-cumulative)	50% of pre-damage market value	No more than 3 vertical feet on no more than 1/3 of the parcel. Compensatory Storage Required in 500-year floodplain. LOMR-Fs prohibited.	none required	500-year protection	Stormwater Management Fee (Monthly)	Yes	336	None		
Platte County	MO	5	No	100-year	Yes	1 foot	none	Allowed	Ag: allowed at grade. Other: allowed < 450 sq ft	Prohibited unless no rise	Prohibited unless no rise	Allowed	prohibited unless no rise. Repair of SD OK if no rise.	Allowed (1 elevated above 500-year WSEL)	50% market value	50% pre-damage market value	NFIP Minimum	required; varies based on DA size	NFIP Minimum	Regional Stormwater Council; Sales Tax	No	NA	Stormwater Mgmt Grant Program		
City of Beatrice	NE	NA	No	100-year	Yes in Zone A	1 foot	1 foot	Allowed	Allowed at grade with elevated electric- no other utilities.	Prohibited for human habitation	prohibited unless no rise	Allowed	prohibited unless no rise. Repair of SD OK if no rise.	Not specified	50% market value	50% pre-damage market value	NFIP Minimum	none required	NFIP Minimum	Street, Highway, & Sales Tax	Yes	120	None		
Boulder County	CO	5	Yes	More conservative of FEMA and Locally-adopted 100-year	Yes	2 feet; 3 feet above HAG in Zone A if no BFE available	2 feet	Allowed	Accessory: Allowed w/ Non-Conversion Agreement and if 10% of the value of the principle structure or < 600 sq. ft. Ag: allowed with wet floodproofing and elevation of service equip.	Prohibited	Prohibited	Allowed; if SD or SI, relocation evaluation required.	Allowed but no additional square footage; 5-year limit to repair SD; design requirements similar to coastal construction	Below 6,000 feet: Prohibited in 100-year. Above 6,000 feet: case by case approval.	50% market value; Cumulative SI starting 9/11/2013	50% pre-damage market value	NFIP Minimum. New construction with LOMR-F must use pre-Fill BFE.	none required	New systems prohibited in 100-year. If no room outside of 100-year, certain design requirements must be met. Also design requirements for repair/replacement OWTS.	Regional Stormwater Partnership; Open Space Tax	Yes	45	Sustainability Grant Program	Maintenance Plan for engineered channelization projects. Local floodway review. Crawlspace restrictions. Storage tanks prohibited in 100-year.	Interim Elevation Certificate sales that requirements. General Permit for minor projects. Eligible for TDCs with removal of floodway structures.
City of Fort Collins	CO	2	Yes	100-year	Yes	Poudre River Floodplain: 2 feet above BFE. FEMA basin and City basin floodplains: 18 inches for new construction, 12 inches for improvements	Poudre River Floodplain: 2 feet above BFE. FEMA basin and City basin floodplains: 18 inches for new construction, 12 inches for improvements	Prohibited in Poudre River floodplain. Allowed in all other floodplains.	Allowed	Residential: Prohibited. Non residential: Prohibited in Poudre R Floodway, allowed in other floodways with with no-rise.	Poudre River – Prohibited. Other floodplains – Allowed with restrictions	Poudre River – No additions, repairs/remodels allowed. Other flood plains – allowed with restrictions	Additions prohibited. Repair of SD prohibited. Repairs/Remodels allowed with restrictions	Prohibited	50% market value (cumulative over a 12-month period)	50% pre-damage market value	NFIP Minimum	New construction or additions in erosion buffer zone is prohibited. Remodeling and Redevelopment is allowed. Limits are delineated on severe erosion streams.	NFIP Minimum	Yes, funded through residential and business stormwater rates	Yes	Not Available	None	Differing regulations for certain floodplains (Poudre River)	BFEs in AO zones are defined as the highest adjacent grade plus flood depth
City of Papillion	NE	7	No	FEMA BFE	Yes	1 foot	1 foot	Allowed	Allowed	Prohibited	Open space ag use only, no-rise required	NS: Allowed, must have 1 ft of freeboard	Open space uses, non-restrictive uses	Unable to find restriction	50% market value	50% market value	No more than 25 percent of the floodway fringe in the floodplain devlopment application area within the West Papillion Creek system.	No more than 25 percent of the floodway fringe in the floodplain development application area within the West Papillion Creek system.	FEMA BFE plus 1 ft	Yes	Yes	None Known	Papio NRD Floodway Buyout		
City of Shawnee	KS	6	No	FEMA BFE	Yes	2 ft above FEMA BFE	2 foot	Allowed if elevated 2 feet above BFE	Allowed if elevated/floodproofed 2 ft above BFE	No buildings, but fill and ancillary construction allowed with no rise	Allowed with no rise	NS: Allowed, if over 50% improvement in last 5 years, must have 2 ft of freeboard if over 50% aggregate improvement in last 5 years.	In practice, same requirements as floodplain repairs/improvements	Elevated above 500-year, not in floodway	50% market value	50% market value	Designated floodways on the FIRM defined based on allowable floodway surcharge of 1.0 ft per County watershed studies. Interestingly, their code seems to indicate floodway is 0.0 foot rise. I checked with the City, and this subsection is not clear for their purposes. They would regulate for a 1.0 foot rise for a new floodway. For Zone A, fill must meet no-rise requirements. I don't think we have any Zone A in Shawnee, though.	All structures, except nonhabitable structures of less than 120 SF and no concrete footing, setback 10' from 100-yr floodplain; Stream Buffer Zone width 100' each side of stream for watershed of 100-5,000 acres; Stream Buffer Zone width 150' each side of stream for watershed of >5,000 acres (not based on floodplain), limited building and disturbance in stream buffer zone	"Located and constructed to minimize or eliminate flood damage"	Yes	Yes	Project Specific	Stormwater cost-share		
Mecklenburg County	NC	8	Yes	Future 100-year BFE	No	1 ft above Community BFE, or 2 ft above FEMA BFE, depending on location	Unable to find restriction	Allowed Outside Community Encroachment Area (0.1 ft floodway for Community Base Flood or future 100-year flood), provided other criteria met.	Accessory structures allowed with restrictions	Prohibited	Prohibited, unless meet FEMA regs and meet 0.1' rise limits for Community Base Flood Event. Community CLOMR required for greater than 0.1 ft rise.	Allowed for NSI, with restrictions, addition must be compliant with all other regs.	Prohibited, unless meet FEMA regs and meet 0.1' rise limits for Community Base Flood Event. Community CLOMR required for greater than 0.1 ft rise.	Prohibited in 100-year floodplain, elevated above 500-year flood elevation or Community BFE, whichever is greater	50% of market value	50% of market value	No fill in the Community Encroachment Area without certification that rise is less than 0.1 feet. No fill in FEMA floodway without no-rise	Created with buyouts	Community BFE plus 1 foot	Yes	Yes	400+	Buyouts		

Notes/Comments:

Key:

Key
City of Lincoln/Lancaster County requirements
Generally less restrictive than Lincoln
Generally more restrictive than Lincoln OR regulation of note
Generally similar to City of Lincoln
Depends

APPENDIX B

Rainfall/Frequency Table by Subbasin

Table B1. The following table details the precipitation depths used in each subbasin with available HEC-HMS models.

Subbasin	Modeled Storm Duration (hours)	10% Annual Chance Precipitation (inches)			2% Annual Chance Precipitation (inches)			1% Annual Chance Precipitation (inches)			0.2% Annual Chance Precipitation (inches)		
		Existing	Updated (Atlas 14)	Future (RCP8.5)	Existing	Updated (Atlas 14)	Future (RCP8.5)	Existing	Updated (Atlas 14)	Future (RCP8.5)	Existing	Updated (Atlas 14)	Future (RCP8.5)
Antelope Creek	6	3.50	3.65	4.02	4.60	5.15	5.67	5.10	5.86	6.39	6.00	7.66	8.20
Cardwell Branch	24	4.69	4.44	4.84	6.00	7.89	8.60	6.68	7.33	8.06	8.20	9.86	10.94
Little Salt Creek	24	4.69	4.53	5.07	6.00	6.49	7.40	6.68	7.44	8.63	8.18	9.95	11.84
Middle Creek	48	5.08	4.86	5.20	6.55	6.89	7.30	7.31	7.81	8.28	8.81	10.50	11.13
Oak Creek	48	5.08	4.79	5.13	6.55	6.74	7.35	7.31	7.70	8.55	8.81	10.30	11.64
Southeast Upper Salt Creek	24	4.70	4.55	4.82	6.00	6.50	6.89	6.70	7.46	7.91	8.40	9.94	10.54
South Salt Creek	48	5.08	5.07	5.42	6.55	7.17	7.67	7.31	8.19	8.76	8.81	10.80	11.56

APPENDIX C

Future Conditions Land Use Loss Parameters

SEUSC			
Node	Effective CN	Future Conditions Land Use CN*	Comment
ExistOutJK	89		From master plan
ExistOutL	89		From master plan
Subbasin-1	79		From master plan
S2A	67		From master plan
S2AA	75	76	From master plan
S2AB	79		From master plan
S2AC	77		From master plan
S2AD	85		From master plan
S2AE	81		From master plan
S2AF	83	89	From master plan
S2B1	74	79	From master plan
S2B2	75		From master plan
S2B3	79		From master plan
S2C	81	86	From master plan
S2E	83	89	From master plan
S2F1	79	85	From master plan
S2F2	82	88	From master plan
S2G	83	89	From master plan
S2H	82	88	From master plan
S2I1	83	88	From master plan
S2I2	78	85	From master plan
S2J	88	91	From master plan
S2K	83	88	From master plan
S2L	81	90	From master plan
S2M1	76	86	From master plan
S2M2	75		From master plan
S2N	76		From master plan
S2P	74		From master plan
S2Q	79		From master plan
S2R	77	86	From master plan
S2S	76		From master plan
S2T	83	88	From master plan

SEUSC - continued			
Node	Effective CN	Future Conditions Land Use CN*	Comment
S2U	78	85	From master plan
S2V	77	86	From master plan
S2W	80		From master plan
S2X	81		From master plan
S2Y	82		From master plan
S2Z	82		From master plan
S5A	81	84	From master plan
S5B	81	83	From master plan
S5C	80	86	From master plan
S5D	80	86	From master plan
S5E	80	86	From master plan
S5F	76	83	From master plan
S5G	77	84	From master plan

*** - blank = no change from effective**

Middle			
Node	Effective CN	Future Conditions Land Use CN*	Comment
R2700W2700	81.2		
R2900W2900	80.7		
R2910W2910	77.7		
R2960W2960	81.2		
R3050W3050	77.6		
R3090W3090	80.9		
R3100W3100	82.1		
R3200W3200	79.8		
R3260W3260	80.3		
R3360W3360	79.6	80.6	Tier 3
R3370W3370	79.8		
R3380W3380	82.8		
R3460W3460	81.4	82.4	Tier 3
R3490W3490	82.2	83.2	Tier 3
R3500W3500	81.8	82.8	Tier 3
R3510W3510	79.4		
R3520W3520	81.7		
R3530W3530	80.6		
R3540W3540	81.2	82.2	Tier 3
R3560W3560	81.6		
R3580W3580	79.2		
R3590W3590	83.5	84.5	Primarily in developed area
R3700W3700	80.3		
R3760W3760	80.6		
R3850W3850	80.9		
R3860W3860	79.8	84.5	Tier 2 Area - made to match developed area

*** - blank = no change from effective**

Oak			
Node	**Effective CN**	**Future Conditions Land Use CN***	**Comment**
R1010W1010	78.2		
R1020W1020	79.7		
R1050W1050	79.3		
R1080W1080	79.4		
R1100W1100	81.4		
R1110W1110	81.2		
R1170W1170	81.9		
R1180W1180	80.3		
R1230W1230	79.7		
R1310W1310	80.3		
R1400W1400	79.7		
R1430W1430	80		
R1450W1450	81.8		
R1490W1490	80.4		
R1500W1500	79.1		
R1520W1520	78		
R1560W1560	78.7		
R1580W1580	81.8		
R1600W1600	81.2		
R1660W1660	80.3		
R1670W1670	80.3		
R1720W1720	81.9		
R1750W1750	78.5		
R1760W1760	80.6		
R1780W1780	81.6		
R1850W1850	78.5		
R1890W1890	80.5		
R1980W1980	81.3		
R2010W2010	78.8		
R2050W2050	78.4		
R2070W2070	78.5		
R2100W2100	77.9		
R2120W2120	80.3		
R2130W2130	80.4		
R2220W2220	78.2		
R2250W2250	81.2		

*** - blank = no change from effective**

Oak - continued			
Node	**Effective CN**	**Future Conditions Land Use CN***	**Comment**
R2260W2260	75.7		
R2280W2280	77.6		
R2290W2290	79.3		
R2320W2320	80.1		
R2330W2330	82.5		
R2370W2370	82.1		
R2380W2380	83.5		
R2390W2390	81.8		
R2400W2400	78.4		
R2410W2410	78.6		
R2420W2420	80.5		
R2510W2510	80.4		
R2550W2550	80		
R2630W2630	79.2		
R2660W2660	81.5		
R2680W2680	79.8		
R2720W2720	79.5		
R2810W2810	80.9		
R3070W3070	84.7		
R3080W3080	78.7		
R3150W3150	79.2		
R3160W3160	83.9		
R3220W3220	84.2	85.2	Tier 3
R3270W3270	77.6	91.1	Tier 2 Area - made to match adjacent developed area
R3310W3310	78.9	79.9	Tier 3
R3320W3320	76.5	77.5	Tier 3
R3390W3390	90.1	91.1	Primarily in developed area
R3420W3420	73.8	74.8	Tier 3
R3450W3450	81.3	91.1	Tier 2 Area - made to match adjacent developed area
R730W730	79.4		
R790W790	82.5		
R900W900	79.1		

*** - blank = no change from effective**

South Salt			
Node	**Effective CN**	**Future Conditions Land Use CN***	**Comment**
R4400W4400	84.5	85.5	Primarily in developed area
R4520W4520	84.4	85.4	Primarily in developed area
R4530W4530	82.5	85.4	Tier 2 Area - made to match adjacent developed area
R4540W4540	87.2		
R4550W4550	86.4		
R4600W4600	86.9		
R4610W4610	87		
R4640W4640	85.9		
R4650W4650	77.9	85.4	Tier 2 Area - made to match adjacent developed area
R4670W4670	86.1		
R4690W4690	86.4		
R4700W4700	85.7		
R4710W4710	86		
R4720W4720	82.8		
R4730W4730	82.6		
R4740W4740	85.3		
R4750W4750	86.6		
R4760W4760	87.8		
R4770W4770	85.2		
R4780W4780	82.7		
R4790W4790	81.7		
R4810W4810	84.8		
R4820W4820	84.3		
R4830W4830	71		
R4840W4840	84.5		
R4850W4850	84.3		
R4860W4860	74.4		
R4870W4870	80.9		
R4880W4880	86.9		
R4890W4890	86.3		
R4900W4900	83.9		
R4910W4910	86.8		
R4920W4920	83.9		
R4930W4930	85		

*** - blank = no change from effective**

South Salt - continued			
Node	**Effective CN**	**Future Conditions Land Use CN***	**Comment**
R4940W4940	84.9		
R4970W4970	85.3		
R4980W4980	84.3		
R5000W5000	84.3		
R5010W5010	82		
R5030W5030	83.4		
R5040W5040	85.5		
R5050W5050	84.5		
R5060W5060	80.2		
R5070W5070	80.4		
R5080W5080	76.1		
R5100W5100	81.1		
R5110W5110	85.9		
R5140W5140	82.1		
R5160W5160	83.3		
R5190W5190	84.3		
R5200W5200	82.3		
R5210W5210	82.3		
R5220W5220	84.5		
R5230W5230	84.1	85.1	Primarily in developed area

*** - blank = no change from effective**

Antelope					
Node	Effective		Future		Comment
	Initial Loss	Constant Loss	Initial Loss	Constant Loss	
HLA1 (Plane 1)	1	0.3	0.8	0.25	Tier II
HLA1 (Plane 2)	1	0.3	0.8	0.25	Tier II
HLA2 (Plane 1)	1	0.3	0.8	0.25	Tier II
HLA2 (Plane 2)	1	0.3	0.8	0.25	Tier II
HLA3 (Plane 1)	1	0.3	0.8	0.25	Tier II
HLA3 (Plane 2)	1	0.3	0.8	0.25	Tier II
HLA4 (Plane 1)	1	0.3	0.8	0.25	Tier II
HLA4 (Plane 2)	1	0.3	0.8	0.25	Tier II
HLA5 (Plane 1)	1	0.3	0.8	0.25	Tier II
HLA5 (Plane 2)	1	0.3	0.8	0.25	Tier II
HLA6 (Plane 1)	1	0.3	0.8	0.25	Tier II
HLA6 (Plane 2)	1	0.3	0.8	0.25	Tier II
HLA7 (Plane 1)	1	0.3	0.8	0.25	Tier II
HLA7 (Plane 2)	1	0.3	0.8	0.25	Tier II
HLA8 (Plane 1)	1	0.3	0.8	0.25	Tier II
HLA8 (Plane 2)	1	0.3	0.8	0.25	Tier II
HLA9 (Plane 1)	1	0.3	0.8	0.25	Tier II
HLA9 (Plane 2)	1	0.3	0.8	0.25	Tier II
HLA10 (Plane 1)	1	0.3	0.8	0.25	Tier II
HLA10 (Plane 2)	1	0.3	0.8	0.25	Tier II
HLA11 (Plane 1)	1	0.3	0.8	0.25	Tier II
HLA11 (Plane 2)	1	0.3	0.8	0.25	Tier II
HLA12 (Plane 1)	1	0.3	0.8	0.25	Tier II
HLA12 (Plane 2)	1	0.3	0.8	0.25	Tier II
HLA13 (Plane 1)	1	0.3	0.98	0.29	Developed
HLA13 (Plane 2)	1	0.3	0.98	0.29	Developed
HLA14 (Plane 1)	1	0.3	0.98	0.29	Developed
HLA14 (Plane 2)	1	0.3	0.98	0.29	Developed
HLB1 (Plane 1)	1	0.3	0.98	0.29	Developed
HLB1 (Plane 2)	1	0.3	0.98	0.29	Developed
HLD1 (Plane 1)	1	0.3	0.98	0.29	Developed
HLD1 (Plane 2)	1	0.3	0.98	0.29	Developed
HLD3 (Plane 1)	1	0.3	0.98	0.29	Developed
HLD3 (Plane 2)	1	0.3	0.98	0.29	Developed
HLD2 (Plane 1)	1	0.3	0.98	0.29	Developed
HLD2 (Plane 2)	1	0.3	0.98	0.29	Developed

Antelope - continued					
Node	Effective		Future		Comment
	Initial Loss	Constant Loss	Initial Loss	Constant Loss	
HLC1 (Plane 1)	1	0.3	0.98	0.29	Developed
HLC1 (Plane 2)	1	0.3	0.98	0.29	Developed
HLD4 (Plane 1)	1	0.3	0.98	0.29	Developed
HLD4 (Plane 2)	1	0.3	0.98	0.29	Developed
HLC2 (Plane 1)	1	0.3	0.98	0.29	Developed
HLC2 (Plane 2)	1	0.3	0.98	0.29	Developed
HLH10 (Plane 1)	1	0.3	0.98	0.29	Developed
HLH10 (Plane 2)	1	0.3	0.98	0.29	Developed
HLH9 (Plane 1)	1	0.3	0.98	0.29	Developed
HLH9 (Plane 2)	1	0.3	0.98	0.29	Developed
HLH678 (Plane 1)	1	0.3	0.98	0.29	Developed
HLH678 (Plane 2)	1	0.3	0.98	0.29	Developed
HLH5 (Plane 1)	1	0.3	0.98	0.29	Developed
HLH5 (Plane 2)	1	0.3	0.98	0.29	Developed
HLH4 (Plane 1)	1	0.3	0.98	0.29	Developed
HLH4 (Plane 2)	1	0.3	0.98	0.29	Developed
HLH3 (Plane 1)	1	0.3	0.98	0.29	Developed
HLH3 (Plane 2)	1	0.3	0.98	0.29	Developed
HLH2 (Plane 1)	1	0.3	0.98	0.29	Developed
HLH2 (Plane 2)	1	0.3	0.98	0.29	Developed
HLH1 (Plane 1)	1	0.3	0.98	0.29	Developed
HLH1 (Plane 2)	1	0.3	0.98	0.29	Developed
HLG2 (Plane 1)	1	0.3	0.98	0.29	Developed
HLG2 (Plane 2)	1	0.3	0.98	0.29	Developed
HLG1 (Plane 1)	1	0.3	0.98	0.29	Developed
HLG1 (Plane 2)	1	0.3	0.98	0.29	Developed
HLE1 (Plane 1)	1	0.3	0.98	0.29	Developed
HLE1 (Plane 2)	1	0.3	0.98	0.29	Developed
HLE3 (Plane 1)	1	0.3	0.98	0.29	Developed
HLE3 (Plane 2)	1	0.3	0.98	0.29	Developed
HLE2 (Plane 1)	1	0.3	0.98	0.29	Developed
HLE2 (Plane 2)	1	0.3	0.98	0.29	Developed
HLE4 (Plane 1)	1	0.3	0.98	0.29	Developed
HLE4 (Plane 2)	1	0.3	0.98	0.29	Developed

Antelope - continued					
Node	Effective		Future		Comment
	Initial Loss	Constant Loss	Initial Loss	Constant Loss	
HLF1 (Plane 1)	1	0.3	0.98	0.29	Developed
HLF1 (Plane 2)	1	0.3	0.98	0.29	Developed
HLF2 (Plane 1)	1	0.3	0.98	0.29	Developed
HLF2 (Plane 2)	1	0.3	0.98	0.29	Developed
HLF3 (Plane 1)	1	0.3	0.98	0.29	Developed
HLF3 (Plane 2)	1	0.3	0.98	0.29	Developed
HLC3 (Plane 1)	1	0.3	0.98	0.29	Developed
HLC3 (Plane 2)	1	0.3	0.98	0.29	Developed
HLC4 (Plane 1)	1	0.3	0.98	0.29	Developed
HLC4 (Plane 2)	1	0.3	0.98	0.29	Developed
AN575 (Plane 1)	2	0.6	1.96	0.58	Developed
AN575 (Plane 2)	2	0.6	1.96	0.58	Developed
AN576 (Plane 1)	2	0.6	1.96	0.58	Developed
AN576 (Plane 2)	2	0.6	1.96	0.58	Developed
AN577 (Plane 1)	2	0.6	1.96	0.58	Developed
AN577 (Plane 2)	2	0.6	1.96	0.58	Developed
AN578 (Plane 1)	2	0.6	1.96	0.58	Developed
AN578 (Plane 2)	2	0.6	1.96	0.58	Developed
AN584 (Plane 1)	2	0.6	1.96	0.58	Developed
AN584 (Plane 2)	2	0.6	1.96	0.58	Developed
AN579 (Plane 1)	2	0.6	1.96	0.58	Developed
AN579 (Plane 2)	2	0.6	1.96	0.58	Developed
AN580 (Plane 1)	2	0.6	1.96	0.58	Developed
AN580 (Plane 2)	2	0.6	1.96	0.58	Developed
AN581 (Plane 1)	2	0.6	1.96	0.58	Developed
AN581 (Plane 2)	2	0.6	1.96	0.58	Developed
AN585 (Plane 1)	2	0.6	1.96	0.58	Developed
AN585 (Plane 2)	2	0.6	1.96	0.58	Developed
AN582 (Plane 1)	2	0.6	1.96	0.58	Developed
AN582 (Plane 2)	2	0.6	1.96	0.58	Developed
AN583 (Plane 1)	2	0.6	1.96	0.58	Developed
AN583 (Plane 2)	2	0.6	1.96	0.58	Developed
AN586 (Plane 1)	2	0.6	1.96	0.58	Developed
AN586 (Plane 2)	2	0.6	1.96	0.58	Developed
AN588 (Plane 1)	2	0.6	1.96	0.58	Developed
AN588 (Plane 2)	2	0.6	1.96	0.58	Developed

Antelope - continued					
Node	Effective		Future		Comment
	Initial Loss	Constant Loss	Initial Loss	Constant Loss	
AN587 (Plane 1)	2	0.6	1.96	0.58	Developed
AN587 (Plane 2)	2	0.6	1.96	0.58	Developed
AN589 (Plane 1)	2	0.6	1.96	0.58	Developed
AN589 (Plane 2)	2	0.6	1.96	0.58	Developed
AN590 (Plane 1)	2	0.6	1.96	0.58	Developed
AN590 (Plane 2)	2	0.6	1.96	0.58	Developed
AN591 (Plane 1)	2	0.6	1.96	0.58	Developed
AN591 (Plane 2)	2	0.6	1.96	0.58	Developed
AN591A (Plane 1)	2	0.6	1.96	0.58	Developed
AN591A (Plane 2)	2	0.6	1.96	0.58	Developed
AN595 (Plane 1)	2	0.6	1.96	0.58	Developed
AN595 (Plane 2)	2	0.6	1.96	0.58	Developed
AN592 (Plane 1)	2	0.6	1.96	0.58	Developed
AN592 (Plane 2)	2	0.6	1.96	0.58	Developed
AN593 (Plane 1)	2	0.6	1.96	0.58	Developed
AN593 (Plane 2)	2	0.6	1.96	0.58	Developed
AN594 (Plane 1)	2	0.6	1.96	0.58	Developed
AN594 (Plane 2)	2	0.6	1.96	0.58	Developed
13000 (Plane 1)	2	0.6	1.96	0.58	Developed
13000 (Plane 2)	2	0.6	1.96	0.58	Developed
AN597C (Plane 1)	2	0.6	1.96	0.58	Developed
AN597C (Plane 2)	2	0.6	1.96	0.58	Developed
AN597D (Plane 1)	2	0.6	1.96	0.58	Developed
AN597D (Plane 2)	2	0.6	1.96	0.58	Developed
9605 (Plane 1)	2	0.6	1.96	0.58	Developed
9605 (Plane 2)	2	0.6	1.96	0.58	Developed
8400 (Plane 1)	2	0.6	1.96	0.58	Developed
8400 (Plane 2)	2	0.6	1.96	0.58	Developed
7900 (Plane 1)	2	0.6	1.96	0.58	Developed
7900 (Plane 2)	2	0.6	1.96	0.58	Developed
7500 (Plane 1)	2	0.6	1.96	0.58	Developed
7500 (Plane 2)	2	0.6	1.96	0.58	Developed
6000 (Plane 1)	2	0.6	1.96	0.58	Developed
6000 (Plane 2)	2	0.6	1.96	0.58	Developed
5800 (Plane 1)	2	0.6	1.96	0.58	Developed
5800 (Plane 2)	2	0.6	1.96	0.58	Developed

Antelope - continued					
Node	Effective		Future		Comment
	Initial Loss	Constant Loss	Initial Loss	Constant Loss	
AN598B (Plane 1)	2	0.6	1.96	0.58	Developed
AN598B (Plane 2)	2	0.6	1.96	0.58	Developed
AN598A (Plane 1)	2	0.6	1.96	0.58	Developed
AN598A (Plane 2)	2	0.6	1.96	0.58	Developed
AN599 (Plane 1)	2	0.6	1.96	0.58	Developed
AN599 (Plane 2)	2	0.6	1.96	0.58	Developed
AN600 (Plane 1)	2	0.6	1.96	0.58	Developed
AN600 (Plane 2)	2	0.6	1.96	0.58	Developed
1400 (Plane 1)	2	0.6	1.96	0.58	Developed
1400 (Plane 2)	2	0.6	1.96	0.58	Developed

Little Salt					
Node	Effective		Future		Comment
	Initial Loss	Constant Loss	Initial Loss	Constant Loss	
LSC0MC235	1.5	0.3	1.5	0.3	
LSC0MC230	1.5	0.3	1.5	0.3	
LSC0MC225	1.5	0.281	1.5	0.281	
LSC0MC220	1.5	0.271	1.5	0.271	
LSC009800	1.5	0.227	1.5	0.227	
LSC0MC215	1.5	0.249	1.5	0.249	
LSC009600	1.5	0.259	1.5	0.259	
LSC0MC210	1.5	0.248	1.5	0.248	
LSC0MC205	1.5	0.263	1.5	0.263	
LSC009405	1.5	0.251	1.5	0.251	
LSC009410	1.5	0.2	1.5	0.2	
LSC009400	1.5	0.26	1.5	0.26	
LSC0MC200	1.5	0.255	1.5	0.255	
LSC0MC195	1.5	0.266	1.5	0.266	
LSC0MC190	1.5	0.299	1.5	0.299	
LSC0MC180	1.5	0.25	1.5	0.25	
LSC0MC185	1.5	0.241	1.5	0.241	
LSC0MC170	1.5	0.259	1.5	0.259	
LSC0MC175	1.5	0.271	1.5	0.271	
LSC0MC165	1.5	0.255	1.5	0.255	
LSC0MC160	5.55	0.123	5.55	0.123	
LSC0MC155	1.5	0.261	1.5	0.261	
LSC0MC150	1.5	0.26	1.5	0.26	
LSC0MC145	1.5	0.278	1.5	0.278	
LSC009005	1.95	0.249	1.95	0.249	
LSC009010	1.95	0.227	1.95	0.227	
LSC009000	1.5	0.256	1.5	0.256	
LSC0MC140	1.5	0.292	1.5	0.292	
LSC008530	2.24	0.261	2.24	0.261	
LSC008525	2.24	0.202	2.24	0.202	
LSC008520	2.24	0.249	2.24	0.249	
LSC008515	3.72	0.131	3.72	0.131	
LSC008510	3.75	0.172	3.75	0.172	
LSC008505	2.24	0.255	2.24	0.255	
LSC008500	2.66	0.222	2.66	0.222	

Little Salt - continued					
Node	Effective		Future		Comment
	Initial Loss	Constant Loss	Initial Loss	Constant Loss	
LSC0MC135	1.61	0.221	1.61	0.221	
LSC008005	2.39	0.286	2.39	0.286	
LSC008000	1.5	0.283	1.5	0.283	
LSC0MC130	3.124	0.246	3.124	0.246	
LSC0MC125	2.78	0.263	2.78	0.263	
LSC0MC122	1.5	0.271	1.5	0.271	
LSC007510	2.41	0.215	2.41	0.215	
LSC027500	3.61	0.228	3.61	0.228	
LSC007505	1.58	0.252	1.58	0.252	
LSC017505	2.15	0.266	2.15	0.266	
LSC017500	1.74	0.237	1.74	0.237	
LSC007500	1.5	0.211	1.5	0.211	
LSC0MC120	1.5	0.263	1.5	0.263	
LSC0MC115	1.52	0.256	1.52	0.256	
LSC0MC105	1.5	0.203	1.5	0.203	
LSC0MC110	2.39	0.267	2.39	0.267	
LSC026520	1.5	0.273	1.5	0.273	
LSC026515	1.5	0.278	1.5	0.278	
LSC026510	1.5	0.268	1.5	0.268	
LSC026505	1.5	0.238	1.5	0.238	
LSC026500	1.5	0.248	1.5	0.248	
LSC006555	1.5	0.284	1.5	0.284	
LSC006550	1.5	0.226	1.5	0.226	
LSC006545	1.5	0.272	1.5	0.272	
LSC006540	1.5	0.22	1.5	0.22	
LSC006535	1.54	0.277	1.54	0.277	
LSC006530	1.8	0.204	1.8	0.204	
LSC006525	6.78	0.186	6.78	0.186	
LSC006520	1.5	0.23	1.5	0.23	
LSC006515	1.5	0.265	1.5	0.265	
LSC016520	3.18	0.198	3.18	0.198	
LSC016515	2.64	0.213	2.64	0.213	
LSC016505	1.67	0.238	1.67	0.238	
LSC116505	3.47	0.19	3.47	0.19	
LSC116500	1.5	0.252	1.5	0.252	
LSC016510	2.34	0.231	2.34	0.231	

Little Salt - continued					
	Effective		Future		
Node	Initial Loss	Constant Loss	Initial Loss	Constant Loss	Comment
LSC016500	1.5	0.237	1.5	0.237	
LSC006510	3.13	0.243	3.13	0.243	
LSC006505	1.5	0.242	1.5	0.242	
LSC006500	1.5	0.213	1.5	0.213	
LSC007020	1.56	0.243	1.56	0.243	
LSC007015	1.5	0.271	1.5	0.271	
LSC007010	1.5	0.28	1.5	0.28	
LSC007005	2.03	0.229	2.03	0.229	
LSC007000	1.5	0.232	1.5	0.232	
LSC006005	3.69	0.205	3.69	0.205	
LSC006000	2.27	0.229	2.27	0.229	
LSC0MC100	1.56	0.236	1.56	0.236	
LSC0MC095	1.5	0.243	1.5	0.243	
LSC015510	2.93	0.278	2.93	0.278	
LSC015505	5.76	0.238	5.76	0.238	
LSC015500	1.5	0.2	1.5	0.2	
LSC005510	1.5	0.275	1.5	0.275	
LSC005505	1.5	0.266	1.5	0.266	
LSC005500	1.5	0.275	1.5	0.275	
LSC0MC090	1.5	0.225	1.5	0.225	
LSC005020	1.5	0.263	1.5	0.263	
LSC005025	1.63	0.244	1.63	0.244	
LSC005015	1.58	0.247	1.58	0.247	
LSC005010	1.5	0.238	1.5	0.238	
LSC025000	3.16	0.229	3.16	0.229	
LSC005005	1.5	0.223	1.5	0.223	
LSC015000	1.5	0.299	1.5	0.299	
LSC005000	1.5	0.263	1.5	0.263	
LSC0MC085	2.14	0.295	2.14	0.295	
LSC0MC075	1.5	0.216	1.5	0.216	
LSC0MC080	2.36	0.199	2.36	0.199	
LSC0MC070	1.77	0.217	1.77	0.217	
LSC004530	1.57	0.267	1.57	0.267	
LSC004525	1.5	0.236	1.5	0.236	
LSC004520	1.5	0.252	1.5	0.252	
LSC004515	1.5	0.267	1.5	0.267	

Little Salt - continued					
	Effective		Future		
Node	Initial Loss	Constant Loss	Initial Loss	Constant Loss	Comment
LSC004510	1.5	0.181	1.5	0.181	
LSC004505	1.5	0.245	1.5	0.245	
LSC014505	1.5	0.26	1.5	0.26	
LSC014500	1.5	0.255	1.5	0.255	
LSC004500	1.78	0.261	1.78	0.261	
LSC0MC071	1.5	0.26	1.5	0.26	
LSC0MC065	1.5	0.244	1.5	0.244	
LSC0MC060	1.5	0.217	1.5	0.217	
LSC004005	1.76	0.268	1.76	0.268	
LSC004000	1.58	0.287	1.58	0.287	
LSC0MC061	1.5	0.22	1.5	0.22	
LSC0MC055	1.5	0.184	1.5	0.184	
LSC0MC053	1.5	0.154	1.5	0.154	
LSC003505	1.5	0.267	1.5	0.267	
LSC003500	1.5	0.247	1.5	0.247	
LSC0MC054	1.5	0.188	1.5	0.188	
LSC0MC052	1.5	0.161	1.5	0.161	
LSC003045	2	0.183	2	0.183	
LSC003040	2	0.189	2	0.189	
LSC003035	2	0.168	2	0.168	
LSC023005	2	0.232	2	0.232	
LSC003030	2	0.163	2	0.163	
LSC023000	2	0.152	2	0.152	
LSC013010	1.5	0.205	1.5	0.205	
LSC013005	1.5	0.188	1.5	0.188	
LSC003025	2	0.261	2	0.261	
LSC013000	2	0.221	2	0.221	
LSC003020	2	0.288	2	0.288	
LSC003015	2	0.145	2	0.145	
LSC003010	2	0.244	2	0.244	
LSC003005	2	0.201	2	0.201	
LSC003000	1.5	0.181	1.5	0.181	
LSC0MC050	1.5	0.139	1.5	0.139	
LSC0MC045	1.5	0.167	1.5	0.167	
LSC002510	1.5	0.244	1.5	0.244	

Little Salt - continued					
Node	Effective		Future		Comment
	Initial Loss	Constant Loss	Initial Loss	Constant Loss	
LSC002505	1.5	0.213	1.5	0.213	
LSC002500	1.5	0.208	1.5	0.208	
LSC052015	2	0.252	2	0.252	
LSC052010	2	0.202	2	0.202	
LSC052005	2	0.264	2	0.264	
LSC052000	2	0.192	2	0.192	
LSC002040	2	0.3	2	0.3	
LSC002035	2	0.266	2	0.266	
LSC002030	2	0.265	2	0.265	
LSC042005	2	0.283	2	0.283	
LSC042000	2	0.195	2	0.195	
LSC002025	2	0.229	2	0.229	
LSC002020	2	0.26	2	0.26	
LSC002015	2	0.26	2	0.26	
LSC132005	2.3	0.2	2.3	0.2	
LSC132000	2.3	0.201	2.3	0.201	
LSC032020	2.3	0.244	2.3	0.244	
LSC032015	2.3	0.225	2.3	0.225	
LSC032010	2.3	0.203	2.3	0.203	
LSC032005	2.3	0.206	2.3	0.206	
LSC032000	2.3	0.246	2.3	0.246	
LSC022005	2	0.259	2	0.259	
LSC022000	2	0.204	2	0.204	
LSC002010	2	0.258	2	0.258	
LSC002005	1.5	0.254	1.5	0.254	
LSC002000	1.5	0.278	1.5	0.278	
LSC012005	1.5	0.283	1.5	0.283	
LSC012000	1.5	0.221	1.5	0.221	
LSC0MC042	1.5	0.174	1.5	0.174	
LSC0MC041	1.5	0.214	1.5	0.214	
LSC0MC040	1.5	0.244	1.5	0.244	
LSC0MC030	1.5	0.172	1.5	0.172	
LSC0MC035	1.5	0.231	1.5	0.231	
LSC0MC025	1.5	0.22	1.5	0.22	
LSC0MC020	1.5	0.192	1.5	0.192	

Little Salt - continued					
	Effective		Future		
Node	Initial Loss	Constant Loss	Initial Loss	Constant Loss	Comment
LSC001575	2	0.268	1.9	0.2546	Tier III
LSC001570	2	0.286	1.9	0.2717	Tier III
LSC001565	2	0.246	1.9	0.2337	Tier III
LSC001560	2	0.246	1.9	0.2337	Tier III
LSC001555	2	0.242	1.9	0.2299	Tier III
LSC001550	2	0.243	1.9	0.23085	Tier III
LSC001540	2	0.235	1.9	0.22325	Tier III
LSC001545	2	0.269	1.9	0.25555	Tier III
LSC001535	2	0.22	1.9	0.209	Tier III
LSC001530	2	0.263	1.9	0.24985	Tier III
LSC041515	1.5	0.196	1.5	0.196	
LSC041520	1.5	0.253	1.5	0.253	
LSC041510	1.5	0.272	1.5	0.272	
LSC041505	2	0.265	2	0.265	
LSC041500	2	0.283	2	0.283	
LSC001525	2	0.219	2	0.219	
LSC001520	2	0.234	2	0.234	
LSC031505	2	0.206	2	0.206	
LSC031500	2	0.214	2	0.214	
LSC001515	2	0.214	2	0.214	
LSC001510	1.5	0.25	1.5	0.25	
LSC021505	2	0.282	2	0.282	
LSC021500	2	0.258	2	0.258	
LSC001505	1.5	0.245	1.5	0.245	
LSC011535	1.5	0.235	1.425	0.22325	Tier III
LSC011540	1.5	0.246	1.425	0.2337	Tier III
LSC011530	1.5	0.195	1.425	0.18525	Tier III
LSC011525	1.5	0.191	1.425	0.18145	Tier III
LSC011520	1.5	0.17	1.425	0.1615	Tier III
LSC111505	1.5	0.3	1.425	0.285	Tier III
LSC111500	1.5	0.291	1.425	0.27645	Tier III
LSC011515	1.5	0.243	1.425	0.23085	Tier III
LSC011510	1.5	0.236	1.425	0.2242	Tier III
LSC011505	1.5	0.274	1.425	0.2603	Tier III
LSC011500	1.5	0.226	1.425	0.2147	Tier III
LSC001500	1.5	0.203	1.425	0.19285	Tier III

Little Salt - continued					
	Effective		Future		
Node	Initial Loss	Constant Loss	Initial Loss	Constant Loss	Comment
LSC0MC018	1.5	0.201	1.425	0.19095	Tier III
LSC001050	2	0.282	1.9	0.2679	Tier III
LSC001045	2	0.25	1.9	0.2375	Tier III
LSC001035	2	0.292	1.9	0.2774	Tier III
LSC001040	2	0.272	1.9	0.2584	Tier III
LSC001030	2	0.293	1.9	0.27835	Tier III
LSC031005	2	0.247	1.9	0.23465	Tier III
LSC031010	2	0.258	1.9	0.2451	Tier III
LSC031000	2	0.285	1.9	0.27075	Tier III
LSC001025	2	0.282	1.9	0.2679	Tier III
LSC001020	2	0.284	1.9	0.2698	Tier III
LSC001015	2	0.247	1.9	0.23465	Tier III
LSC021005	2	0.238	1.9	0.2261	Tier III
LSC021000	2	0.175	1.9	0.16625	Tier III
LSC001010	2	0.207	1.9	0.19665	Tier III
LSC001005	2	0.14	1.9	0.133	Tier III
LSC011010	1.5	0.274	1.425	0.2603	Tier III
LSC011005	1.5	0.258	1.425	0.2451	Tier III
LSC011000	1.5	0.192	1.425	0.1824	Tier III
LSC001000	2	0.17	1.9	0.1615	Tier III
LSC0MC015	1.5	0.183	1.5	0.183	
LSC0MC010	1.5	0.221	1.5	0.221	
LSC0MC007	1.5	0.247	1.5	0.247	
LSC000705	1.5	0.258	1.5	0.258	
LSC000600	1.5	0.15	1.5	0.15	
LSC0MC005	1.5	0.162	1.5	0.162	
LSC000700	1.5	0.196	1.5	0.196	
LSC000510	1.5	0.239	1.5	0.239	
LSC000505	1.5	0.165	1.5	0.165	
LSC000500	1.5	0.15	1.5	0.15	
LSC0MC000	1.5	0.169	1.5	0.169	

Little Salt - continued					
	Effective		Future		
Node	Initial Loss	Constant Loss	Initial Loss	Constant Loss	Comment
N2V	1.5	0.3	1.425	0.285	Tier III
N2U	1.5	0.3	1.425	0.285	Tier III
N2S	1.5	0.3	1.425	0.285	Tier III
N1C	1.5	0.3	1.425	0.285	Tier III
N1D	1.5	0.3	1.425	0.285	Tier III
N1B	1.5	0.3	1.425	0.285	Tier III
N1A	1.5	0.3	1.425	0.285	Tier III
N1E	1.5	0.3	1.425	0.285	Tier III
N2W	1.5	0.3	1.425	0.285	Tier III
N1F	1.5	0.3	1.425	0.285	Tier III
N1J	1.5	0.3	1.425	0.285	Tier III
N1I	1.5	0.3	1.425	0.285	Tier III
N1L	1.5	0.3	1.425	0.285	Tier III
N1M	1.5	0.3	1.425	0.285	Tier III
N1O	1.5	0.3	1.425	0.285	Tier III
N1N	1.5	0.3	1.425	0.285	Tier III
N1Q	1.5	0.3	1.425	0.285	Tier III
N1G	1.5	0.3	1.2	0.25	Tier II
N1K	1.5	0.3	1.2	0.25	Tier II
N1P	1.5	0.3	1.2	0.25	Tier II
N1R	1.5	0.3	1.2	0.25	Tier II
N1H	1.5	0.3	1.2	0.25	Tier II

Cardwell			
Node	**Effective CN**	**Future Conditions Land Use CN**	**Comment**
R30W30	85.1	86	Tier 2 Area - made to match adjacent developed area
R10W10	85.4	86.4	Tier 3
R40W40	84.5	86	Tier 2 Area - made to match adjacent developed area
R70W70	82	86	Tier 2 Area - made to match adjacent developed area
R60W60	80.6	86	Tier 2 Area - made to match adjacent developed area
R80W80	83.6	86	Tier 2 Area - made to match adjacent developed area
R140W140	82.5	83.5	Tier 3
R170W170	99	99	Tier 3
R160W160	99	99	Tier 3
R150W150	87.1	88.1	Tier 3
R120W120	77.4	78.4	Tier 3
R90W90	84.5	86	Tier 2 Area - made to match adjacent developed area
R110W110	72.7	73.7	Tier 3
R20W20	75.6	76.6	Tier 3
R130W130	83	84	Tier 3
R100W100	81	86	Tier 2 Area - made to match adjacent developed area
R190W190	83.4	84.4	Tier 3
R220W220	85.4	86.4	Tier 3
R200W200	84.7	85.7	Tier 3
R260W260	80.5	81.5	Tier 3
R230W230	81.2	82.2	Tier 3
R180W180	80.5	81.5	Tier 3
R210W210	80.4	81.4	Tier 3
R250W250	85.3	86.3	Tier 3
R240W240	85.2	86.2	Tier 3
R280W280	78	79	Tier 3
R270W270	79.4	80.4	Tier 3
R300W300	83.1	84.1	Tier 3
R50W50	73.2	74.2	Tier 3

Cardwell - continued			
Node	**Effective CN**	**Future Conditions Land Use CN**	**Comment**
R290W290	82	83	Tier 3
R340W340	80.8	81.8	Tier 3
R320W320	83.7	84.7	Tier 3
R330W330	82.6	83.6	Tier 3
R350W350	80.6	81.6	Tier 3
R310W310	80.7	81.7	Tier 3
R370W370	82.3	83.3	Tier 3
R360W360	81.1	82.1	Tier 3
R380W380	79	80	Tier 3
R390W390	79.2	80.2	Tier 3
R400W400	80.1	81.1	Tier 3
R410W410	83.8	86	Tier 2 Area - made to match adjacent developed area
R420W420	77.4	86	Tier 2 Area - made to match adjacent developed area
R460W430	79.4	80.4	Tier 3
R440W440	82.6	83.6	Tier 3
R470W450	85.4	86.4	Tier 3
R480W460	80.3	81.3	Tier 3
R490W470	81	82	Tier 3
R530W490	81.3	82.3	Tier 3

APPENDIX D

Relationship Between Percent of Subbasin to be Developed in the Future vs. Increase in Discharge

This relationship was determined for each annual chance exceedance event using the seven subbasins modeled in HEC-HMS. Increase in discharge because of future land use changes in the five subbasins without HEC-HMS models were determined using these relationships.

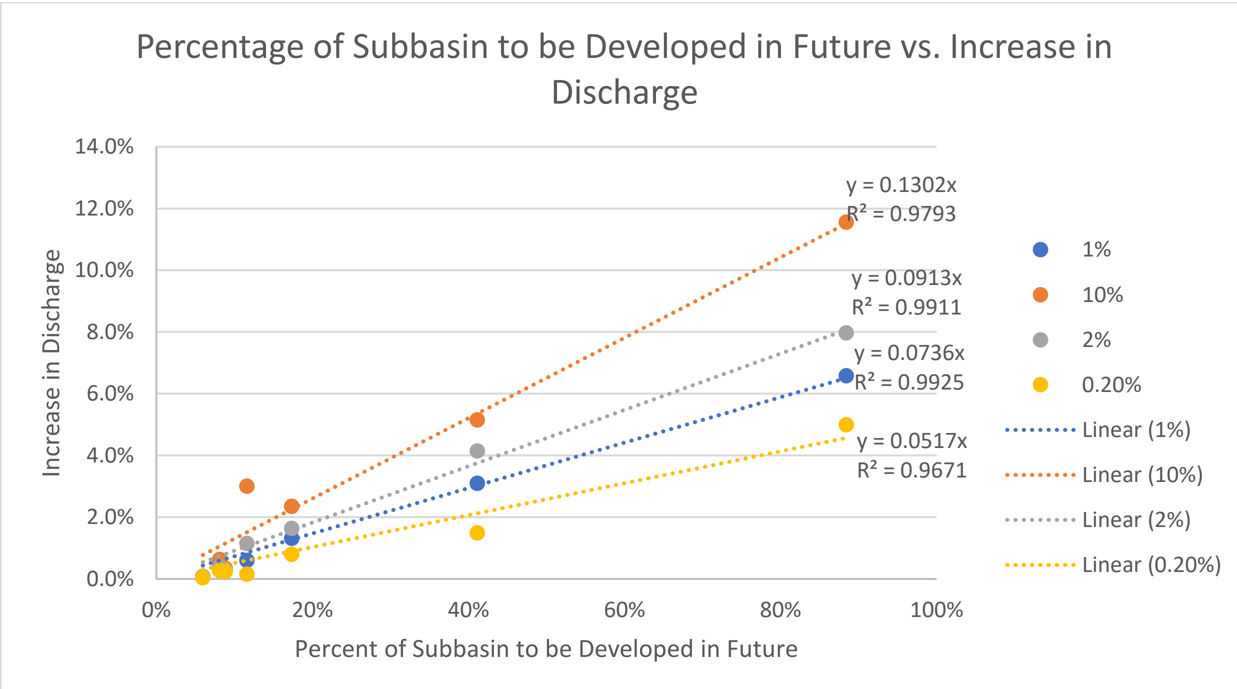

Figure D1. Percentage of Subbasin to be Developed in Future vs. Increase in Discharge.

APPENDIX E

Relationship Between Ratio of Future to Updated Precipitation vs. Ratio of Future to Updated Discharge

This relationship was determined for all annual chance exceedance events in the seven subbasins modeled in HEC-HMS for the three modeled GCMs: bcc, csiro, and hadgem. The ratio of **updated** to **future conditions** discharge for the other five subbasins and the other four GCMs were determined using this relationship.

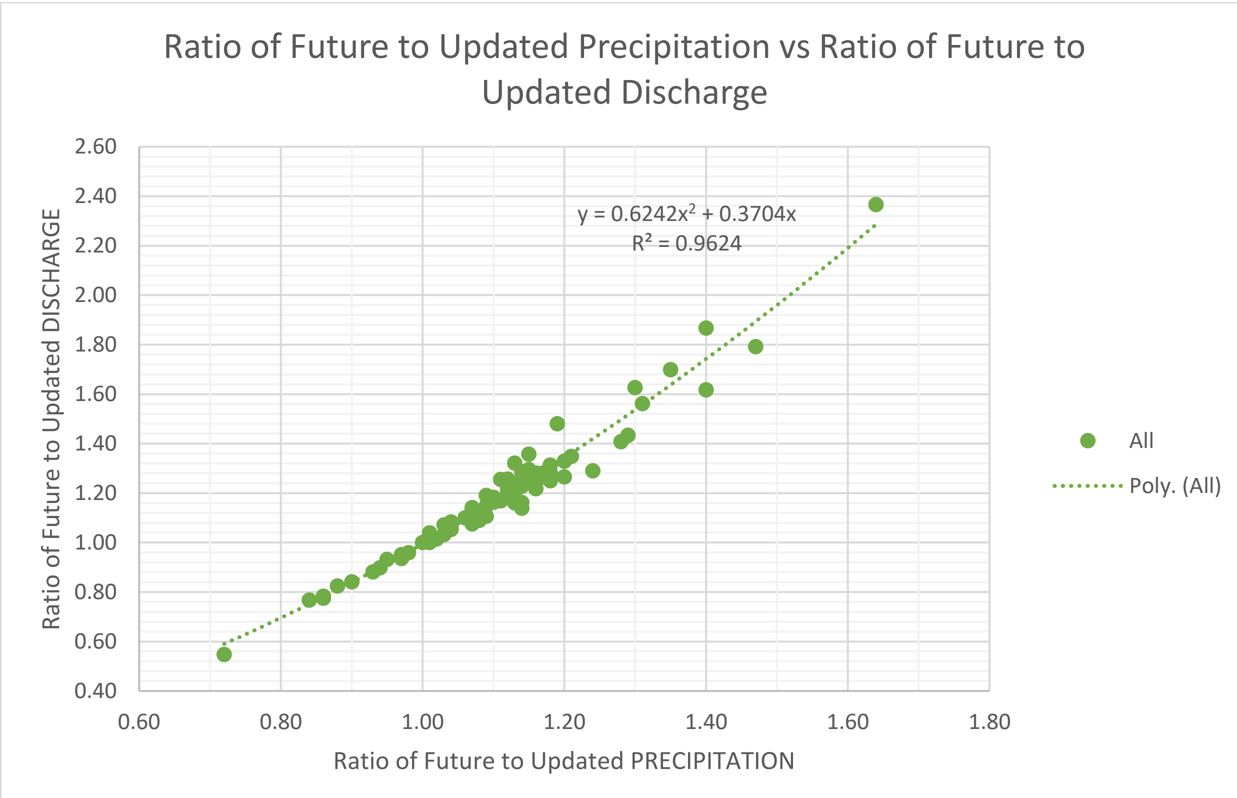

Figure E1. Ratio of Future to Updated Precipitation vs. Ratio of Future to Updated Discharge.

APPENDIX F

Description of the Manual Method Used to Estimate Dam Costs

The preliminary opinions of probable cost for the dams that were not conceptually designed were manually estimated. A least squares regression analysis was performed to develop a "best fit" line for preliminary opinion of probable cost versus contributing drainage area and is shown in the figure below.

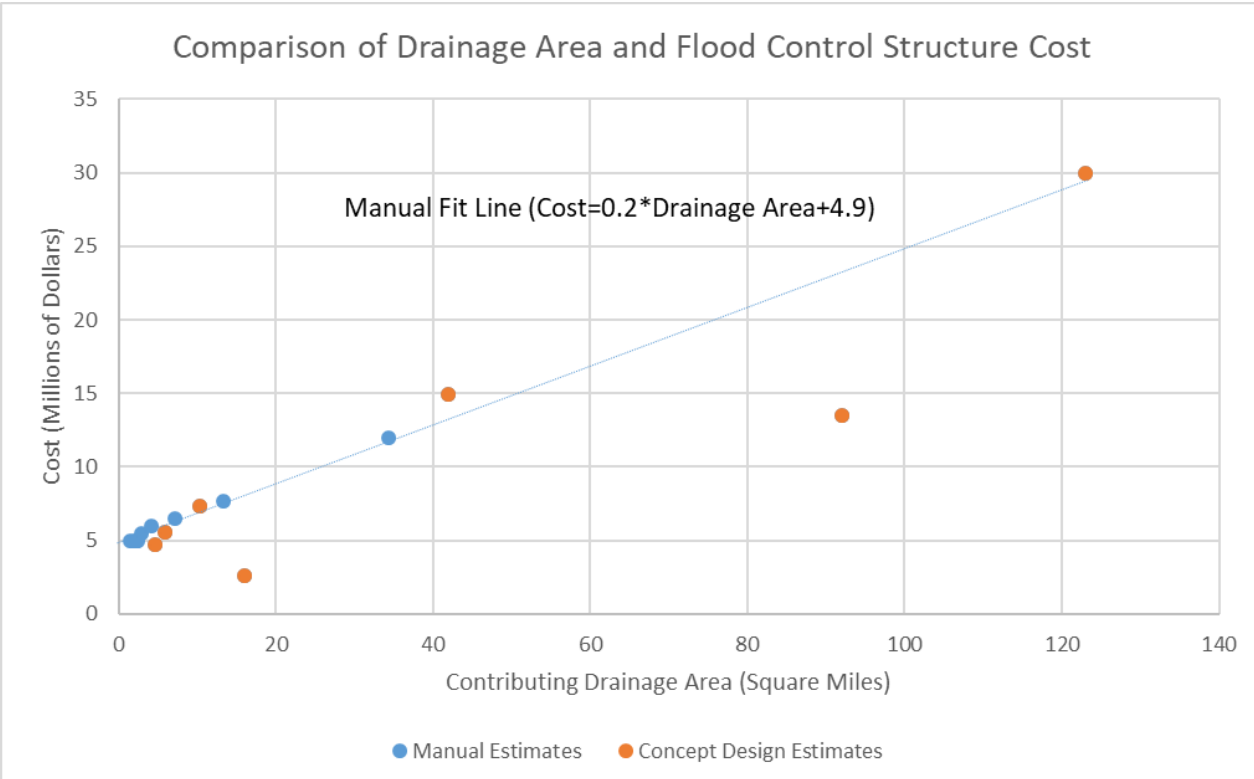

Figure F1. Preliminary Opinion of Probable Cost vs. Contributing Drainage

The preliminary opinions of cost for two of the dams are both lower than typical dams for contributing drainage areas of their respective sizes, because of their configurations. These unusually low opinions of cost values result in a lower "best fit" line. The "best fit" line was manually adjusted to provide a better fit with the remainder of the data points. The dams with manually estimated preliminary opinions of probable cost are consistent with the "best fit" line.

APPENDIX G

Methodology Used for Adjusting Input Hydrographs to the HEC-RAS Model

The dams in the unnamed tributaries to Salt Creek, Cardwell Branch, Haines Branch, and Middle Creek watersheds were not modeled using HEC-HMS. Hydrologically, these dams were accounted for by adjusting the input hydrograph to the HEC-RAS model by a drainage area factor. The drainage area factor was developed by computing the ratio of area that remains uncontrolled by the proposed dam to the total uncontrolled area of the tributary today. That ratio is raised to the 0.6 power and the resultant number (Drainage Area Factor) is multiplied by the runoff hydrograph to determine the resultant hydrograph with the dam in place.

$DAF = (A_{uncontrolled} / A_{total})^{0.6}$

DAF is the Drainage Area Factor, which is used to adjust the runoff hydrograph for the subbasin to reflect post-dam conditions. The 0.6 exponent in the above equation is derived from regional regression equations for watersheds in eastern Nebraska. The regional regression equations developed in Peak-Flow Frequency Relations and Evaluation of the Peak-Flow Gaging Network in Nebraska, Water Resources Investigations Report (Soenkson et al. 1992; WRIR 99-4032) and in Development of Regression Equations for Hydrologic Analysis Using GIS (Strahm et al. 2003) show peak runoff rates are a function of the drainage area to the 0.5 to 0.6 power. The remainder of the factors used to compute runoff for a basin are assumed to be consistent for a subbasin within the basin. Thus, the other factors are not included in the DAF equation. Using the 0.6 exponent, instead of 0.5, results in a slightly more conservative estimate of runoff reduction because of reduced contributing drainage area.

$A_{uncontrolled}$ is the remaining uncontrolled drainage area after the dam is constructed.

A_{total} is the uncontrolled drainage area of the subbasin before the dam was constructed.

The input hydrographs for the HEC-RAS model were originally developed using TP40 rainfall totals (**existing conditions** model). In the previous section, the hydrographs were adjusted to reflect **updated conditions** (NOAA Atlas 14) precipitation values, and again to reflect future **conditions** precipitation values, respectively. Thus, an **existing conditions** simulation, an **updated conditions** simulation, and a **future conditions** simulation were created. These three simulations are the pre- dam (or pre-flood control) simulations.

With the dams in place, the runoff hydrographs for **existing**, **updated**, and **future conditions** are adjusted by the hydrograph coefficients to reflect the construction of the dams. The hydrograph coefficient in Table F1 is the product of the of the DAF and the percentage of change of runoff rates because of increased precipitation. These are the post-dam (or post-flood control) simulations. These simulations provide an estimate of what can be done to mitigate or offset the increased precipitation and subsequently, runoff amounts.

The South (Upper) Salt Creek and Oak Creek watersheds were modeled in HEC-HMS. The size of the potential dams is limited because of potential impacts to upstream infrastructure or communities. Thus, larger principal spillways are required, and the potential peak flow reductions are limited. The Cardwell, Haines, and Middle Branch structures control large areas but still leave at least 40 percent of the watershed uncontrolled. The potential dams on the unnamed tributaries control most of the remaining uncontrolled watershed and do not impact upstream infrastructure or communities. Thus, these dams can be configured for greater reduction of peak flows, and the watersheds have lower hydrograph coefficients.

Table G1 and Table G2 show the contributing drainage areas and flood reduction factors for the 1 percent annual chance flood event (Table G1) and for the 0.2 percent annual chance flood event (Table G2) for the dams analyzed.

Table G1. Comparison of Contributing Drainage Areas and Flood Reduction Factors for Dams Analyzed – 1 Percent Annual Chance Flood Event.

Subbasin	Existing Uncontrolled Area (in acres)	Proposed Uncontrolled Area (in acres)	Drainage Area Ratio	Drainage Area Factor	**Existing Conditions** Hydrograph Coefficient	**Updated Conditions** Hydrograph Coefficient	**Future Conditions** Hydrograph Coefficient
South (Upper) Salt Creek	167	22.4	0.134^	0.299^	0.61*	0.67*	0.74*
Unnamed Tributary 1	2.0	0.33	0.167	0.342	0.34	0.39	0.45
Unnamed Tributary 2	2.4	0.40	0.167	0.342	0.34	0.39	0.45
Unnamed Tributary 3	4.1	0.68	0.167	0.342	0.34	0.39	0.45
Cardwell Branch	8.3	5.4	0.649	0.806	0.81	0.90	0.98
Haines Branch	52.5	29.6	0.565	0.752	0.75	0.86	0.98
Middle Creek	62	25.6	0.411	0.641	0.64	0.73	0.79
Oak Creek	175	26	0.148^	0.318^	0.59*	0.66*	0.70*

^ Existing uncontrolled area does not consider the many small dams. Drainage area ratio may be much higher than value shown.

Value taken directly from HEC-HMS, ratio of peak flow without dams to peak flow with dams for a given precipitation condition (existing** or TP 40, **updated** or NOAA Atlas 14, and **future**).*

Table G2. Comparison of Contributing Drainage Areas and Hydrograph Coefficients for Dams Analyzed – 0.2 Percent Annual Chance Flood Events.

Subbasin	Existing Uncontrolled Area (in acres)	Proposed Uncontrolled Area (in acres)	Drainage Area Ratio	Drainage Area Factor	**Existing Conditions** Hydrograph Coefficient	**Updated Conditions** Hydrograph Coefficient	**Future Conditions** Hydrograph Coefficient
South (Upper) Salt Creek	167	22.4	0.134^	0.299^	0.57*	0.71*	0.80*
Unnamed Tributary 1	2.0	0.33	0.167	0.342	0.34	0.46	0.54
Unnamed Tributary 2	2.4	0.40	0.167	0.342	0.34	0.46	0.54
Unnamed Tributary 3	4.1	0.68	0.167	0.342	0.34	0.46	0.54
Cardwell Branch	8.3	5.4	0.649	0.806	0.81	1.04’	1.14’
Haines Branch	52.5	29.6	0.565	0.752	0.75	1.01’	1.20’
Middle Creek	62	25.6	0.411	0.641	0.64	0.85	0.94
Oak Creek	175	26	0.148^	0.318^	0.59*	0.61*	0.70*

^ Existing uncontrolled area does not consider the many small dams. Drainage area ratio may be much higher than value shown.

Value taken directly from HEC-HMS, ratio of peak flow with dams to peak flow without dams for a given precipitation condition (existing** or TP 40, **updated** or NOAA Atlas 14, and **future**).*

*’A hydrograph coefficient greater than one indicates the potential dams cannot provide enough flood reduction to offset the increased runoff because of increased precipitation for **updated** or **future conditions**.*

REFERENCES

Peak-Flow Frequency Relations and Evaluation of the Peak-Flow Gaging Network in Nebraska, Water Resources Investigations Report (Soenkson et al. 1992; WRIR 99-4032)

Development of Regression Equations for Hydrologic Analysis Using GIS (Strahm et al. 2003)

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