Using GIS and historical flood data to analyze the risk and vulnerability of a rural community, past and present:

The Neosho River in Coffey County, Kansas

By

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ABSTRACT

Flooding is among the most destructive natural disasters. Continuous monitoring of potential flooding is necessary for decision makers and planners. Using GIS, analysis and visual representation allow for vulnerable areas to be identified and analyzed for risk. If potential flood risk areas can be identified, assessed, and understood, then minimizing the damage to properties and saving lives can increase.

Coffey County, Kansas is located in east-central Kansas and is home to 8,500 people, Wolf Creek Nuclear Operating Corporation, and John Redmond Reservoir. With the construction of John Redmond, flooding has significantly decreased, but the flood history of this county still looms. Coffey County's topographic characteristics make the location ideal for flood risk assessment as the city of Burlington lies along the Neosho River, protected upstream by a reservoir. Although the likelihood of a historic flood, like the one Burlington experienced in 1951, is minimal, being prepared should be, and is, a priority for all of Coffey County.

This research emphasizes the importance of defining an area's critical infrastructure, locating these areas, and assessing their potential flood risk. This information is vital to the awareness and preparedness of a community. Obtaining and simulating historical flood data allows for viewers to visualize the potential risk to their homes, infrastructure, and population. Using GIS analysis tools, visual representations were produced that can be used by emergency responders, city planners, and other decision makers to aid in creating and utilizing a flood risk assessment and response plan for the community.

ACKNOWLEDGEMENTS

This study was especially near to my heart as I was born and raised in Coffey County. I remember listening to stories that my grandparents told about the 1951 flood; the devastation it had on crops, mobility, and ultimately everyday life. When I began my graduate studies at the University of Kansas, I never dreamed that I would one day provide a tool that could be valuable to my “home.” Now, with my background achieved through my graduate studies, I am able to not only be able to provide this research to my community but also live and work in that community and contribute my knowledge to Coffey County residents every single day.

I would first like to thank my adviser, Dr. Stephen Egbert, for all of his guidance and patience throughout this research. There will never be enough gratitude for all of the endless trips to Beto Junction and for the support you provided to me throughout this process. You never stopped believing in me and I will never be able to thank you enough for that. I would also like to thank Dr. Jude Kastens for the creation of the simulated depth grid layer for this research and for all of the feedback and patience throughout the last few years. This work would have been impossible without you. Also, I would like to thank Bill Johnson for stepping in and agreeing to be on my committee.

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Throughout this research, my family has been there every step of the way. I especially would like to thank my mom and dad for their support and for allowing me to always follow my dreams. To my dad, I am sorry I was not able to finish this project before your passing. I hope this

completed work makes you proud. I would also like to thank my husband for his endless support and for always encouraging me to "keep going." I am forever grateful for all of your daily reassurance. And lastly, to my son, Hayden. Everything I do in life is for you. Even though you are too young to realize it, you are my strength and guiding light.

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LIST OF ACRONYMS AND ABBREVIATIONS

DEM	Digital Elevation Model
DNR	Department of Natural Resources
DTF	Depth-to-Flood
EPA	Environmental Protection Agency
EPZ	Emergency Planning Zone
FEMA	Federal Emergency Management Agency
FST2DH	Flood and Sediment Transport Model
FSP	Flood Source Pixel
GIS	Geographic Information System
HEC-RAS	Hydrological Engineering Center River Analysis System
HWM	High Water Mark
LiDAR	Light Detection and Ranging
NOAA	National Oceanic and Atmospheric Administration
SLIE	Segmented Library of Inundation Extents
USGS	United States Geological Survey
WSE	Water Surface Elevation

1. INTRODUCTION

1.1. Background

Flooding is among the most destructive natural disasters. According to the National Oceanic and Atmospheric Administration's National Weather Service division (NOAA-NWS), over the last thirty years the average toll comes to $8.2 billion in property damage and an average of 89 fatalities per year (http://www.nws.noaa.gov/hic/). Three-fourths of all the presidential disaster declarations are associated with flooding (http://www.noaanews.noaa.gov/stories/s600c.htm). Generally, coastal flooding receives the most attention due to its widespread impacts, but river basin flooding can be just as devastating and is the type of flooding that occurs most commonly in the Midwest.

Kansas weather is unpredictable at best. Generated by major pressure systems that move from west to east, storms can dump heavy rainfall within minutes to hours causing rivers to swell and overflow rapidly and inundate nearby infrastructure. Major floods not only cause direct damage to the areas affected, they also have a cascading effect due to the disruption of transportation systems, food and water supplies, and other economic damages to local businesses and agriculture (West 2010).

Although continuous monitoring of potential flooding on a broad scale occurs, especially for urbanized areas, there is a significant need to better understand flood events and their potential socio-economic impacts in more rural areas. With increases in housing, production and storage structures, and agricultural development near rivers, combined with projected climate change patterns, susceptibility to flooding in all populated or industrialized areas, including rural regions, has become an increasing occurrence.

Determining areas vulnerable to flooding is important for decision makers for planning and management activities (Yalcin & Akyurek 2004). Understanding the combination of geographic and population characteristics (density, distribution, type of dwellings) of an area will help determine vulnerability to flooding. Additionally, understanding social and economic vulnerability can assist the overall flood management and response in a given area. By investigating the potential disruptions and vulnerability of everyday life, one can better understand, prepare for, and cope with a natural disaster. Using GIS mapping, analytical, and visualization capabilities allows the identification of vulnerable areas and helps create visual products for analyzing that risk. When combined with existing geospatial information such as roads, population, built structures, property values, critical infrastructure, and hazardous materials in a GIS environment, it is possible to identify structures and population at risk, help route supplies and personnel, aid decision making with regard to where to pre-position temporary shelters and distribution points, give early estimates of likely flood losses, and more (Zerger & Wealands 2004). This research aims to contribute to understanding the physical and socio-economic impacts of flood vulnerability in a region of rural east-central Kansas with the goal of creating the foundation for a community-based flood risk assessment to aid in planning for potential flood events and minimizing damage to property and risk to lives.

1.2. Goals and Research Questions

Creating a community-based flood assessment involves much more than collecting numbers and calculating estimates of monetary damage for the overall community. By looking into the important infrastructure that makes a community function on a daily basis, one can get a better, more detailed understanding of how disruptive a flood event in rural areas of the United States could be. While it is not easy to measure the cost of "intangible" damage associated with a flood, my intent is to examine the potential disruption of everyday life and the economic impacts of a flood event at different stages, along with collection and analysis of numerical information. Through understanding the potential vulnerability to flooding in a specific rural setting, I hope to be able to increase the awareness of potential flood inundation among community leaders and first responders and introduce recommended strategies to help decrease the vulnerability of people and businesses in Coffey County. I also hope that this research will be a means for people in other parts of rural America to aid in thinking about what the impacts of flooding would have on their daily lives and provide a basis for solutions to reduce their individual vulnerability and improve preparedness in case of a major flood event. The research questions and objectives for this study include:

1. *What potential critical infrastructure, key assets, variables and flood data are needed in order to create a practical GIS-based flood risk assessment?* First, this research will define and map critical infrastructure and key assets in Burlington, the county seat of Coffey County, Kansas. Each location impacted by a flood event differs in its geographical characteristics and infrastructure; therefore, the potential impacts of a flood event vary by location, and critical infrastructure can vary by site. On a local scale, a flood risk assessment needs to address the local needs of residents, which includes recognizing key community facilities, locating heavily utilized areas, being aware of seasonal calendars of economic and social activity, and noting highly populated areas.
2. *How can historical flood information be leveraged to facilitate the development of future awareness strategies in a rural environment?* Reconstructed historical floods, such as the flood of 1951 that inundated wide areas of eastern Kansas, are valuable sources of data that can be utilized to create geographical representations of flood inundation scenarios. With the increase of modern infrastructure, it is hard to imagine that critical infrastructure

features such as levees and dams would ever fail, but it does happen and citizens need to be aware and prepared in case of a flood disaster, including those extreme events that are rare but potentially catastrophic.

2. RESEARCH CONTEXT

2.1. River Flooding Impacts

The attractiveness of river floodplains for settlement, transportation, agriculture, and other economic activity increases the number and susceptibility of homes and other structures built within floodplains to flood hazards. At present, 800 million people live in flood-prone areas worldwide; 70 million are exposed to flooding every year (UNISDR, 2011). In most countries, riverine flooding constitutes the greatest single hazard, as in the United States where it accounts for about two-thirds of all federally declared disasters (Smith 2013). The NOAA website defines a river flood as an occurrence when water levels rise over the top of river banks due to excessive rain from tropical systems making landfall, persistent thunderstorms over the same area for extended periods of time, combined rainfall and snowmelt, or ice jams.

The Mississippi River stretches from Minnesota down to the Gulf of Mexico, winding through several states. Despite being a famous tourist attraction filled with rich biological diversity and lush floodplain areas, the river is also well-known for the large floods that it can produce. Although flooding occurs along the Mississippi yearly, extreme events from two years in particular stand out as having greatly impacted the way our government policy makers coordinate response planning. In the Great Mississippi Flood of 1927, flooding caused by continuous rainfall throughout the winter of 1926 into the spring of 1927 caused the banks of the Mississippi to overflow. In addition to the immense rainfall, for one of the first times in history human modifications to the area negatively impacted the floodplain. By industrializing along the river and haphazardly creating limited flood control structures, humans modified the natural way floodwaters spread out of their banks. By deepening channels and building levees or dams, builders forced floodwaters to follow manmade alternate routes which increased runoff, amplified the flow of flood waters around settlements, and had major impacts both up and downstream. The river remained above flood stage for 153 consecutive days, inundating around 27,000 square miles of land, overwhelming or breaching levees all the way from Illinois to the Gulf of Mexico (Barry, 2002). This flood event proved to be a major turning point in river flood management strategies in the United States, as a flood of this magnitude broke barriers between social and political mandates. The Flood Control Act of 1928 authorized the construction of new flood-control infrastructure on the Mississippi River. Numerous levees were built, channels were dredged, and debris was cleaned up, all in hopes to help control the floodwaters of the Mississippi River. Settlers and local entities along the riverbanks were charged with maintaining the completed projects and minimizing their footprints along the river. The Flood Control Act of 1928 set precedence for future floodplain management strategies that would require efforts from federal, state and local entities throughout the United States.

More than sixty years later, the Great Flood of 1993 provided a stark reminder that flood management is an ongoing process. Due to abnormally high rainfall during the summer of 1993, this event became one of the costliest natural disasters in modern American history, totaling approximately $12 billion in property damage. As a human catastrophe, the flood affected parts of nine Midwest states, causing 52 deaths, leaving 74,000 people homeless, and disrupting 30,000 jobs and day-to-day life for 149,000 households (Wilkins 1996, Wright 1996). This natural disaster also awakened many policy makers to the hazards of allowing uncoordinated development in floodplain environments (Theiling 1999).

2.2. Flood Risk and Vulnerability

The importance of understanding potential risks of large flood events allows populations impacted by the events to be aware and prepared. In recent years, a number of studies have recognized the importance of estimating people's vulnerability to natural hazards, rather than retaining a narrow focus only on the physical processes of the hazard itself (Hewitt 1997; Varley 1994; Mitchell 1999). A large number of studies of rural flooding vulnerability and socio-economic impacts have been carried out in developing countries (Mwape 2009). In those areas, major flood events tend to have severe impacts because of the limited infrastructure to divert flood waters and because of the high poverty levels in communities that tend to be established near frequently flooded areas. Floodplain encroachment has seriously increased flood risk and damage potential, especially from urban floods due to heavy socio-economic infrastructural development on these floodplains (Ndabula et al. 2012).

To better understand the tools needed for decision making, the concepts of risk and vulnerability, in reference to this research, need to be defined. The diversity of the definitions and frameworks for both of these terms is dependent on how the researcher views both risk and vulnerability. Risk is the probability of a loss, and this depends on three elements: hazard, vulnerability, and exposure (Crichton 1999). Risk therefore is defined as the possibility of loss or injury and can be expressed by the following equation (Su, Kang, Chang & Chen 2005):

$$R = H \times V \times E$$

Here:

R = Risk

H = Hazard, the probability of a potentially destructive phenomenon occurring within a determined period and region

V = Vulnerability, the degree of loss sustained by a particular element or group of elements exposed to risk due to a natural phenomenon of certain intensity.

E = Exposure, the element at risk such as population, property or other human activities.

The term “vulnerability” was first developed in the field of social sciences. Early applications were in the natural hazards fields, but vulnerability theory has been extended from a narrow focus on exposure to geophysical risk to embrace the human responses and adaptations to other threats (Smith 2013). In the disaster literature, the concept of vulnerability refers to a technical assessment of a population’s susceptibility to the harmful consequences of a disaster event (Cutter 1996; Mitchell 1989; Deyle et al. 1998). The term “exposure” is another component of vulnerability and is defined as human activities affected by the hazardous event (Su, Kang, Chang & Chen 2005). These could include population, agriculture land, roads, or human life.

The Federal Emergency Management Agency (FEMA) is taking major strides toward alerting the public of their own individual risks and helping to build resilience to flooding. The FEMA Flood Map Service Center (https://www.fema.gov/msc-theme-template-v1) produces interactive flood hazard information that allows an individual to search by a geographical address to identify whether that particular area has been mapped with flood risk zones and their boundaries based on historic, meteorological, hydrologic, and hydraulic data. The FEMA website is often utilized for insurance requirements and premiums. FEMA is making it a priority because of the increasing risks of flood disasters, and the importance of people being informed and knowing their flood risk for a particular area. Users should note that there are limitations to this tool. The estimated 100-year (or 1% annual chance) flood extent data, which form the core of FEMA’s map set, are the basis for insurance requirements nationwide; therefore, FEMA uses only this information to produce their maps. Although FEMA uses some of the most carefully assembled flood risk information available, there are still discrepancies in small areas because of limitations of scale and topographic data. The use of FEMA flood maps is an ongoing debate and the need for more up-to-date, detailed, and accurate mapping and risk calculation is often stressed.

2.3. Utilizing Historical Flood Data

Historical flood data are often used in aiding the creation of a flood frequency analysis. The United States Geological Survey (USGS) began measuring the flow in the nation's rivers in 1889 using stream gages (Smith 2012). Today, several agencies (for example, NOAA, state departments of natural resources (DNR), and the Environmental Protection Agency (EPA)) all monitor stream patterns, but the USGS is responsible for measuring flood stage information at most stations. Comparison between historical reference conditions and modern conditions can document changes related to natural processes, human impacts, and river management practices and policies (Remo 2008). This information can provide valuable resources that help with both analyzing historical extents and assist in future management strategies. Historical data for rivers can include maps, old surveys, photographs, and numerical statistics.

2.4. Using a GIS to Identify Flood Risk Areas

GIS techniques have proven to be beneficial for a variety of disaster-related prediction and response efforts. Early identification of vulnerable areas can help in local planning and relief efforts as well as increasing awareness to the public. Having this information in a readily accessible form can allow response priorities to be established before an event occurs and can aid in timely and efficient preparedness. Armed with definitive information, government agencies can initiate corrective and remedial efforts before a disaster strikes (Chapman and Canaan 2001). Rapid acquisition and integration of topographic data, imagery and geoprocessing tools in a GIS can help decision makers analyze and implement a plan of action in case of a flood event. Basically, two different types of products of rapid mapping are required by emergency planning and response personnel and other end users during a flood event: (1) overview maps of flooded areas, and (2) damage maps combined with additional information, such as flood extent variation or land-use types within a flooded area (Allenbach et al. 2005).

Typical floodplain analyses involve three major steps: data collection and preparation, model development and execution, and floodplain mapping (Dodson and Li 1999). Like most research, data collection is the most crucial step and can be the most time-consuming component of an analysis. Fortunately, a majority of the data collection can be conducted and the data cleaned, formatted, and retained before the event occurs. This includes two major categories of data: gage data and economic data. Historical gage station data provide information about frequency and magnitude of potential flood events. Measuring the quantity and variability of water flow in the streams within an area allows for flood forecasting. The two most fundamental items of hydrologic information about a river are stage, which is water depth above some arbitrary datum (reference elevation), commonly measured in feet in the U.S., and flow or discharge, which is the total volume of water estimated to be flowing past a point on the river for some period of time, usually measured in cubic feet per second or gallons per minute. These two key factors are measured at a location on the river called a stream-gaging station or gage (Mason & Weige 1995).

Flood forecasts are based upon river modeling that provides estimates of how a river will respond to an increase in water levels from rainfall or snowmelt runoff. Often, these forecasts can contribute to early response and preparation in the event of a localized flood. The second key data category focuses on socioeconomic information, which includes the layout of the land such as where buildings exist, where people live and where areas of interest, such as key infrastructure, are located. Often this information is obtained both to ensure that flood forecasts account for all of the alternative factors that could affect the extent of a flood event and potential risk as well as for local non-flood-related tax purposes.

There are numerous models currently in use to analyze flooding. One-dimensional models treat flow through both the channel and floodplain as only occurring fully governed by forces in the longitudinal direction (Cook 2008). HEC-RAS (Hydrologic Engineering Center's River Analysis System), a one-dimensional hydraulic model created by the U.S. Army Corps of Engineers (USACE), is one of the most well-known models in use. HEC-RAS allow users to perform one-dimensional steady flow, unsteady flow, sediment transportation and temperature modeling for natural rivers and channels. Limitations in the commonly-used HEC-RAS steady flow simulation include the assumptions that the flow is constant and one-dimensional, and that river channels have small slopes (Cook 2008).

Today, advances in the development of two-dimensional hydraulic modeling are showing advantages over one-dimensional models. Two-dimensional hydraulic modeling is showing advantages in its accuracy in modeling water movement over 1-D flood modelling. Two-dimensional hydraulic models are based on integration over the flow depth to obtain depth-averaged velocity values and are solved using an appropriate numerical approach (Cook 2008). For example, the HEC-RAS 2-D model seems to be a significant-breakthrough in 2-D modeling and, because the model was developed using government resources, the model is in the public domain and is freely available to anyone. This model is also approved by FEMA and is being used more often for FEMA's FIRM mapping. 2-D modelling in HEC-RAS has the ability to incorporate more available spatial data such as land cover and terrain. The ability to model 1-D, 2-D or a 1-D and 2-D combined model is an advantage of HEC-RAS. This model has shown impressive results in modelling real-time dam or levee breaches. The Federal Highway Administration has also created a two-dimensional model known as the depth-averaged Flood and Sediment Transport Model (FST2DH). The FST2DH is a two-dimensional finite element numerical model that simulates water movement and the transport of non-cohesive sediment in rivers and estuaries (Foehlich 2003). The Federal Highway Administration created this model because of a special interest arising from complex conditions such as those occurring around highway river crossings or channels around dams.

The last step in creating a floodplain analysis is using the data collected and executing the model to create a geographical representation of the areas that are vulnerable to flooding. Floodplain mapping can provide information about the risk and vulnerability of certain locations and is the key element in creating a floodplain assessment. Having an interactive GIS-based visual representation of the risk and vulnerability of an area is beneficial for users and enhances the ability for personnel to create an assessment and in preparation for future management and response efforts.

3. STUDY AREA AND FLOOD HISTORY

3.1. Study Area

Coffey County is located in east-central Kansas approximately 60 miles south of Topeka, the state’s capital. Approximately 8,500 people currently reside in Coffey County. Centrally located, Burlington, the county seat, lies on the Neosho River and is the largest town in the county; it houses approximately 3,500 people, or nearly half of the county’s citizens. Radiating outward from Burlington, there are five smaller, incorporated towns in Coffey County: Lebo, Waverly, New Strawn, Gridley, and LeRoy. There are also several smaller, unincorporated areas.

Figure 3.1. 2005 Kansas Department of Transportation (KDOT) map of Coffey County, Kansas.

Four miles north of Burlington lies John Redmond Reservoir. Due to high frequency flooding along the Neosho River, construction of John Redmond began in 1959 primarily to assist with flood control. The Army Corps of Engineers built the dam and continues to operate the reservoir today. Aside from being built for the purpose of flood control, storage from John Redmond also provides a stable water supply for Coffey County Lake (formerly known as Wolf Creek Lake), the cooling pond for Wolf Creek Nuclear Generating Station. The city of Strawn originally was located where the existing dam for John Redmond sits and was often flooded in the past. Due to frequent flooding and the construction of the reservoir, the city of Strawn was relocated to higher ground, approximately six miles east of the former townsite, and renamed New Strawn. Aside from flood control, the reservoir is frequently used for recreational purposes such as fishing and camping.

Wolf Creek Nuclear Operating Corporation, which is located in Coffey County, operates the only nuclear power plant in the state of Kansas. The Wolf Creek Generating Station is located approximately four miles northeast of Burlington and has been providing energy to citizens in both Kansas and Missouri since 1985. Coffey County Lake is an enlargement of the Wolf Creek Lake impoundment that was constructed as the cooling pond for Wolf Creek Generating Station. This lake, too, is often used for recreational purposes and has proven to be one of the best fishing lakes in the state. Often, inflow from the Wolf Creek watershed is not enough to provide sufficient water supply for Wolf Creek Generating Station to operate, and when this occurs John Redmond Reservoir aids in providing water to Coffey County Lake.

Since Coffey County houses a nuclear power plant, a majority of the county's emergency management focuses on the Wolf Creek Generating Station. Twenty-one emergency planning zones (EPZs) have been established, evacuation routes have been mapped, and mock scenarios are played out throughout the year in order to prepare county workers, state workers, emergency responders and citizens in case of a disaster at Wolf Creek Generating Station. Figure 3.2 illustrates the EPZs within Coffey County.

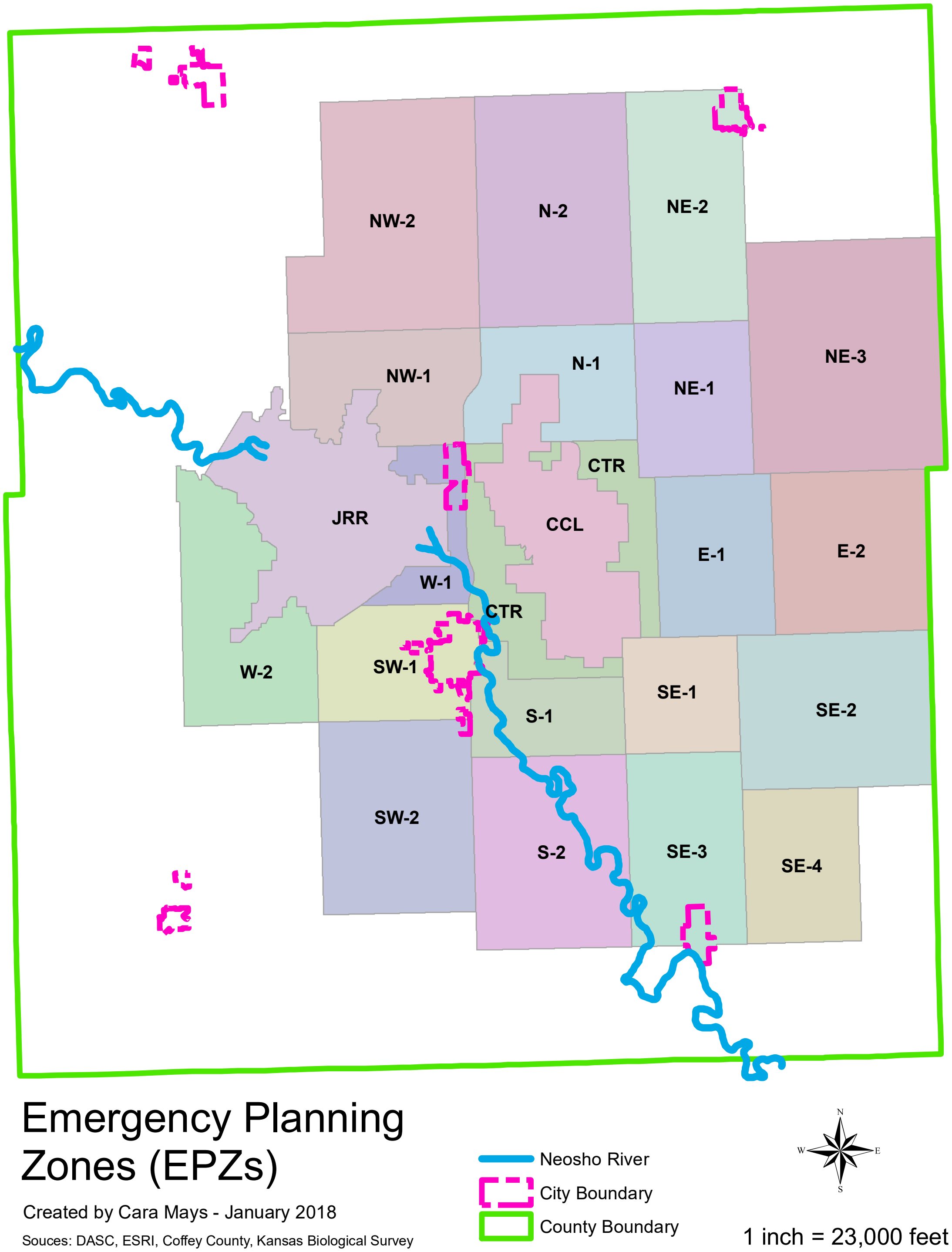


Figure 3.2. Coffey County Emergency Planning Zones (EPZs).

Coffey County has several unique factors that increase its vulnerability during a flood event. First, disruption of operations at Wolf Creek Generating Station due to flooding not only potentially could impact the citizens of Coffey County but other counties nearby. Second, John Redmond Reservoir controls flooding downstream. If a major flood event should occur, the impacts would not only affect Coffey County residents but possibly other areas downstream as well. Third, the Neosho River, the major waterway in Coffey County, flows straight through the heart of the county and is adjacent to two of the major cities in the county that contain a large part of its commercial infrastructure and residents.

3.2. Flood History

The main intention behind the construction of John Redmond Dam, which was named after the publisher of the local newspaper, was to help control flooding and provide water conservation and water supply for communities in Coffey County and communities along the Neosho River. Dam outflow structures allow the amount of water released from the reservoir to be controlled by the Corps of Engineers. Before John Redmond Dam was constructed, the Neosho River flooded 57 times in 34 years. The most memorable flood was in 1951, one year after Congress authorized construction of the dam. This event is remembered by many Kansans as the Great Flood of 1951 which displaced many citizens and caused millions of dollars in flood damage. The entire business district in Burlington was under water. Those water levels can still be seen on some of the older buildings in downtown Burlington to this day (Figures 3.3 and 3.4).

A majority of the land along the Neosho River is devoted to agricultural purposes, and in 1951 a majority of the crop yield in the Neosho floodplain was lost. With the construction of John Redmond Dam, farmers were able to continue growing their crops in the fertile soils on the river lowlands of Coffey County with less concern for flood losses. Moreover, Burlington, the largest city in the county, could operate normally without the fear of another large flood and the risks of potential life and property loss dramatically decreased.

Figure 3.3. Inside the Burlington Post Office. The red circle identifies a sign indicating the height that floodwaters reached in 1951. Photo was taken by Wade Camp for GO571 Geohydrology at Emporia State University. Photo taken in 2007.

Figure 3.4. United States Postal Service Office in Burlington, Kansas. The floor visible in Figure 3.3 is level with the top of the building entrance stairs. Photo was taken by Wade Camp for GO571 Geohydrology at Emporia State University. Photo taken in 2007.

4. RESEARCH AND METHODS

4.1. Defining Coffey County's Critical Infrastructure and Key Assets

To begin this research, it is important to define the terms *critical infrastructure* and *key asset*. With increases in technology, natural disaster occurrences and terrorism threats, the concepts of critical infrastructure and key assets have evolved. Infrastructure that provides assistance in ensuring the health, well-being, and productivity of citizens is critically necessary and needs to be considered as potential critical infrastructure or key assets. The Homeland Security website defines critical infrastructure as "the backbone for our nation's economy, security and health. We know it as the power we use in our homes, the water we drink, the transportation that moves us, and the communication system we rely on to stay in touch with family and friends" (http://www.dhs.gov/what-critical-infrastructure). Categories of critical infrastructure, as defined by the Office of Homeland Security, include entities such as: Agriculture, Food, Water, Public Health, Emergency Services, Government, Defense Industrial Base, Information and Telecommunications, Energy, Transportation, Banking and Finance, Chemical Industry and Hazardous Material, and Postal and Shipping.

The Department of Homeland Security Strategy documents also recognize the importance of infrastructure that constitutes key assets. Key assets are defined as "such assets and activities that alone may not be vital in the continuity of critical services on a national scale, but an attack on any one them could produce, in the worst case, significant loss of life and/or public health and safety consequences (The National Strategy for The Physical Protection of Critical Infrastructures and Key Assets. (2003, February); https://www.dhs.gov/xlibrary/assets/Physical_Strategy.pdf). These are categorized into three groups:

1. locations that represent our nation’s heritage such as national monuments or historical attractions;
2. locations that represent our national economic power or technological advancements such as hazardous storage facilities or power plants;
3. locations of prominent commercial centers such as schools or office buildings.

Using the definitions established by the Department of Homeland Security, these terms were used to identify what Coffey County infrastructure needed to be considered for this research. After those locations were deemed critical or key assets, information about each location, if accessible, such as definitive location and population numbers for any given time, was gathered and organized. After the identification process was completed, GIS layers were created using location data and aerial imagery in ArcGIS. Location information was provided by both the Coffey County Appraiser’s Office and Emergency Management Office. Point shapefiles were created with attribute information such as identification of the property and official address. Additional information, such as type of infrastructure existed on several of the layers. The following layers were deemed critical to Coffey County or key assets to the community: health facilities, nursing homes, schools, electrical substations, utility facilities, public safety facilities, civil administration facilities, public transportation housing, post offices, banks, gas stations, pharmacies, and grocery stores.

4.2. Obtaining Additional Coffey County GIS Data

Additional information obtained from the Coffey County Appraiser’s Office included an address point layer, a road centerline file, county parcels, and a county agricultural use layer. These map layers are continuously updated by the Coffey County Appraiser's Office GIS Department. The office uses an ArcGIS server to edit and maintain these layers.

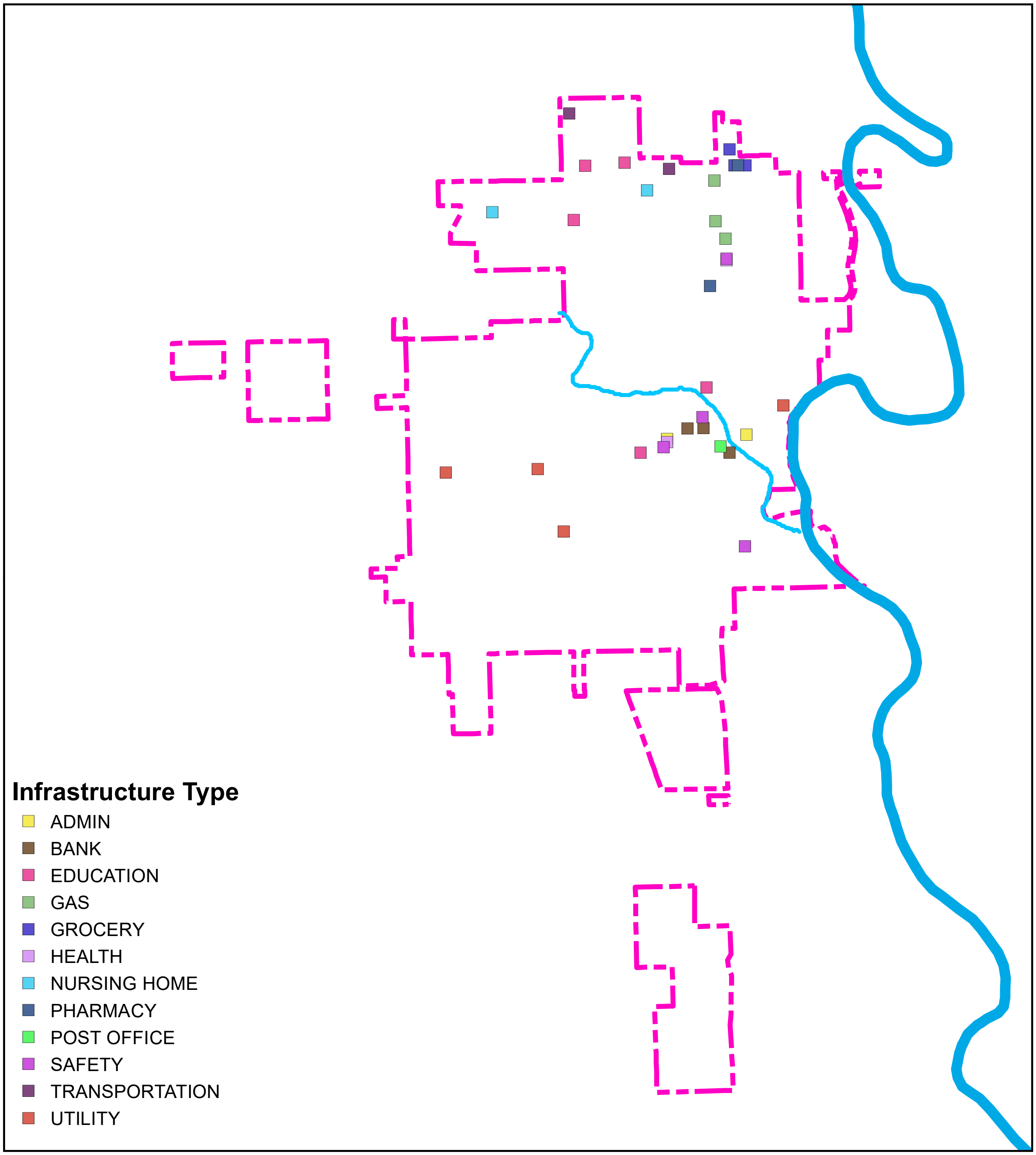
The Coffey County address point layer provides data about existing structures that have been conformed to the standards of the Next Generation 911 Initiative, a project currently ongoing in the state of Kansas to help create seamless GIS data for emergency management and response purposes. Data within this layer include situs address, type of address, occupancy status, and name of resident. The centerline file provided information such as road name, road type, and surface type. This layer will be used to locate areas as well as totaling infrastructure impacts necessary for planning and response.

With access to the state-hosted appraisal querying tool, I was able to query the desired parcel attribute information for the entire county. The attribute data queried for each parcel in Coffey County included: Reference ID number, total parcel acreage, Land-Based Classification Standard (LBCS) function code, and agricultural use. The LBCS function code indicates how the property is being utilized. Coffey County has 131 different ways to identify a parcel. This parcel information was transformed into vector data formats to be used for analysis. Finally, the agricultural layer provides information about the way that the land is used within a parcel. It determines whether a property contains agriculture land, is solely native or tame grass, or is used as a homesite location. These attributes help the Appraiser's Office determine the value of a property and how a landowner is taxed but also provides valuable information for flood hazard mapping analysis. Table 4.1. lists the GIS layers acquired for the analysis conducted for this research.

Attribute Name	Source	Created or Obtained
Health Facilities	Coffey County	Created
Nursing Homes	Coffey County	Created
Educational Facilities	Coffey County	Created
Electric Substations	Coffey County	Created
Utility Facilities	Coffey County	Created
Special Needs Residents	Coffey County	Created
Public Safety Facilities	Coffey County	Created
Civil Admin Facilities	Coffey County	Created
Transportation Housing Facilities	Coffey County	Created
Postal Services	Coffey County	Created
Banking Entities	Coffey County	Created
Grocery Suppliers	Coffey County	Created
Parcel Ownership	Coffey County	Obtained
Agricultural Land Use	Coffey County	Obtained
Roadways	Coffey County	Obtained
Lidar	Coffey County	Obtained

Table 4.1. Table of GIS layers.

Once the critical infrastructure in Burlington was identified and located, a GIS point layer was created and overlaid with the city boundary, Neosho River and Rock Creek tributary. Figure 4.1 illustrates the distribution of present-day critical infrastructure. As can be seen, the locations of many of these services have migrated away from the Neosho River. The main take-away from this map is the establishment of services in the northern part of Burlington subsequent to the 1951 flood, which will be discussed later in this thesis.



2018 Critical Infrastructure

Created by Cara Mays - January 2018

Souces: DASC, ESRI, Coffey County, Kansas Biological Survey

1 inch = 2,500 feet

Neosho River

Rock Creek

City Boundary

Figure 4.1. The city of Burlington's critical infrastructure locations in 2018.

4.3. Obtaining Historical Information for Areas around the Neosho River

Growing up in Coffey County, I have personally heard stories of how busy downtown Burlington used to be. Downtown was where a majority of the town amenities were located, the "heart" of the community if you will. Today, several buildings lie empty as businesses have shut down or moved to different locations within the city, such that downtown is no longer the community focus it once was. There were two additional sets of data I needed to complete this research in regard to the traditional downtown area. I needed the current occupancy information of the buildings downtown (i.e. the present footprint of downtown) and secondly what businesses or activities occupied those buildings in 1951. I began my research at the Coffey County Museum located in Burlington. Here, I was provided several photos and maps of what downtown Burlington looked like in 1951.

Next, I met with people in our community who either lived during the flood or had previously shown interest in the history of downtown Burlington. These individuals were suggested by a long-time prominent resident of our community who knew of their experiences and would be willing to speak about what they remembered from the flood. This was solely a volunteer effort. The interview process was very relaxed. Four members of our community who were adults during the 1951 flood event met at a local restaurant. I intended for the interviews to follow a format. I had a series of questions to ask, but once these individuals began remembering certain memories about downtown Burlington in 1951 and the flood, the interview process was more a "story-telling" meeting. Through this meeting, the individuals were able to collaboratively look at the footprint of the current downtown and identify each building and what occupied that building in 1951. Through these interviews, I was able to hear numerous stories about the flood, first-hand experiences of the struggles and tribulations that people experienced and the fear they had that another would occur. I truly believe those stories helped me paint the picture of what it was like in 1951 far beyond any other data could.

4.4. Obtaining the Simulated Flood Layer

In recent years, the increased recognition of the need for real-time, accurate information regarding the footprint of major flood events has led to the development of the Eastern and Central Kansas Segmented Library of Inundation Extents (SLIE). The SLIE allows for estimating wide-area floodwater spread and depth at different stage levels. Rapid and affordable methods are necessary to identify flood prone areas over extensive river reaches to provide information about flood potentials that can affect floodplain development by individuals, and private and public organizations (Kastens 2008). This database was developed by the Kansas Applied Remote Sensing Program (KARS), funded in part by the Kansas GIS Policy Board and the AmericaView Program. Currently the SLIE spans 66 counties. Originally, the SLIE was developed for 40 counties in eastern Kansas using USGS NED elevation data during 2007-2009. The SLIE recently was expanded to cover an additional 26 counties in central Kansas, all but two of which possessed recently acquired, high quality LiDAR elevation data, and an update is underway for the 40 eastern Kansas counties using LiDAR as well. There are numerous uses for this data including flood risk assessment purposes.

The FDLPLN ("Floodplain") model developed by Dr. Jude Kastens at the Kansas Biological Survey was used to create the SLIE (Kastens 2008). FLDPLN was developed to estimate floodplain extents as a function of floodwater stage (or water surface elevation), and the primary outputs are "Depth to Flood" (DTF) values for pixels exposed to riverine flooding (Williams 2013). This 2-dimensional, pseudo-kinematic wave propagation model is driven by topographic data and has exhibited close agreement with manual flood extent delineation from flooded imagery (Kastens 2008) as well as extent estimates produced using HEC-RAS 1-D (Dobbs 2010) and HEC-RAS 2-D (Dobbs 2017) models developed to simulate major flooding. FLDPLN has significant advantages over existing hydrodynamic models (Kastens 2008). For example, the model:

1. is nearly automated and has few input requirements;
2. can be used to identify and map historical floodplains;
3. can be used to estimate inundation extents for major, sustained flood events.

This model was created to be used as a solution for a broad range of needs. Emergency response agencies can benefit from its capabilities for rapid and accurate information that can be used to assess human and property impacts from flooding. In addition, the model can provide mapping information pertinent to river ecology studies (Williams et al. 2013) and it can be used to assess floodplain connectivity characteristics of wetlands and riparian areas and impacts of levees. For this research, the model provides an estimate of the areas impacted by a flooding event and provides a key base layer to overlay and analyze potential flood impacts in Coffey County, Kansas.

Historical flood stage data were obtained from readings on the National Oceanic and Atmospheric Administration (NOAA) Advanced Hydrologic Prediction Service (AHPS) website. The AHPS provides information such as real-time stage, historic crest data information, gage location, and gage datum. Gage data from three sites were utilized. Brief descriptions of each gage site were taken from the USGS.

The Neosho River at the Burlington gage site (BRLK1) is located along the Neosho River on the east side of the city of Burlington, near what the locals call the “river bridge.” The flood stage for this gage site is 27 feet. At 40.2 ft, flood waters reach the top of the bridge deck. At 41.5 ft, overflow is very widespread and can reach a width of 2 miles.

The Neosho River at LeRoy gage site (LRYK1) is located along the Neosho River on the south side of the city of LeRoy. The flood stage for this gage site is 23 feet, at which point significant overflows begin and about 100 acres of nearby land are inundated. At 27 ft, the Missouri, Pacific and the Missouri, and Kansas and Texas Railroad tracks overflow. The railroad, now abandoned, was operating in 1951. At 43 ft, flood waters reach the top of the bridge deck on Reaper Lane over the Neosho.

The Neosho River at Iola gage site (IOLAK1) is located along the Neosho River where 1200th Street intersects US-54 Highway. The flood stage for this gage site is 15 feet. At 27 feet, the base of the Iola Water Power plant begins to receive overflows. At 33 ft, approximately one-third of the city of Iola would be expected to be inundated by 3 feet of flood waters.

4.5. Creating a Risk Map for Critical Infrastructure

The initial focus of this research was to create a flood risk map for the city of Burlington based on simulation of the 1951 event. After identifying the critical infrastructure and mapping those locations, overlaying the depth-to-flood layer over the critical infrastructure layer allows identification of those services that still remain in the potential flood hazard areas. Figure 4.2 illustrates the location of critical infrastructure, for the city of Burlington, in 2018, relative to the simulated 1951 depth grid.

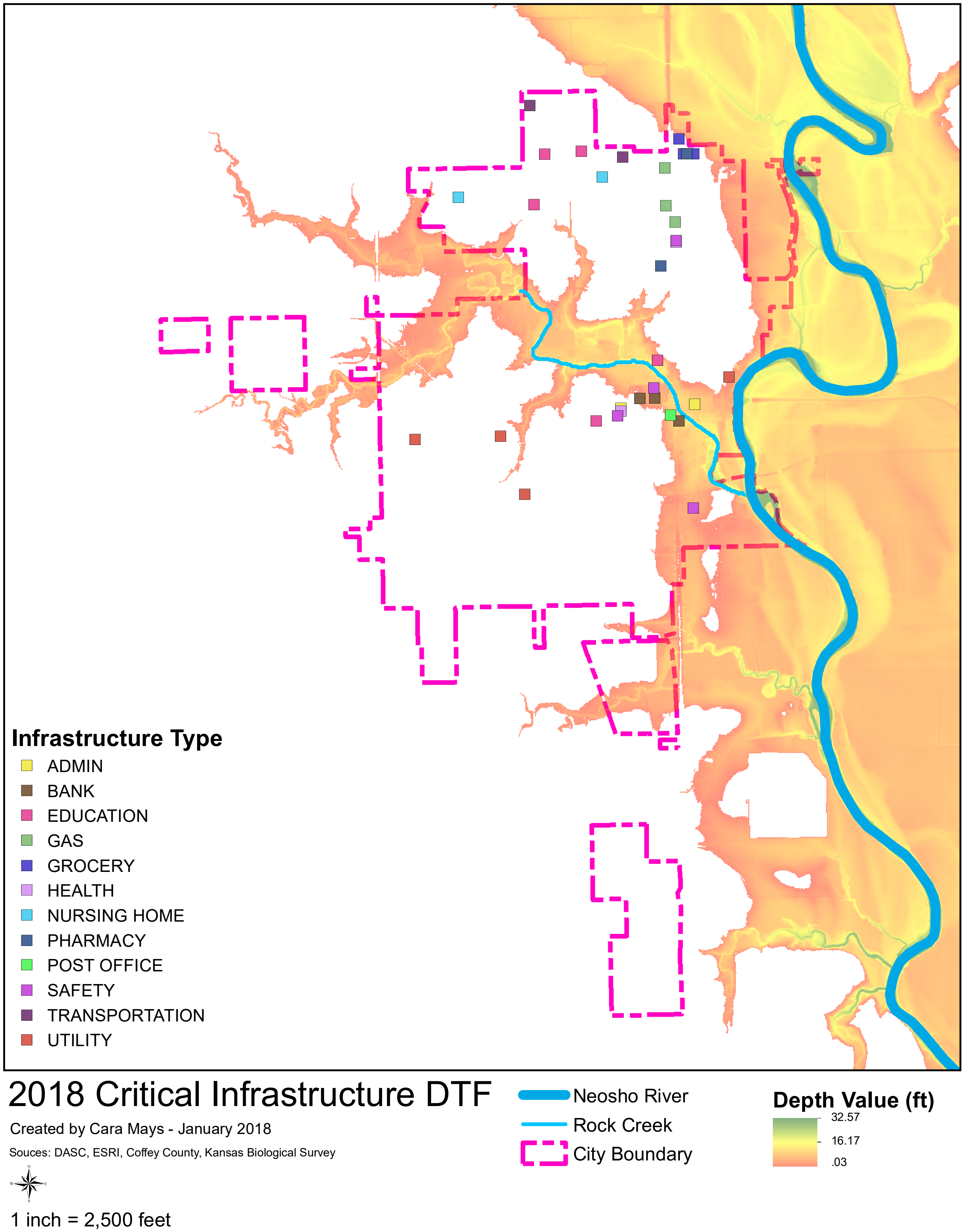


Figure 4.2. The city of Burlington's critical infrastructure in 2018 with the simulated 1951 depth grid overlaid.

Out of the 32 identified current critical infrastructure locations identified, nine of those locations remain in the flood risk area. Those locations include: three banks, the city administrative building, post office, fire station, a preschool, the city water distribution plant, and the city police building.

The development of the northern part of Burlington illustrates that the migration of not only critical infrastructure, but a majority of the commercial industry of Burlington, allows for their protection in case of a major flood event such as the type of flooding that occurred in 1951. What I believe to be crucial to everyday health and operations services, such as the hospital, grocery store, and pharmacies, lie outside the flood risk area. However, although a majority of the critical infrastructure has migrated north and west of downtown Burlington, businesses do still occupy buildings within the flood risk area and these businesses are still vulnerable to a major flood event as shown in Figure 4.3.

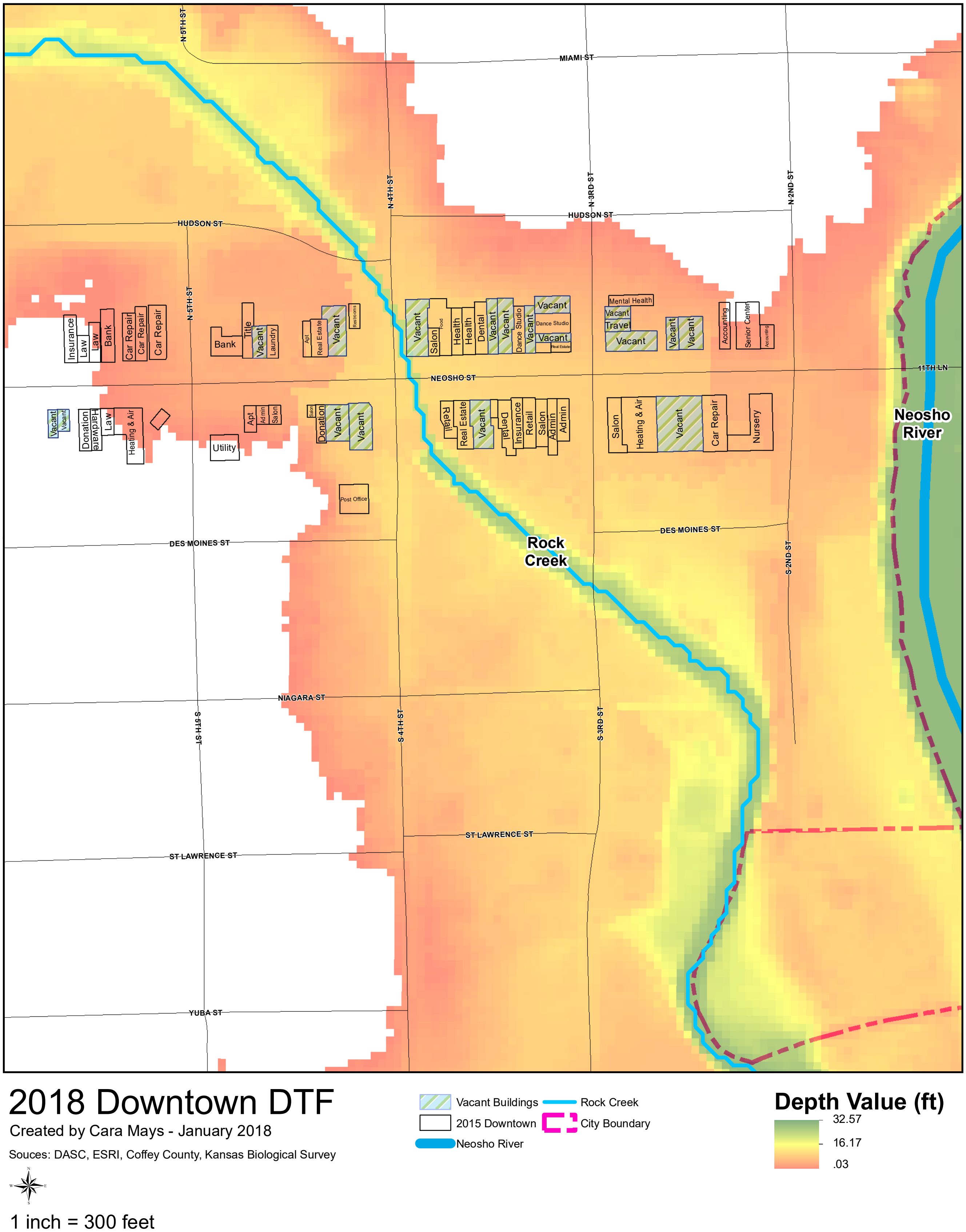


Figure 4.3. 2018 Downtown Burlington with the simulated 1951 depth grid overlaid.

4.6. Overlaying and Analyzing the GIS Data for the 1951 Flood

The maximum observed stages recorded at the three Neosho River gages during the 1951 flood were used to obtain SLIE-based estimates for the flood extent and a depth grid for the study area. I then used historical photographs to evaluate the reasonability of these simulated results, which are based on modern elevation data representative of the landscape 60 years later. This assessment is crucial, not only for evaluating the historical flood of 1951 but also for creating an accurate analysis of the potential impact of a flood event in the present day.

Once the simulation was completed, I first looked at the two high water mark (HWM) locations and compared the flood-depth values. I also used several photographs of the 1951 flood extracted from historical records to validate the simulation. By comparing the flooding visible in the historical photographs with locations on the ground in the depth-to-flood maps, the viewer can gain a clearer understanding of the flood depths in Burlington in 1951, especially when flood waters can be observed on the sides of buildings. While not as precise as actual flood depth measurements would be, they nonetheless provide powerful visual evidence of the impacts of flooding.

By obtaining the data to create multiple GIS layers of local infrastructure and landuse (as described above), I could overlay them on the flood extent layer. Then, using a series of GIS tools in Arcmap, I created a series of maps that show the impacts of predicted flood inundation on Burlington's infrastructure during various flood events. These maps illustrate modern day flood inundation areas and illustrate what infrastructure would be impacted. This allows a better understanding of what response steps will need to be taken in case of a major disaster and also help those responsible for those areas of interest become aware of their potential risk of a flood event and what they can do to be prepared in case of an emergency. For example, using the

Agricultural Land Use (aguse) layer, which illustrates the type of land use for a given property, I can investigate the potential agricultural damage that could occur during a flood event. By creating a series of maps, I will then have a visual aid to be used as a source for analysis and response efforts.

Next, I recreated the old downtown area of Burlington by digitizing the buildings and identifying what types of businesses existed in those buildings in 1951. As discussed earlier, I used interviews with people who lived and worked downtown at the time of the flood, old deed information, and historical records such as yearbooks and newspaper clippings to identify and cross-reference the building occupancy in 1951. This set the foundation to again overlay the flood extent layer and, using GIS tools, virtually analyze the impact of the 1951 flood in 1951. The product of this process is a series of maps that help visualize and analyze what the disruption of everyday life would have been like when the 1951 flood occurred. From this process, I hoped to be able to create an appealing visual interpretation of what the 1951 flood looked like using modern technology to recreate the downtown area and increase awareness for emergency response personnel in the event of a major flood. Figures 4.4 and 4.5 illustrate the 1951 downtown building occupancy and critical infrastructure. These maps will be utilized later on in this research for comparison to the present-day downtown and critical infrastructure.

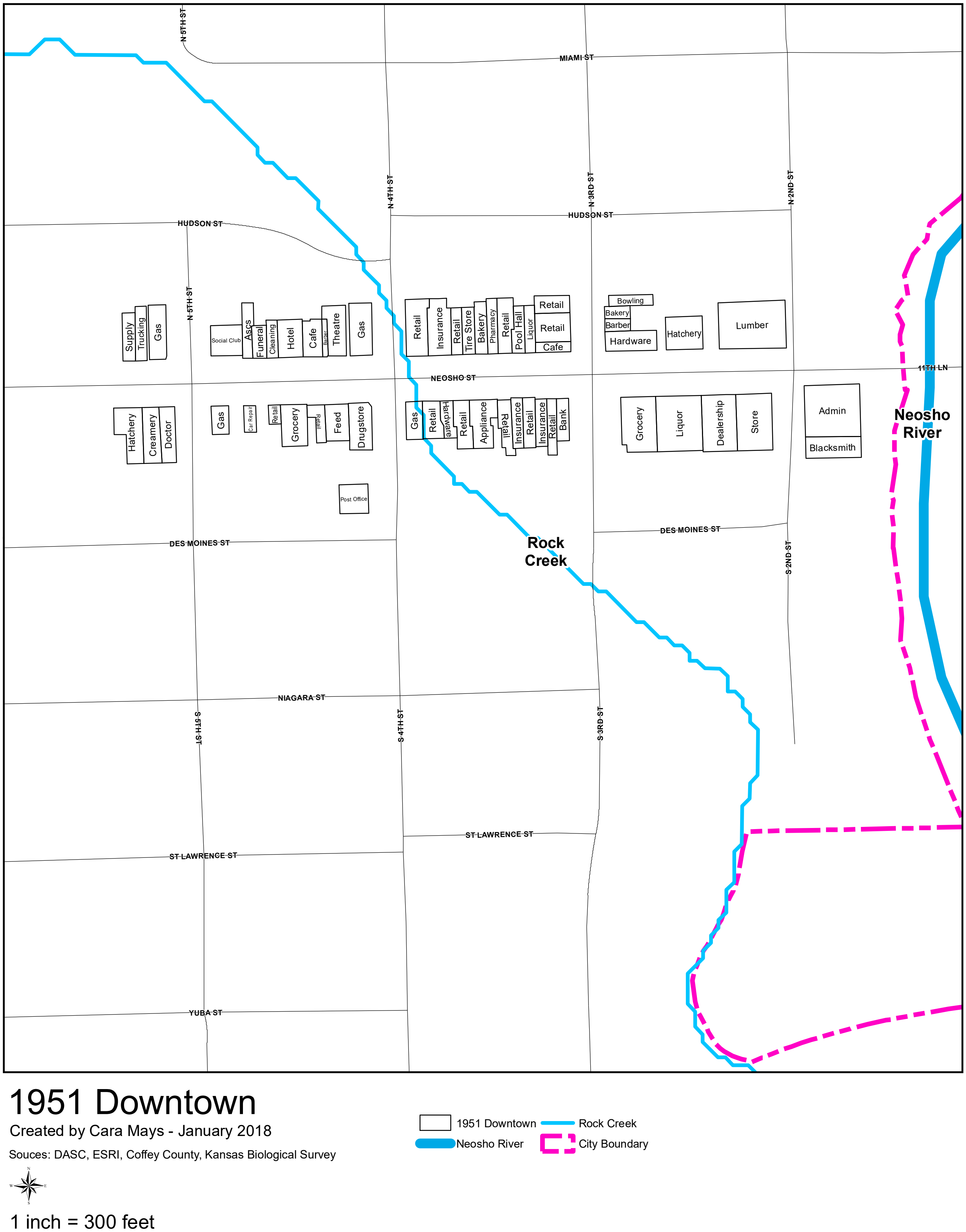
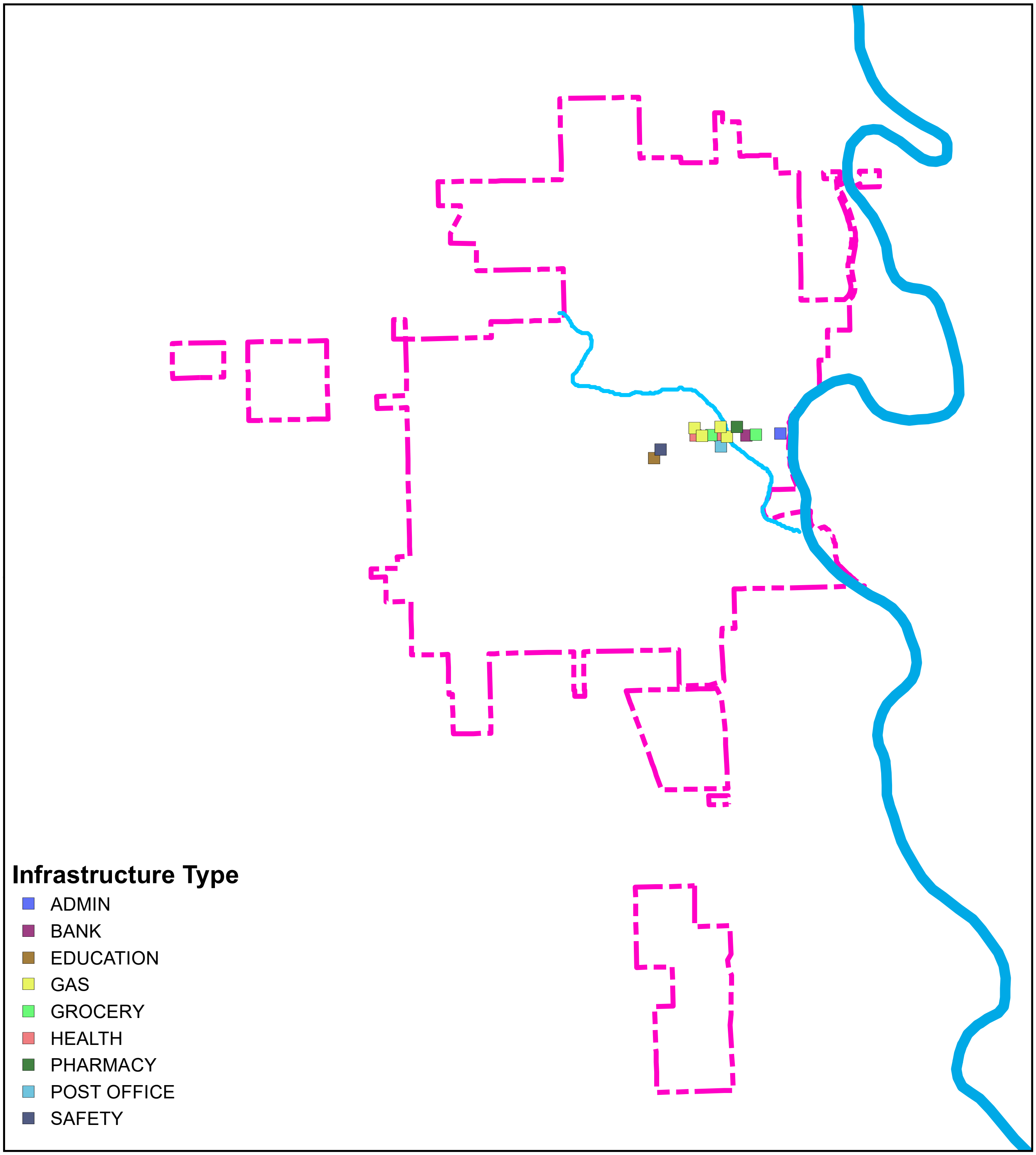


Figure 4.4. 1951 Downtown Burlington.



1951 Critical Infrastructure

Created by Cara Mays - January 2018

Souces: DASC, ESRI, Coffey County, Kansas Biological Survey

1 inch = 2,500 feet

Neosho River
Rock Creek
City Boundary

Figure 4.5. The city of Burlington's critical infrastructure locations in 1951.

5. RESULTS AND DISCUSSION

5.1. Creation of the Depth-to-Flood Layer

Based on Dr. Kastens' previous work at the Kansas Biological Survey in recreating historic flood events, I contacted him for his assistance in providing the flood extent and depth grid for the study area in reference to the 1951 flood event. An existing Segmented Library of Inundation Extents (SLIE) was used to simulate the 1951 flood extent for the Neosho River in Coffey County, Kansas. LIDAR elevation data provided the digital elevation model (DEM) that helped create the foundation for the SLIE. The standard units are given in feet to correspond with the units used for the United States stream level monitoring system.

Water surface crest elevation values from 1951 for each of the three gage sites (Table 5.1) were used as SLIE selectors for calibration and extracted from the SLIE. The crest elevation values were subsequently converted to DTF information (Table 5.1). A description explaining the DTF process was provided by Dr. Kastens, as follows: "Each gage is associated with its closest FSP or flood source pixel along the stream path. Once a DTF value for an FSP is determined, all floodplain pixels associated with that FSP and which have a DTF value less than or equal to the specified FSP DTF value are included in the inundation extent, with the estimated floodwater depth at each pixel equal to the difference between the FSP DTF value and the pixel's base DTF value."

Gage Location	NWS Gage ID	Datum (ft)	1951 Crest (ft)	1951 Crest Date	1951 Crest WSE (ft)	DEM* (ft)	1951 DTF** (ft)
Burlington	BRLK1	983.56	41.53	7/12/1951	1025.09	992.22	32.87
Le Roy	LRYK1	961.63	34.48	7/12/1951	996.11	966.47	29.64
Iola	IOLK1	928.91	33.26	7/13/1951	962.17	928.20	33.97

Table 5.1. Parameters for simulating the 1951 flood along the Neosho River.
**Elevation values are from the conditioned DEM used to generate the source SLIE.*
***DTF = Crest + Datum - DEM = Crest WSE - DEM*

To round out the simulation away from the gages, Dr. Kastens stated that “DTF values for FSPs between gages were linearly interpolated based on their relative distance from the nearest upstream and downstream gages.” For FSPs above the upper gage (BRLK1) and below the lower gage (IOLK1), the respective DTF values were held constant at the value associated with the nearest gage. While the Neosho River flood simulation starting point was close to BRLK1, a substantial portion of the modeled Neosho River study reach occurred below IOLK1. Though it would have been preferable to use a gage further downstream along the Neosho River for interpolating FSP DTF values below IOLK1, at the time of the 1951 flood, the next stream gage (PPFK1) was located more than 50 mi downstream at Parsons, where the Neosho River is more than 110’ lower in elevation than at IOLK1. Thus, it did not seem appropriate to use this information. Figure 5.1 shows the study area and final flood-depth grid for the Neosho River.

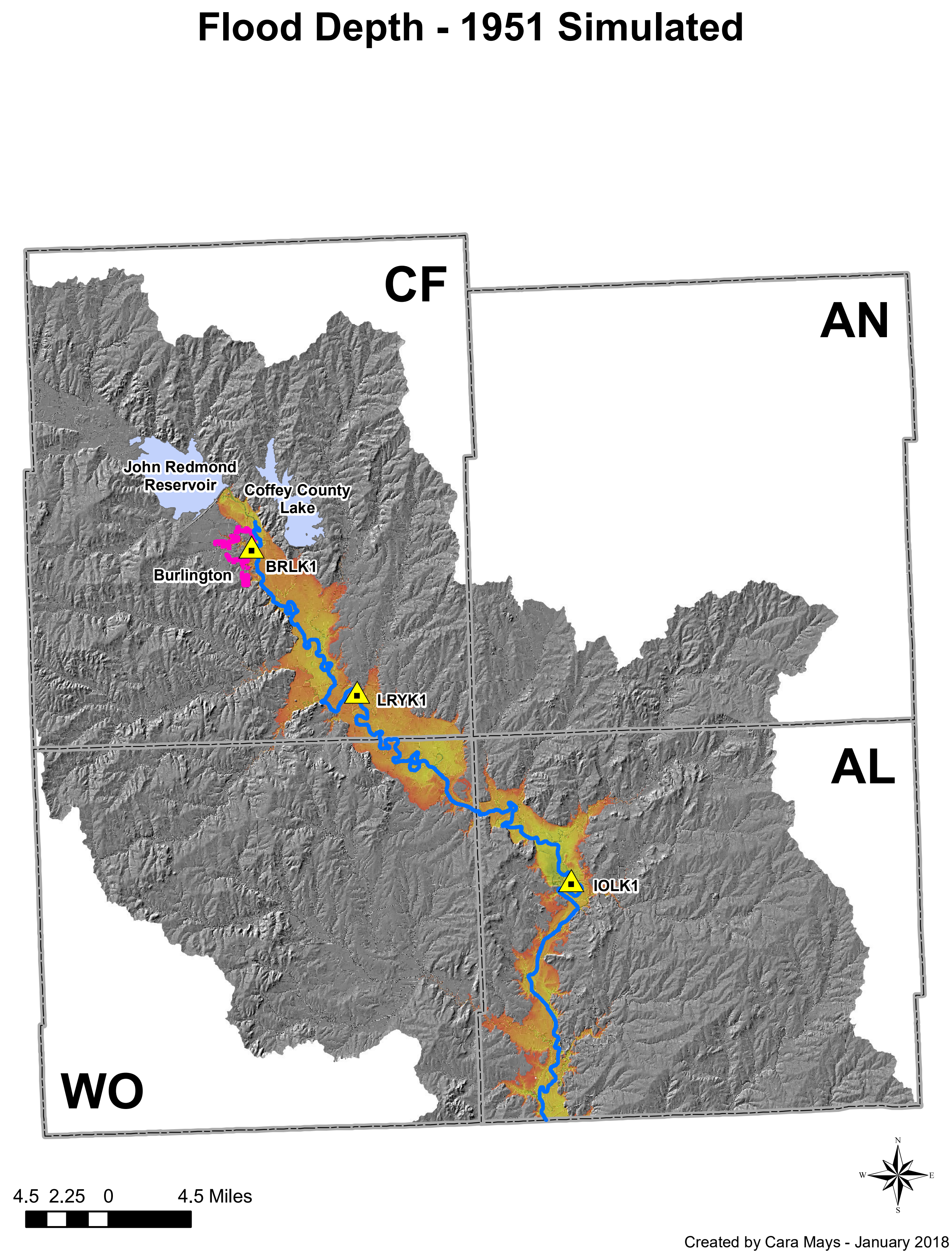


Figure 5.1. Four-county (Coffey, Anderson, Woodson, Allen) study area for the 1951 flood simulation. John Redmond Reservoir was constructed in 1959 by the U.S. Army Corps of Engineer's principally for flood control.

5.2. The Role of Rock Creek in the 1951 Flood

A high-water mark is a documented physical marker or known value, at certain location, used in expressing the level reached by flood waters. These markers can be fixated on a structure, represented by landscape impacts, or documented in historical records. These are points whose values must be reached in order to validate the reconstruction of a flood. They are also constant reminders to the public to continue to be aware of the potential of flooding in a given area. In Dr. Kastens' research on *Reconstructing the Texas Flood of 1938*, HWMs were utilized to calibrate the FLDPLN model simulation (Kastens 2010).

Only two reference HWMs could be located from the 1951 flood within the city of Burlington, both of which lie in the floodplain of Rock Creek, which also happens to be a backwater area for Neosho River flooding. Figure 5.2 illustrates the locations of the two HWMs. Although the two HWMs are extremely close in proximity, it should be noted that HWM #1 is further upstream than HWM #2.

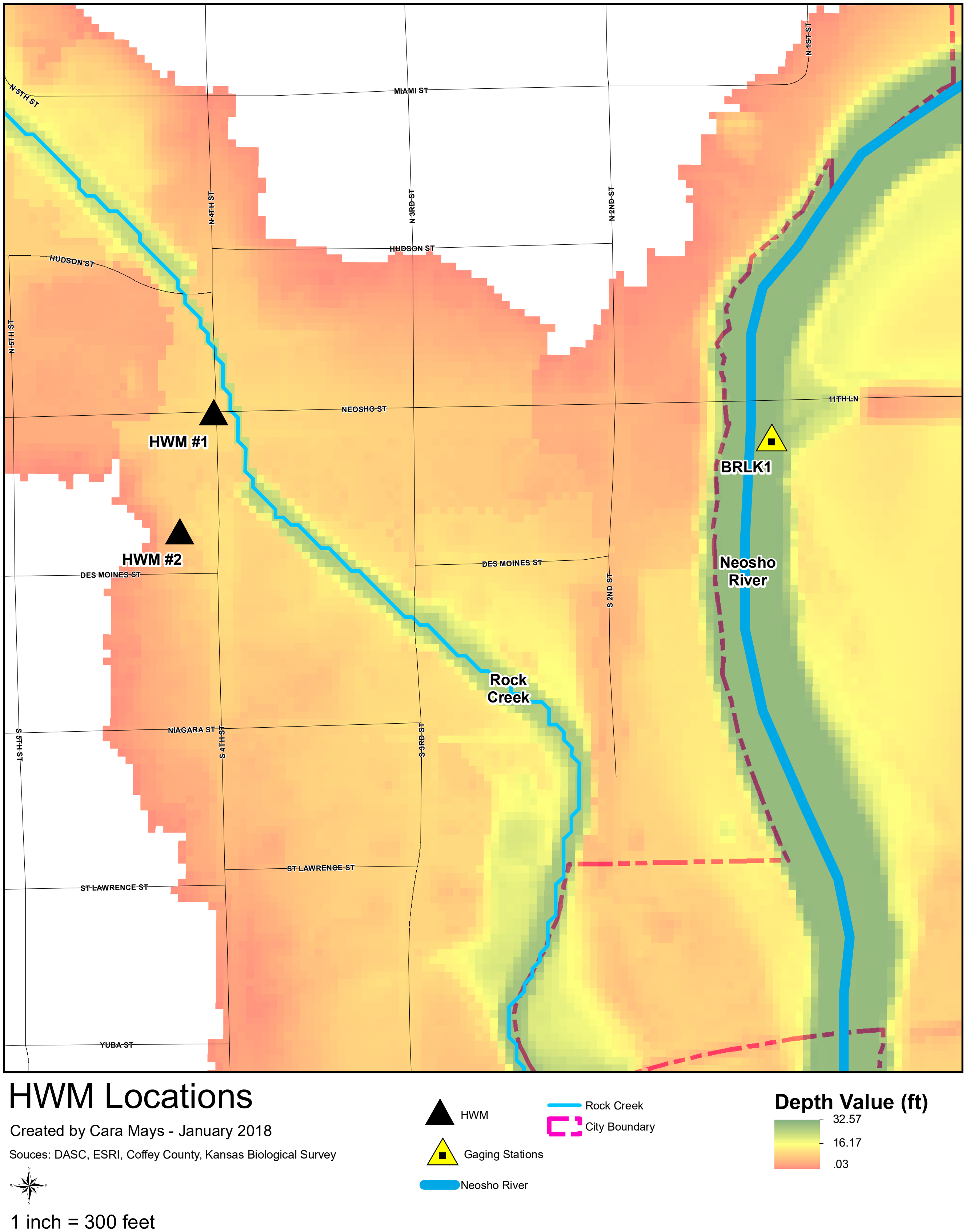


Figure 5.2. High Water Mark (HWM) locations within the city of Burlington.

Rock Creek is a tributary that runs west-to-east through the center of the city of Burlington but is not mentioned as a contributing factor to the 1951 flooding of downtown Burlington in any of the historical references. The Neosho River flood simulation did show inundation at both of the HWMs along Rock Creek, but the WSE was found to be insufficient by about five feet at each HWM, suggesting that additional flooding to this area came from Rock Creek. With this assumption, a second inundation library was created for a 1.2-mile portion of Rock Creek. This library helped provide the additional data needed to reach the WSE for each HWM.

An estimate was needed for the DTF values that would provide a reasonably accurate simulation of the Rock Creek flood extent in 1951. The HWM depth can be calculated using [HWM WSE] – [HWM elevation]. Dr. Kastens then used base DTF values at each HWM FSP that provided the DTF values needed for Rock Creek flooding to just reach both HWMs at the recorded depths. Next, HWM depth values were then added to the base DTF values to determine the DTF values to use at each HWM FSP to achieve the HWM WSE values in 1951. Once the HWM FSP DTF was determined, DTF values for FSPs between the two HWMs (which were especially close together) were computed by linearly interpolating WSE along the stream (FSP) path between the two HWMs and then subtracting the respective FSP elevation values. Note that this is a different strategy than used for simulation between gage FSPs along the Neosho River (i.e., WSE interpolation instead of DTF interpolation), due to the assumed smoothness of the floodwater surface between HWM FSPs that were spatially much closer to each other than were the stream gages.

Between the Rock Creek FSP associated with the downstream-most HWM #2 and the Rock Creek endpoint FSP at the confluence of the Rock Creek with the Neosho River, the Rock Creek floodplain empties into the much larger Neosho River floodplain (Figure 5.3.), which causes Rock

Creek floodwaters to disperse. To adjust for this, the WSE at the Rock Creek FSP for HWM #2 was linearly reduced to converge to the Neosho River WSE at the confluence. For the portion of Rock Creek between the starting FSP and the FSP associated with HWM #1, backwater from the Neosho River extended back to and above the chosen Rock Creek starting point, which means Rock Creek would have added depth to the flat-water surface generated by the Neosho River. Conservative estimates for the additional depth from the Rock Creek tributary were calculated. Figure 5.3 (b) shows the resulting depth grid from the Rock Creek flood simulation. Figure 5.3 (c) shows the Neosho and Rock Creek depth grids being combined to form the final depth grid for the study area.

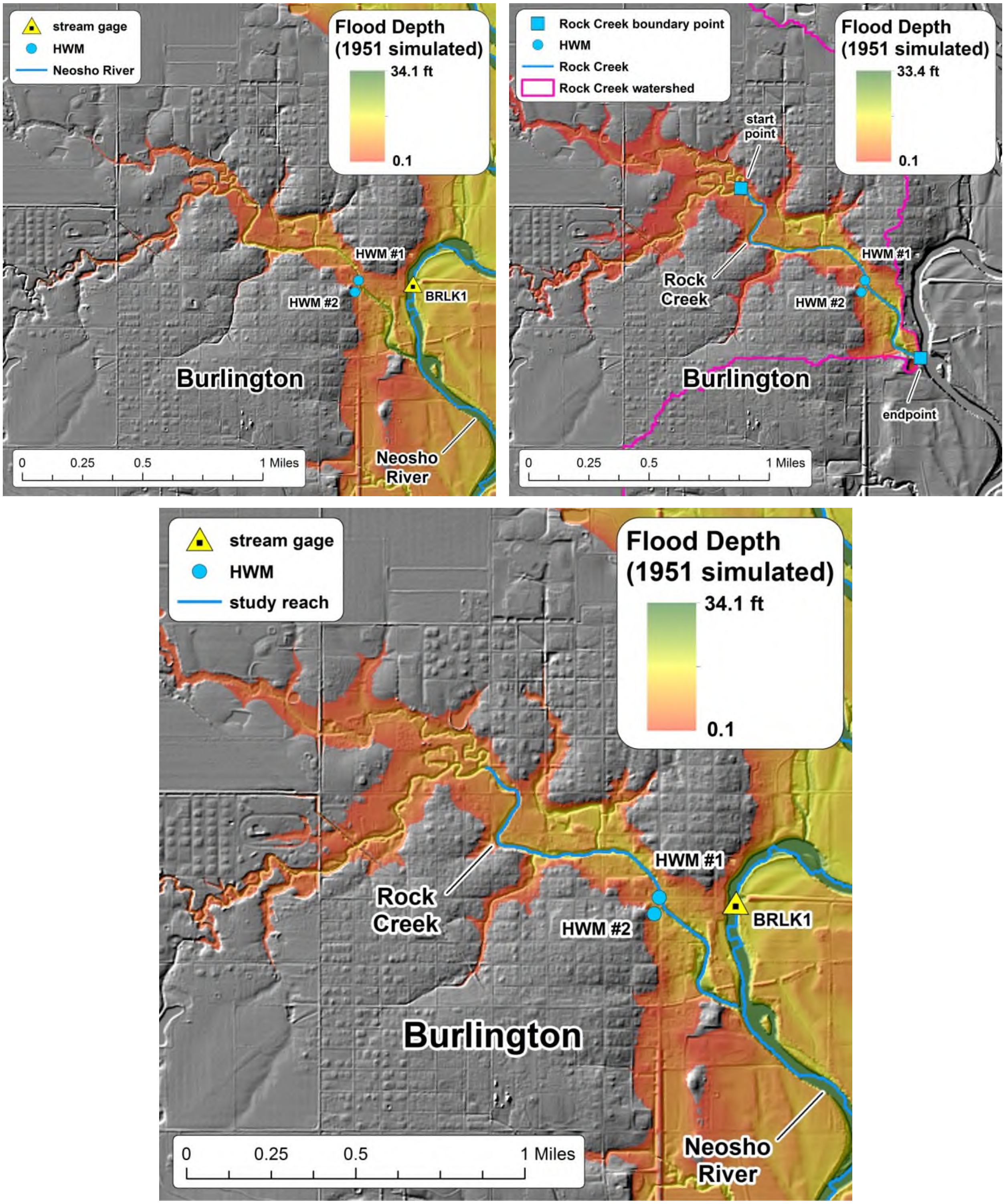


Figure 5.3. (a) The flood depth grid for the Rock Creek tributary floodplain simulated using only backwater flooding from the Neosho River. (b) The flood depth grid for the Rock Creek tributary floodplain simulated by targeting HWM information along with reasonable WSE assumptions upstream and downstream from the HWMs. (c) The final depth grid for the Burlington area, created by computing the maximum value composite of (a) and (b).

5.3. Validation

Through previous research completed by Dr. Kastens, it is evident that the FLDPLN model can be used for inundation mapping (Kastens 2008), but validation is necessary, which was made more difficult in this case with the limited data available for the research area. As there were only two HWMs and data from three gage sites to use for the simulation, validation of the 1951 flood simulation was carried out using old photographs with abstract descriptions (Figures 5.4 through 5.8, below).

Figure 5.4 (a) and (b) illustrate the intersection of Hwy 75 and Neosho Street. This picture also was utilized as a HWM using the description of "estimated 10-12 feet above the intersection (Coffey County Republican 2007). Figure 5.4. (c) is the depth grid overlaid onto Coffey County GIS layers. From this illustration, it can be seen that the depth at the intersection of Hwy 75 and Neosho Street did indeed inundate to 10 feet or above, primarily along the Rock Creek tributary.

Figure 5.4 (a). Flood water here is estimated to be 10-12 feet above the intersections of Neosho Street and Highway 75 (4th Street). (Photo copied from the book titled “150 Years of History in Burlington, Kansas”).

Figure 5.4 (b). Another view of the intersection of Highway 75 (4th Street) and Neosho Street in Burlington, Kansas. (Photo copied from the book titled “150 Years of History in Burlington, Kansas”).

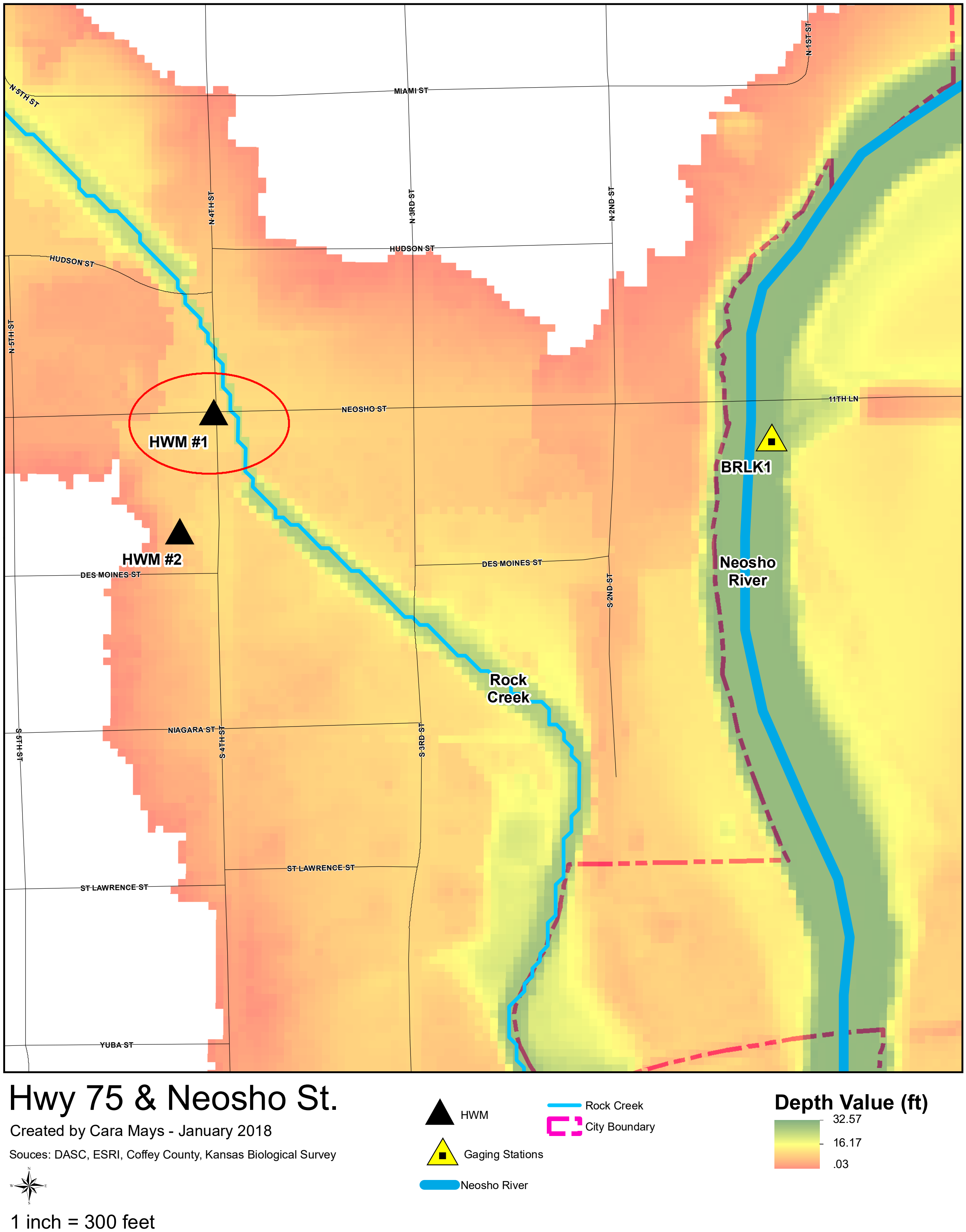


Figure 5.4 (c). Simulated 1951 depth grid overlaid onto Coffey County roads and the Burlington city boundary. The red circle indicates the location of the intersection of Highway 75 (aka 4th Street) and Neosho Street in the city of Burlington. Extracted depth values around this location range from 5.51 ft. to 24.24 ft.

Figure 5.5 (a) shows a person standing near the entering point of the flood waters at the intersection of Highway 75 and Yuba Street. Although there is not a date that implies if this was taken when the flood waters peaked or as the waters were rising or receding, the author assumes that the photograph was taken during high water levels, and this is illustrating how far south the flood waters inundated Highway 75 (4th Street). The flood depth map, Figure 5.5 (b) confirms that the water levels were low at this intersection.

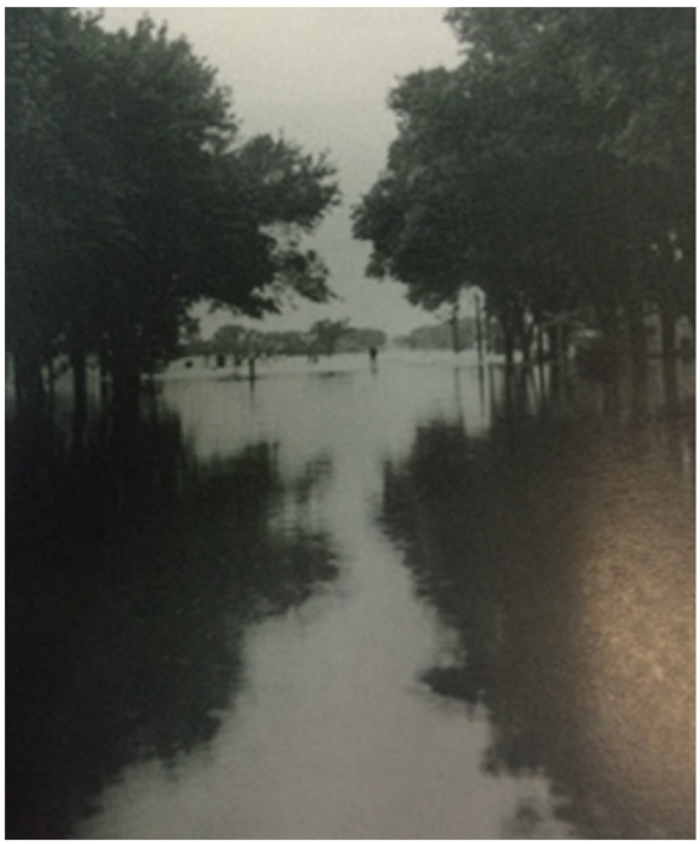


Image 5.5 (a). Flood waters looking south at the intersection of Highway 75 (aka 4th Street) and Yuba Street in Burlington, Kansas. (Photo copied from the book titled "150 Years of History in Burlington, Kansas").

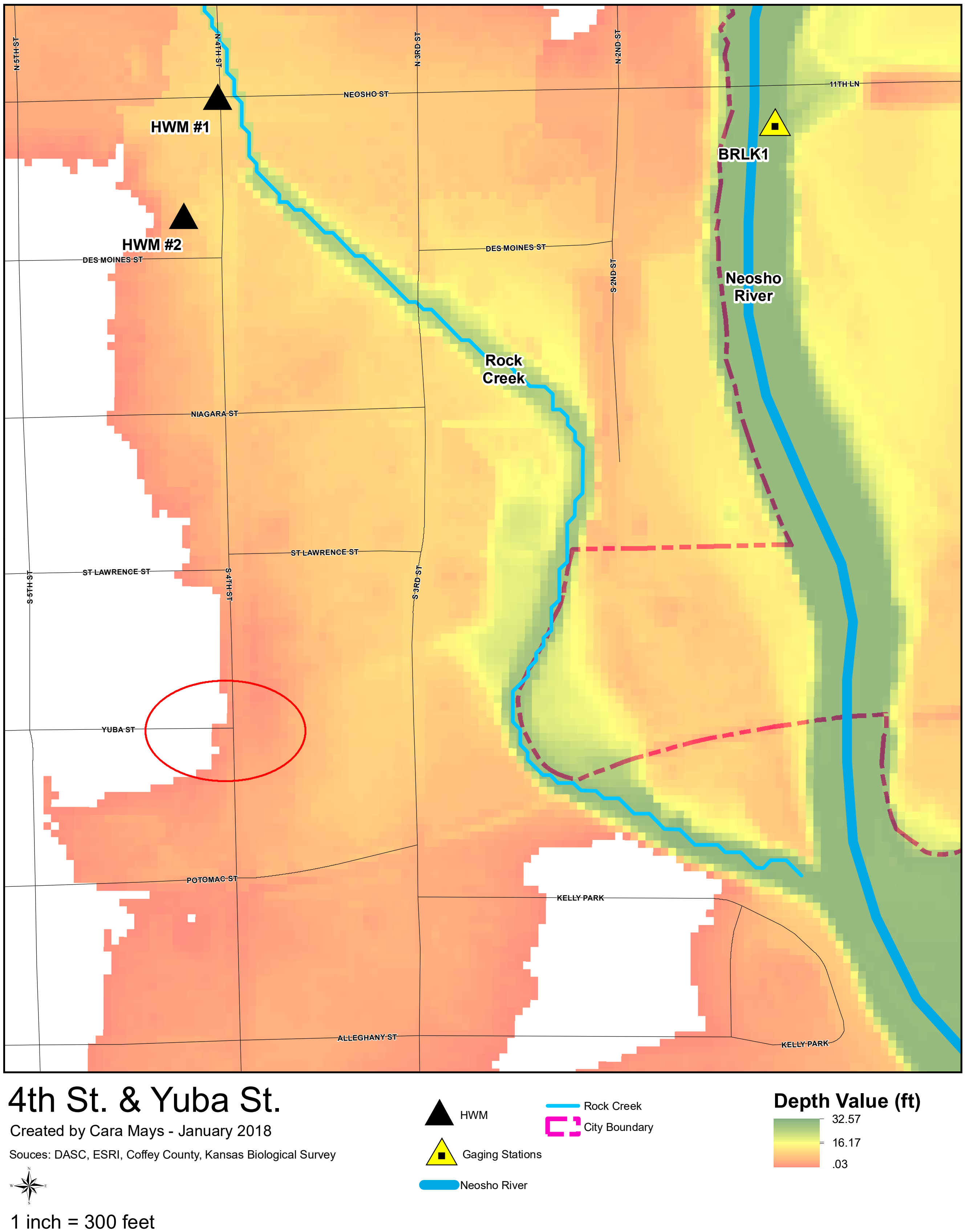


Figure 5.5 (b). Simulated 1951 depth grid overlaid onto Coffey County roads and the Burlington city boundary. The red circle indicates the location of intersection of 4th St. (aka Highway 75) and Yuba Street in the city of Burlington. Extracted depth values around this location range from .069 ft. to 5.64 ft.

Figure 5.6 (a) and (b) show the north and south sides of the 300 block of Neosho Street, respectively. Figure 5.6 (c) verifies that the 300 block was inundated with the highest flood waters in downtown Burlington.

Figure 5.6 (a). North side of Neosho Street. (Photo copied from the book titled “150 Years of History in Burlington, Kansas”).

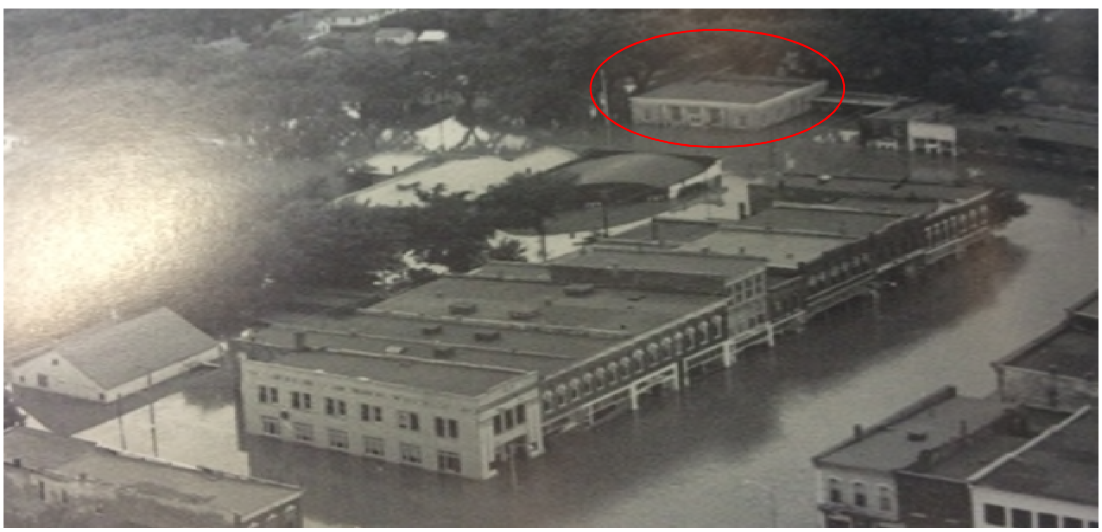


Figure 5.6 (b). Aerial view of Block 300 of Neosho Street. (Photo copied from the book titled “150 Years of History in Burlington, Kansas”). Red circle indicates the Post Office where HWM #2 was found and used.

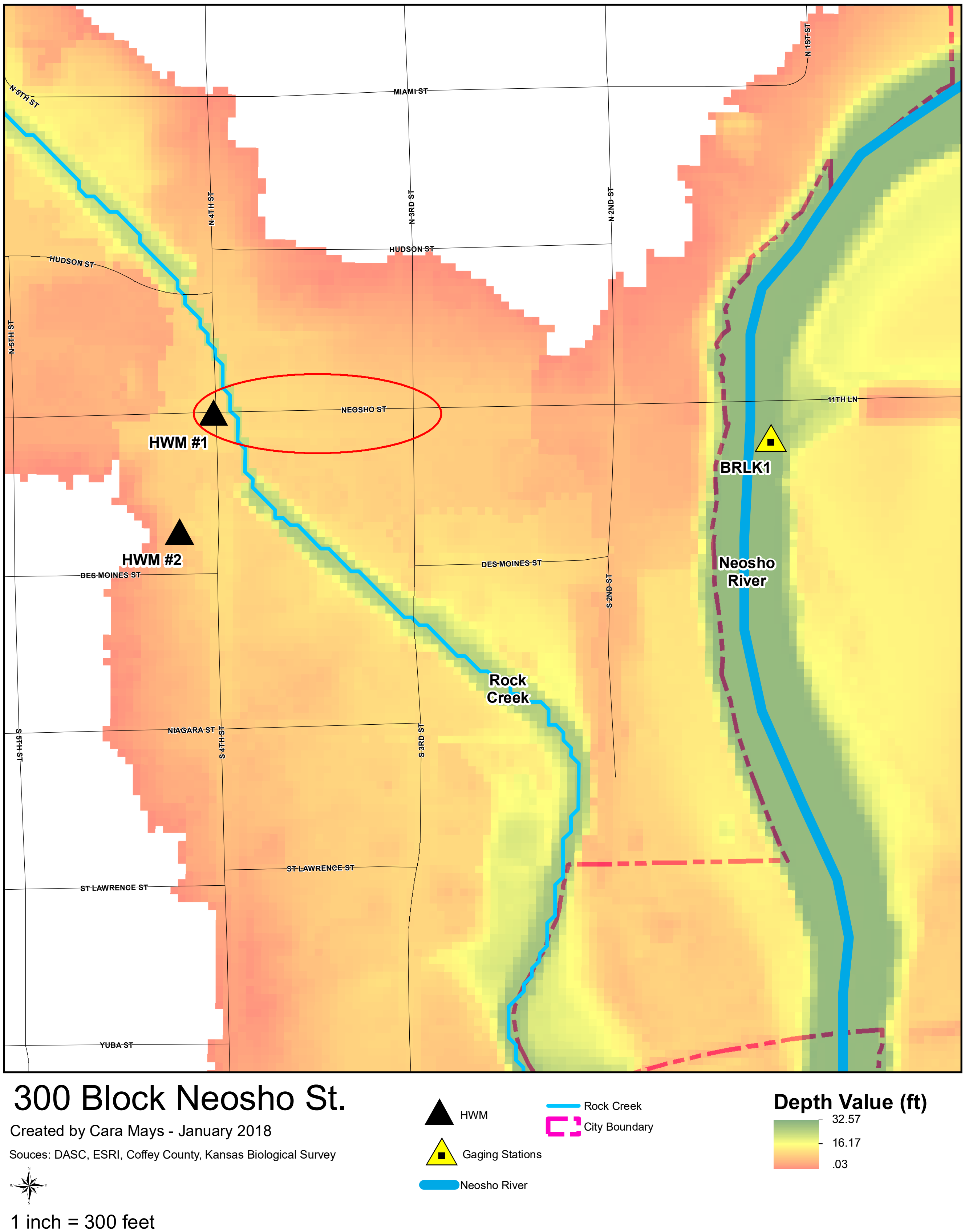


Figure 5.6 (c). Simulated 1951 depth grid overlaid onto Coffey County roads and the Burlington city boundary. The red circle indicates the location of the 300block of Neosho Street in the city of Burlington. Extracted depth values around this location range from 8.30 ft. to 28.64 ft.

Figure 5.7 (a) shows the East River Bridge, where the Neosho River crosses Neosho Street. Figure 5.7 (b) illustrates the flood extent at this same location. This area of the simulated flood waters was particularly fascinating to me. For one, there is a major difference in flood water depths on the east side versus the west side of the Neosho River. Looking at elevations, the east side of the Neosho river floodplain is substantially lower than the west side, where the river is closer to the valley wall. Elevation changes are about 18 feet from one side to the other. This figure also begins to paint the picture of the widespread impact this flood had in the rural areas of Coffey County.

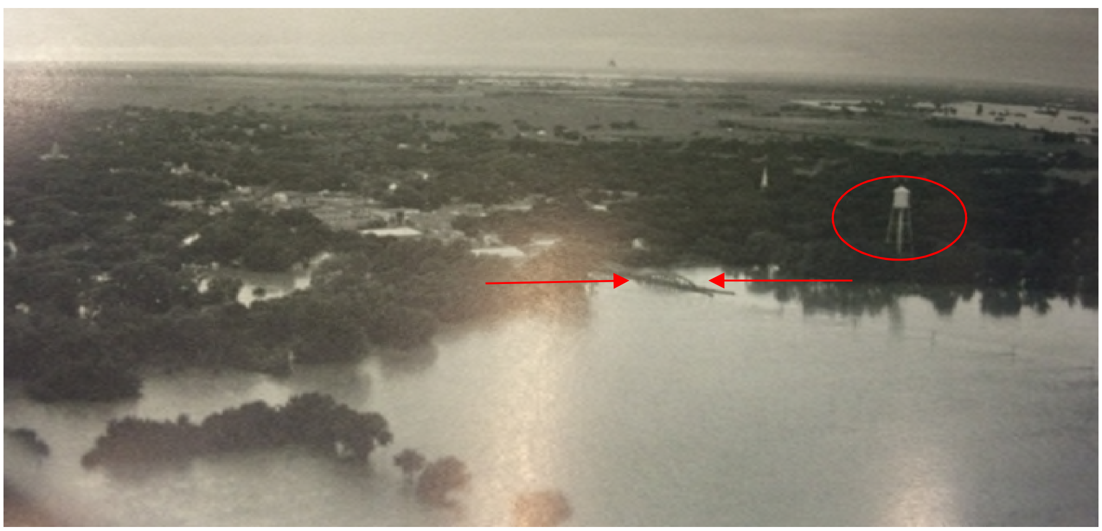


Figure 5.7 (a). Aerial view of East River Bridge in Burlington, Kansas. Note location of the city water tower. (Photo copied from the book titled "150 Years of History in Burlington, Kansas").

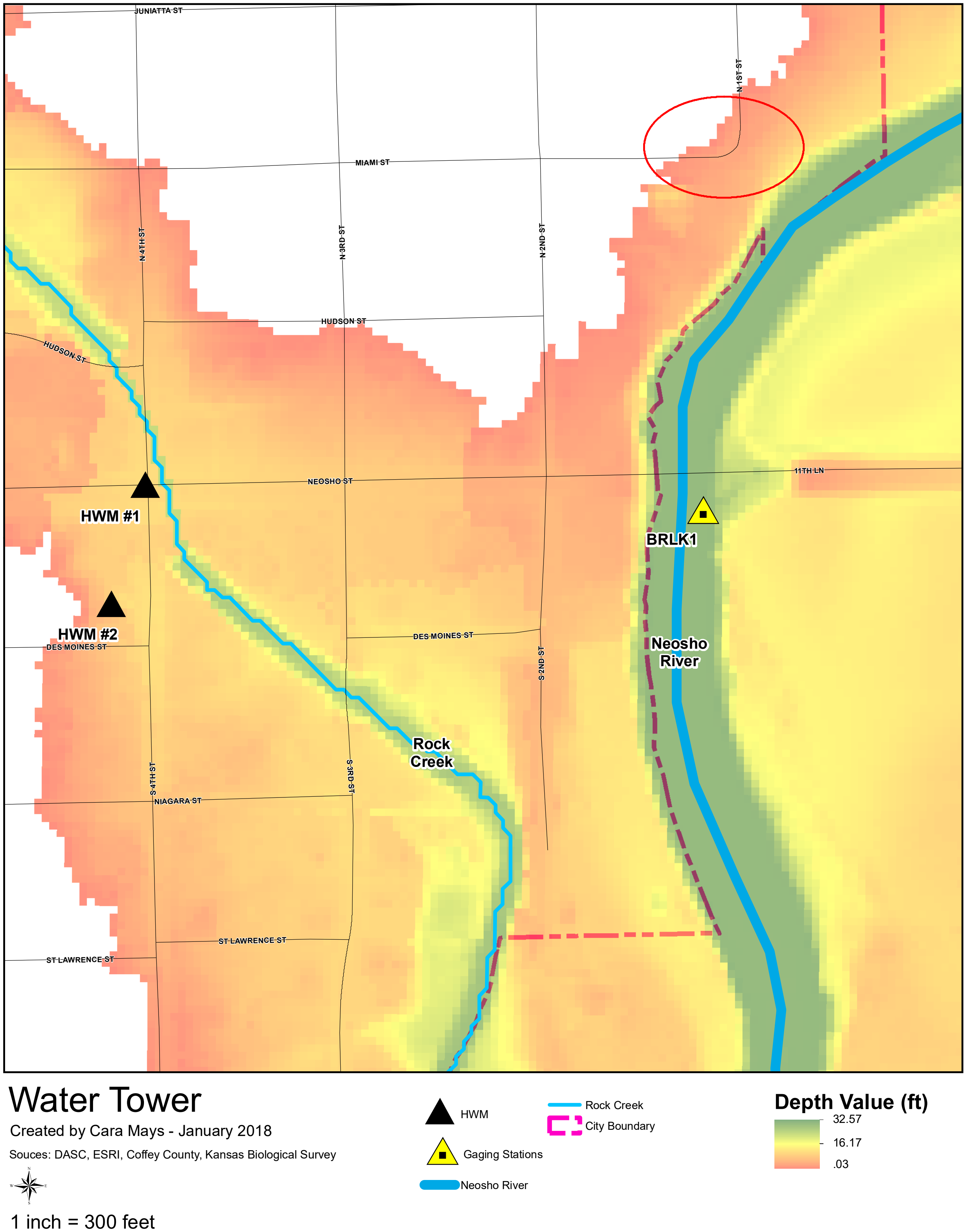


Figure 5.7 (b). Simulated 1951 depth grid overlaid onto Coffey County roads and the Burlington city boundary. The red circle indicates the location of the water tower that sits alongside the Neosho River in Burlington. Extracted depth values around this location range from .16 ft. to 12.86 ft.

Figure 5.8 (a) is a photograph of the North River Bridge where Highway 75 crossed the Neosho River. This would have been the main access road to Burlington from the north. Access into the city must have been very difficult to find in 1951 as the local drainage flooded from the cardinal directions around Burlington. Figure 5.8 (b) shows the flood extent north of Burlington. This illustration also reinforces that the post-flood relocation of critical infrastructure to the northern part of Burlington has been well planned.

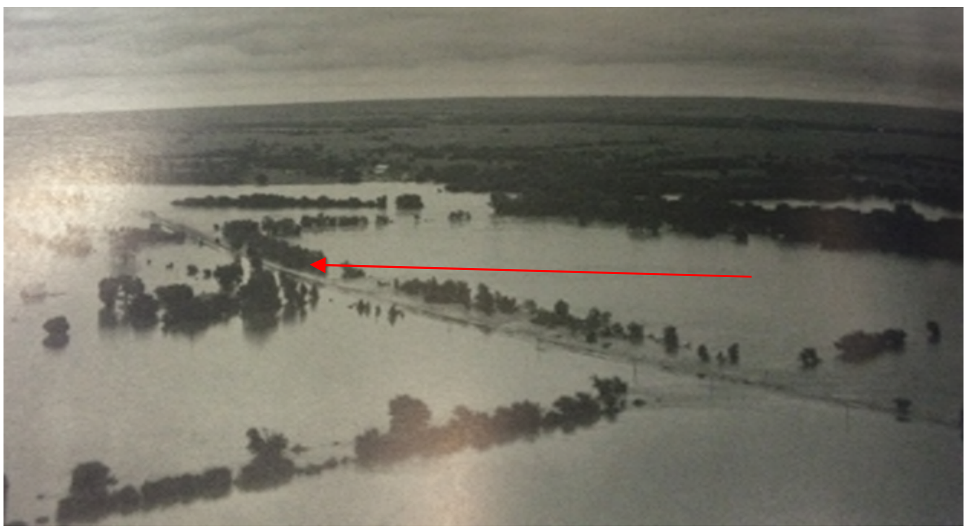


Figure 5.8 (a). Aerial view (facing northeast) of flood extent outside Burlington city limits at the North River Bridge. (Photo copied from the book titled "150 Years of History in Burlington, Kansas").

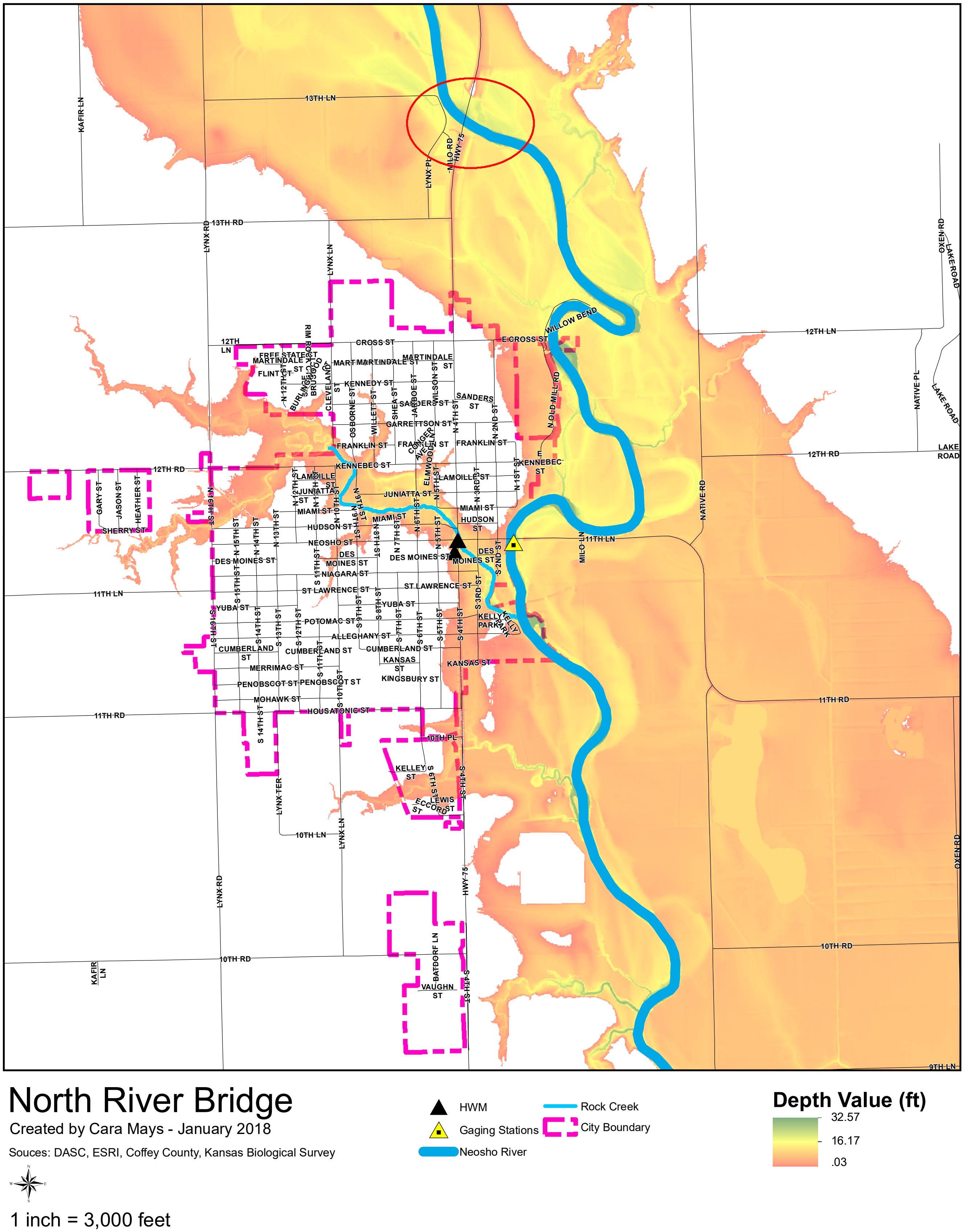


Figure 5.8 (b). Simulated 1951 depth grid overlaid onto Coffey County roads and the Burlington city boundary. The red circle indicates the location of the North River Bridge, north of Burlington. Extracted depth values around this location range from .49 ft. to 31.50 ft.

The DTF values generated by the model appear to create generally accurate flood extent estimates for the 1951 flood. The flood depth simulation through Burlington was calibrated using the two HWMs and was then qualitatively examined by comparing historical references in photographs to estimate extents and depths. This simulation of the 1951 flood not only paints a picture of the magnitude of this event, but also is a valuable visual representation to use for future emergency response planning and training efforts and for zoning and planning inside and outside of the city limits of Burlington.

5.4. Limitations and Concerns

The paucity of historic flood data for this study area created limitations. The initial intentions of the study were met. The author was able to create visualizations of a flood event to be used as a tool to facilitate the development of an action plan in the event of a major flood in Coffey County. The author was able to obtain land use data and other valuable information to assist in creating a flood risk assessment but the historical flood data were scarce. Such limitations may create an inconclusive flood model for the study area. The limitations in this study can help expose the need for well-documented flood data to be created and maintained for numerous reasons, including the use for potential future flood risk evaluations.

A concern for the author is the use of these data to accurately map flood inundations for today's purposes. This visual source must be presented as a broad or "worst-case-scenario" aspect for emergency response and planning guides. A lot has changed over the last 67 years in terms of the characteristics of the land. With the construction of John Redmond Reservoir, the likelihood of a flood like that of 1951 is much reduced. Since the construction of John Redmond, the frequency of high water crests has decreased. The top nine historic crests all exist before the construction of the dam. The LeRoy gage site, however, have experienced some high water even after John Redmond was built. The sixth highest recorded max stage for the LeRoy gage was recorded in 2007, when water levels crested at 28.70 ft., illustrating that protection from John Redmond Reservoir is reduced further downstream. Along with the migration of the focus of commercial and other development and land use change, there have been many landscape changes that could factor into what the next major flood event would look like. Still, looking at historical events helps remember what 1951 looked like and that the possibility of flooding that could cause significant damage still exists.

5.5. Rock Creek Impact

In the initial floodwater simulation of the Neosho River, the observed floodwater depths at the HWMs were not being met by the simulated flood values. Therefore, it was apparent that additional sources of water must have contributed to the magnitude of the flood in 1951 in Burlington. The Rock Creek tributary, which runs through the middle of the city of Burlington, also is located within the Neosho floodplain and was believed to be the source of additional flooding needed to achieve the observed depths at both of the HWMs. In historical recaps of the 1951 flood, the records talk about how incredible it was to watch the Neosho River flood downtown Burlington. Even the locals who remember the 1951 flood talk about how devastating the “Neosho River flood of 1951” was. As a result, when I began my research I focused primarily on the floodplain of the Neosho River. Even though I cross the Rock Creek tributary daily on my commute to work, I never once considered that Rock Creek might have been a major factor in the downtown flooding of 1951. As the Neosho River flooded, apparently Rock Creek simultaneously frequency of high water crests has decreased. The top nine historic crests all exist before the construction of the dam. The LeRoy gage site, however, have experienced some high water even after John Redmond was built. The sixth highest recorded max stage for the LeRoy gage was recorded in 12007, when water levels crested at 28.70 ft., illustrating that protection from John Redmond Reservoir is reduced further downstream. Along with the migration of the focus of commercial and other development and land use change, there have been many landscape changes that could factor into what the next major flood event would look like. Still, looking at historical events helps remember what 1951 looked like and that the possibility of flooding that could cause significant damage still exists.

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5.6. Downtown and Service Migration

Downtown, small-town U.S communities in the Midwest look a lot different than they did 50 or 75 years ago. If you were to take a Sunday drive through any one of a number of rural communities in Kansas today, you would likely see a repeating picture of downtowns littered with vacant buildings and dilapidated structures. Crumbling infrastructure, consolidation and migration of services, and population loss are three key factors determining the fate of the downtown areas of rural U.S. towns, and Burlington, Kansas, is no exception. When you look back at pictures of downtown Burlington in the 1950s, you see cars flooding the streets, business doors wide open, and people walking up and down the sidewalks. Downtown Burlington in 1951 was the heart of the community, home to approximately 2,300 people. In the 1950s, Burlington did not offer a full-range hospital; instead, your local, independent "Doc" Johnson had his walk-in clinic located in the 300 block of Neosho Street. The only two grocery stores in the town existed within downtown. The gas stations, all banks, pharmacy, funeral services, administrative buildings, lodging, and other retail services all lined the streets in downtown Burlington.

Today, when you look at the former downtown area, the administrative building or city hall still persists, but otherwise you see a number of vacant structures, and what buildings are occupied provide a handful of places to eat and a few retail services. Today, approximately 2,600 people live within the city limits so Burlington has not seen a huge influx of growth since the 1950's. A majority of the critical infrastructure or services needed on daily basis for a sustainable life now exists on the north end of Burlington. This is where the full-service clinic and hospital is built. The only grocery store in Burlington is located here. Every operational gas station and two pharmacies are located in the north part of the city.

So, why has downtown Burlington's focus shifted towards the northern part of the city? Did the 1951 flood impact the migration of these services? When was zoning in Burlington created, and were the zoning regulations altered after the flood? Or did the migration of services have absolutely nothing to do with downtown flooding and resulted more from weakening infrastructure and lower-cost site availability for new constructed services? I contacted the Burlington zoning administrator and historical museum director in hopes to find information regarding Burlington zoning and the migration of services within Burlington. Limited data were available. We searched informal city minutes and any historical documents to see if there was any mention of zoning modification after 1951. With the sparse zoning data, relying more on memories of those who lived during this time was just as valuable. Downtown Burlington was remembered during the 1950s and 1960s as a leisurely environment. But as societal changes began to occur, business expansion in downtown was no longer feasible. Limited parking became an issue and the existing buildings were becoming too small to house the growing businesses. With an increase in highway traffic, the northern part of the city became an attractive area for business development. Land availability and highway access paved the way for newly constructed businesses. One of the first businesses to locate in the northern part of Burlington was a grocery store, Bob's IGA, which nearly tripled the size of the existing downtown grocery store. Soon after, a new hospital was constructed. Land was purchased for the hospital in March 1951, before the flood occurred and construction was finalized in 1954. With the land purchase occurring before the flood, this is a good indication that business development in the northern part of Burlington was already on the minds of business owners and city officials and the 1951 flood only accelerated the timeline of the new development.

Figure 5.9 allows comparison of the critical infrastructure of 1951 versus present-day critical infrastructure relative to the depth-to-flood layer. This figure allows visualization of migration of services, and although the reason for this migration has not been fully confirmed, I believe Burlington residents began accepting the transition to developing new businesses and relocating others, out of the flood risk area, because of the 1951 flood impacts. As mentioned before, a few critical infrastructures still remain in the flood zone, but the overall migration pattern is apparent.

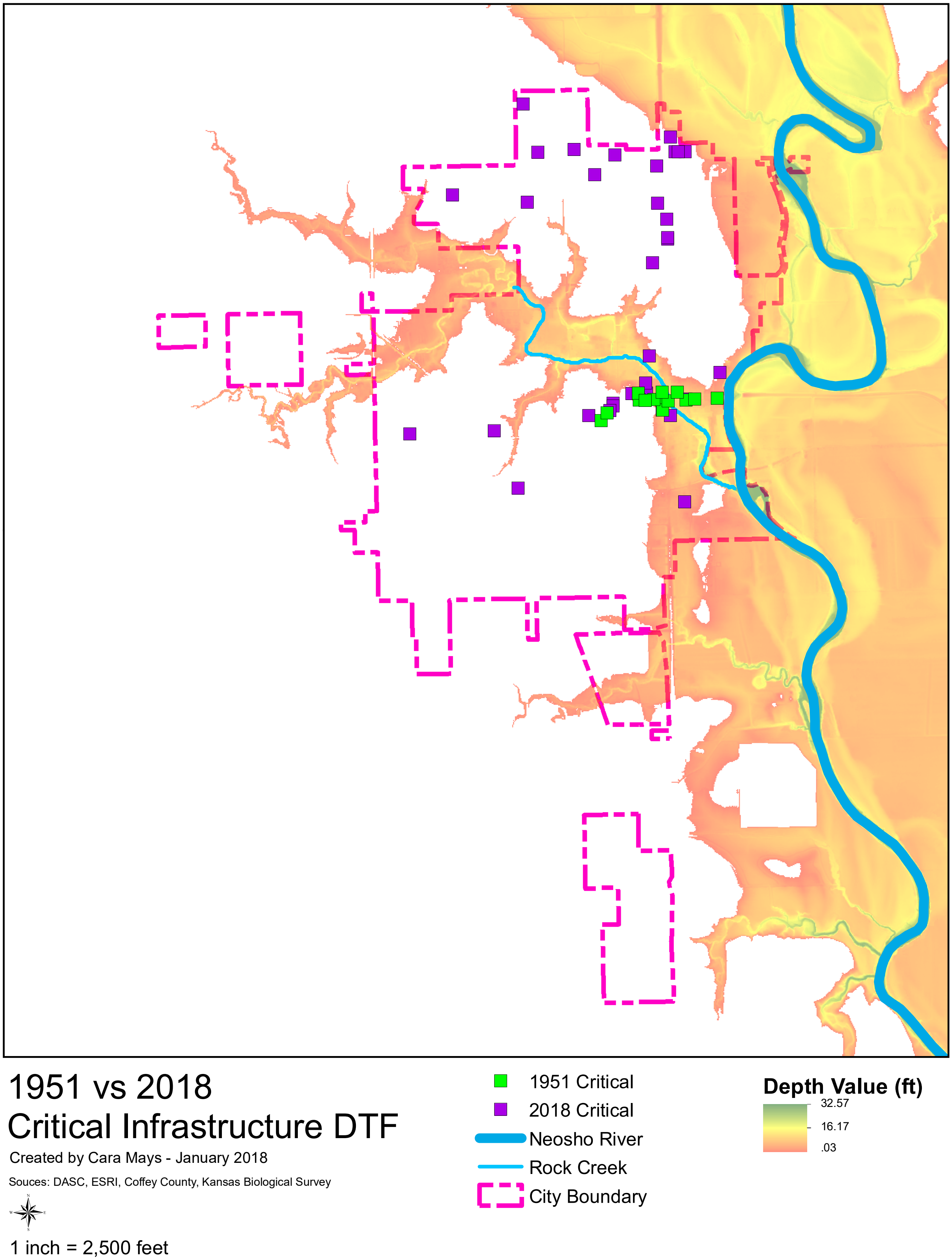

Figure 5.9. 1951 vs 2018 critical infrastructure in the city of Burlington with the simulated 1951 depth grid overlaid.

5.7. Information Sharing

One of the intentions of this research was to provide local decision makers and emergency responders with information that could assist in the event of a flood emergency. Secondly, I had hoped this research would continue to raise awareness to residents of Coffey County that although unlikely, a devastating flood event is still a potential risk. I listed the Coffey County Board of Commission, Coffey County Emergency Manager, Coffey County Sheriff, Burlington City Police Chief, Coffey County Fire Board, and Coffey County EMS as my targeted audience to introduce my research and ask for feedback in how these data could be utilized for response efforts in the event of an emergency. Each entity will be provided a packet containing a summarized background of this research and maps to show the potential of floodplain mapping. As my research is close to its completion, I hope to secure feedback and new ideas in the near future from all entities working together, utilizing this research to continue to make the necessary changes in our emergency response plan in the case of a major flood event or other potential disasters.

6. CONCLUSION

In this research I have had to consider what type of data is needed and available to recreate a historic flood assessment for a rural community. There is a need for rapid and affordable floodplain modeling as well as an understanding of how historic flood event modeling can assist emergency managers and other users understand the potential risks from flood events. This research intended to create a general flood-risk assessment in order to create a picture of what life was like during past flood events and how the lives of today would be impacted in the event of another major flood.

Limitations of this research are crucial in creating awareness and the need to record and document future flood information. The most common product available in predicting a flood event currently is the FEMA Flood Maps. These maps are available online and are primary used for insurance purposes. FEMA flood maps portray, in a static display, what is called the “100-year-floodplain.” This delineates the area estimated to have a chance to flood at least 1 year out of 100, or equivalently, which has at least a 1% chance to flood in a particular year. These are widely used in Kansas and elsewhere around the U.S. FEMA floodplain maps currently impact property valuations, insurance premiums, and ability to obtain permits to create new construction on a property. Although these maps are heavily utilized, there is a crucial need for real-time, event-specific flood inundation information. With the capabilities of modern-day mapping, the ability to recreate historic data provides a great tool for better understanding and visualizing the potential risk to a community. With the ability to model a historic flood event, emergency preparedness can be increased. By anticipating what areas could be impacted, the disruption of everyday life could be mitigated if the necessary measures are taken prior to a major flood event.

It was extremely evident early on that the collecting of critical infrastructure data can vary depending on the characteristics of a location. Looking at our small community, the number of critical infrastructure facilities is lower, but those facilities impact the vast majority of our residents, county-wide. For example, in large cities if one hospital is impacted by a natural disaster and cannot perform operations, often there are other facilities within a small radius able to provide services to those in need. In Coffey County, if the hospital is inoperable, the closest major health facility is Newman Regional Health in Emporia, Kansas, 45 minutes away from Burlington. The identification of critical infrastructure in the study area was dependent on how the author viewed services relating to the needs of the community.

This study not only provides beneficial tools for Coffey County, but can be applied in other rural jurisdictions that have similar characteristics. It is my hope that these methods will be replicated in other rural communities to help increase awareness, gain ideas, decrease vulnerability, and ultimately increase preparedness in case of a major flood event.

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