Flood risk perception near intermediate-sized Kansas dams

by

Christy Roberts Jean

B.A., Kansas State University, 2014
M.A., Kansas State University, 2016

AN ABSTRACT OF A DISSERTATION

submitted in partial fulfillment of the requirements for the degree

DOCTOR OF PHILOSOPHY

Department of Geography and Geospatial Sciences
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Abstract

Kansas ranks second in the largest number of dams in the United States, behind Texas (FEMA 2015). In 2020, Kansas dams reached an average age of 52 years, with many exceeding their designed life expectancy or in need of rehabilitation. Climate change and increased urbanization projections suggest more frequent and extreme flooding in the future, requiring greater demands on current infrastructure (O’Neill et al., 2016). Researchers have explored the physical side of flood risk management to a considerable extent. Still, relatively little is known about how flood risk perception varies in areas associated with at-risk dams. Local populations near intermediate-sized dams are less likely to receive attention due to their size and remoteness but are often more susceptible to failures because of dam construction type and design, lack of knowledge or awareness of dam and reservoir conditions, and irregular maintenance. Dam selection was based on the size and age of the structure, primary purpose, and location. Specifically, dams had to be at least 50 years in age, intended mainly for flood control, and likely to experience increased frequency and more intense 24-hour rainfall totals in the future. Understanding risk perceptions now will help prepare decision-makers for communicating with residents and dealing with disaster situations in the near future.

A sequential mixed methods design was applied, whereby quantitative and qualitative approaches were used successively to gain in-depth individual perspectives from selected residents and insights from water resource experts on flood risk perception near at-risk dams. The combination of individual risk evaluations and in-depth personal insights provided by this mixed methodology not only provides basic information about the status of thinking about potential dam hazards, but also may be useful for developing strategies that address risk for people living near intermediate-sized dams. Questionnaires were mailed to 1,100 randomly sampled households near ten selected dam sites in eastern Kansas Purposefully selected interviews were conducted with dam safety and water resource experts associated with the selected dams.

Closed-ended data provided through questionnaire responses were analyzed through correlation and contingency analyses to explore statistical significance. Qualitative thematic analysis of interviews and open-ended responses provided depth to the close-ended material, in addition to providing another perspective of flood risk perception near aging dams from dam safety and water resource experts. The quantitative results suggested that flood risk perception was higher among residents located within flood zones, but respondents generally were not concerned with the efficacy of aging dams in their locales. The qualitative results identified and explained variations in outcomes for flood experiences, expectations of the dam in its current state and in the event of a dam failure, flood vulnerability, and risk communication. They provide insight on concerns related to dam management, recent flood events, and of how perception relates to physical risk based on location. A significant concern was the lack of accessible and accurate data for intermediate-sized dams that would contribute to local knowledge on flood risk and improved emergency preparedness for high-risk dams.

Intensification of education about dams and flood risk awareness near intermediate-sized dams in Kansas appears to be needed, based on this research. It is likely that such needs also are present in other states. Follow-up research should be conducted to determine the statewide perception of aging dams and their potential to exacerbate flood risks in additional areas. Similar studies should be pursued elsewhere.

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Approved by:

Major Professor
Lisa M. Butler Harrington

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List of Abbreviations

ASCE	American Society of Civil Engineers
CDC	Centers for Disease Control
DEM	Digital Elevation Model
DWR	Division of Water Resources
EAP	Emergency Action plan
FEMA	Federal Emergency Management Agency
FRD	Flood Retarding Dam/Flood Risk Database
FRM	Flood Risk Map
FRR	Flood Risk Report
GIS	Geographic Information Science
HDW	Hot, dry, and windy events
HVRI	Hazards and Vulnerability Research Institute
HUC	Hydrologic Unit Code
IPCC	Intergovernmental Panel on Climate Change
IRB	Institutional Review Board
KDA	Kansas Department of Agriculture
KDWPT	Kansas Department of Wildlife Parks and Tourism
LULCC	Land Use/Land Cover Changes
NID	National Inventory of Dams
NFHL	FEMA National Flood Hazard Layer Viewer
NOAA	National Oceanic and Atmospheric Administration
NSSL	The NOAA National Severe Storms Laboratory
NRCS	Natural Resources Conservation Service
NWS	National Weather Service
PET	Potential Evapotranspiration
RUCC	Rural-Urban Continuum Codes
SAKW	State Association of Kansas Watersheds
SES	Social-Ecological Systems
SFHA	Special Flood Hazards Areas

SoVI	Social Vulnerability Index
TDM	Tailored Design Method
USACE	United States Army Corps of Engineers
USDA	United States Department of Agriculture
USGS	United States Geological Survey
USDA-ERS	United States Department of Agriculture’s Economic Research Service

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Chapter 1 - Introduction

In response to nationwide flooding, the federal government enacted the Flood Control Act of 1936 to protect rural farmlands and the steady urban population growth occurring in flood-prone areas (Arnold 1988). Large-scale projects such as dams and other infrastructure were constructed at a uniformly high pace across the country, eventually changing the way people make decisions about what they deem safe enough for where they live, work, learn, or worship (Starr 1976). Every four years, the American Society of Civil Engineers (ASCE) uses a committee of 25 civil engineers to grade the nation on the current infrastructure conditions and needs in the United States. Among the 17 infrastructure categories, ASCE reports specifically on the condition of dams, which play an important role in providing essential benefits for drinking water, irrigation, hydropower, flood control, and recreation (ASCE 2021). In 2021, the ASCE reported that the number of high-hazard potential dams have doubled since 2001, as development encroaches on rural dams and reservoirs (ASCE 2021). Limited funding, an increased need for emergency action plans for high-hazard dams[1], a lack of public awareness and local knowledge, and insufficient dam data contributed to a “D” on the nation’s 2021 infrastructure report card. The average design life of most dams varies between 50-100 years, putting today’s dams in unfavorable circumstances. Among the 91,457 identified dams in the United States, 74 percent are considered high hazard potential, with an average age of 57 years (NID 2020).

In the past five years, dams worldwide have made front-page news and proliferated in media stories and news feeds with images of emergency evacuations and destruction from

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[1] [1]A high-hazard potential classification is given to dams where failure will probably cause loss of human life.

floodwaters. Large dams, with a height exceeding 100 feet, often get the most media attention but are by far the fewest in number in the US with respect to size categories. Less than two percent of United States dams are considered large. The majority of dams are under 50 feet high and are managed by private owners. Nonetheless, large dam failures are fundamental in prompting necessary awareness and action for smaller counterparts that face similar problems. Most dams, despite their size, are no longer able to operate at full capacity due to increased demands from nearby populations, climatic changes, sedimentation, and budget/manpower constraints (Annandale 2005, NRC 2012, Stratz and Hossain 2014, ASCE 2021). Still, people will continue to live near water bodies due to resource needs (and, often, aesthetic, and recreational attraction).

Destructive dam failures have become an annual occurrence as the demand for deteriorating dams increases from more frequent and more intense rainfall events. In 2017, the 770 ft. Oroville Dam in California, the tallest dam in the United States, succumbed to excessive rainfall and spillway damage, resulting in the evacuation of nearly 190,000 people and over $1 billion in repairs (Fountain et al. 2017). The following summer, a late August catastrophic rain event near Monroe, Wisconsin, resulted in the failure of 5 dams within the West Fork Kickapoo and Coon Creek watersheds and caused significant damage and downstream flooding. According to a USDA NRCS engineer, the failures were caused by a combination of weakness in the dam foundations and extreme amounts of runoff (Pomplun 2020). In March 2019, Spencer Dam in Holt County, Nebraska, was compromised after excessive rain and melting snow resulted in significant flooding around the area. The 92-year-old earthen dam had significant hazard potential but was considered in “fair” condition with minor deficiencies, none of which were considered to affect the integrity of the dam (Hammel 2019). Spencer Dam had no emergency spillway, as do most flood control dams, because its primary purpose was to provide hydroelectric power. The Nebraska Department of Natural Resources indicated that the dam was breached due to natural causes; however, a retiree from the U.S. Army Corps of Engineers spoke of the concerns about Spencer Dam's construction in the 1970s. He stated that the amount of silt and debris in the reservoir would eventually deteriorate the earthen dam's structure, which was only designed to last 50-60 years without reinforcement (Hammel 2019). In May of 2020, Michigan's Sanford Dam and Edenville Dam, completed in 1925 as hydropower dams along the Tittabawassee River, failed due to excessive flooding. Approximately 11,000 residents evacuated as floodwaters rose 10 feet above flood level (Singhvi and Griggs 2020, Bennett 2020).

Not every dam/reservoir combination displaces a large population when built or when flooding happens, but almost every dam was built in order to accommodate growing populations and economic development in urban and rural areas by providing flood control, domestic water supply, hydropower, irrigation, and/or recreation. In the Midwest, in combination with flood-related losses, flooding in rural areas has the potential to affect human and animal health through disease, well water contamination, increased concentrations of mold and bacteria, and increased mental health stress (Haskins et al. 2020). Smaller communities may not have sufficient access to flood updates or accessibility to plan for potential flooding or to obtain appropriate personal protective and readiness equipment (e.g., flashlights, emergency blankets, bottled water, and food supplies, sandbags) for dealing with floodwater.

In addition to the consequences of aging, recent findings of upward trends in extreme precipitation totals in Kansas are consistent with current climate change predictions (Rahmani et al. 2016) and have implications for increased flood and dam failure concerns. In addition to natural climate fluctuations, extreme weather events like heat waves, heavy rain, drought, associated wildfires, and flooding are being exacerbated by human-induced climate forcing due to increased greenhouse gas emissions and land-use changes (IPCC 20 22). Radiative effects from increased CO_2 concentrations are expected to intensify the global water cycle, resulting in increased flood risk (Milly et al. 2002). Increases in the frequency, magnitude, and duration of heavy rainfall events are also expected (USCGRP 2018). Flooding and drought events will become more common, as the hydrologic cycle continues to change. Trends toward increasing magnitudes and frequencies of heavy rainfall events can impact runoff generation, consequently causing hydrological, economic, social, and environmental challenges (Rahmani et al. 2016). For example, soil infiltration rates will decrease between frequent rain events, leading to increased runoff and flooding. Environmental challenges include pollutant transport and transformation, flora and fauna population impacts, natural resource depletion, and other types of environmental degradation.

Shifts in hydrologic events will affect the functioning of dams and other runoff control structures (Rahmani et al. 2016). Economic impacts of reduced dam effectiveness and failures can affect property values, with particular impacts on lower income families (O'Neill et al. 2016). Many residents do not invest in flood insurance, and the expense is often out of reach for low- income families. People with lower incomes also are more likely to live in higher hazard flood zones because the hazard presence reduces property prices. Additionally, flood zones may change more rapidly than residents' awareness, and so the need for flood insurance and other means of mitigating the hazard may not be a part of people's thinking.

Given the number of people who reside in flood-prone areas near and downstream from dams, the idea that the benefits of these structures will exceed the cost (financial and/or physical) may be seen as a worthwhile trade-off despite the risk (Starr 1976). Residents may be unaware of the risk of dam failure, although vulnerable populations risk displacement and may suffer loss with damage to homes, businesses, schools, and infrastructure, or interruption of daily activities should flooding occur. Relocation following flood damage is often met with resistance and a strong desire to rebuild residents' sense of normalcy based on conditions before the disaster (Nelson 2014). This can potentially expose people to greater risk by rebuilding too soon in hazardous areas or further deferring future recovery plans (Nelson 2014). Reasons why individuals would voluntarily stay in (or return to) high risk areas have been explored through risk-benefit analysis (Starr 1976), more commonly referred to as cost-benefit analysis (Aerts et al. 2018), risk and risk perception studies that focus on the ability of the public to appraise their own flood risk through experience (a 'contextualist perspective') (Burningham et al. 2007), and public risk perceptions that are crucial for developments in flood risk management (Kellens et al. 2011). **What is generally lacking in the literature is exploration of residents' views of the potential for dam failures and perceptions of associated risks**. As compared to major dams, medium-size dams are more neglected as potential risks for which residential understanding may be especially lacking.

Research Questions

Through the lenses of cultural theory, risk and vulnerability, and environmental perception, the goal of this research is to **improve understanding of flood risk perception near intermediate-size dams in eastern Kansas**. Increased preparation and mitigation of potential harm is more likely with increased risk perception; conversely, a lack of risk perception where risk actually exists increases the likelihood of losses (O'Neill et al. 2016, National Research Council 2012a, National Research Council 2012b). Current research on community dam failure preparedness and related risk communication is scarce but suggests that one possibility is that people fail to respond appropriately because they do not believe the dam will actually collapse (Mehta et al. 2020). Individuals in a community may assess flood risk differently due to their location within the floodplain, their exposure to a flood event, and the communication of flood information (Atreya and Ferreira 2012). Risk perception matters because of its effects on preparedness and potential losses: where there is a disconnect between actual risk and the perception of risk, actions may need to be taken to better prepare residents for hazards. The emphases on agricultural production (KDA 2020) and steady population growth in urban areas (Hunt and Panas 2018) have put Kansas on the map as having the second greatest number of dams in the United States, following the much larger state of Texas (FEMA 2013). As of 2018, there are over 5,000 dams registered in Kansas, with “flood control” being the primary purpose for the majority of these state, local, and privately-owned dams.

Understanding that problems of aging dam infrastructure, land use/land cover changes (LULCC) (including population distribution), and climatic trends pose problems and potential threats, it is critical to address conditions that affect levels of vulnerability to dam failures. Higher levels of perceived risk are expected in areas that are more exposed to the hazard whereas low risk perception is expected where an individual’s false sense of security may result in a failure to perceive the threat as a risk (Terpstra et al. 2009). Such a (false) sense of security is most likely to happen when the purpose of a nearby dam is specifically for flood control. Knowledge and risk perception influence decision making, preparedness, and response behaviors, and are important for the mental preparedness for potential dam failure (Mehta et al. 2020).

This study focuses on Kansas dams that share the characteristics most likely to be associated with dam failure and the populations who reside near them. Through this research, I **seek to 1) contribute to understanding flood risk perception where only part of the population is at actual foreseeable risk (Research Objective 1) and 2) compare how perceptions relate to physical risk situations (RO2).** This research also will fill gaps related to at-risk infrastructure and bridge risk communication gaps (RO3). The following research questions guided this study:

1. Which intermediate-size flood control dams in eastern Kansas are most at risk of dam failure? (Relevant to RO1, RO2)
2. How do local populations' perceptions of risk and vulnerability to at-risk dams vary? (RO1, RO2, RO3)
    a. Do perceptions align with factors related to failure risk? (RO2, RO3)
3. How can risk communication be improved among vulnerable populations? (RO3)

Summary and Organization

For centuries, dams have played a pivotal role in providing a diverse set of purposes, including water supply, flood risk management, and hydropower. Despite human interventions to control rivers, natural processes, such as erosion and deposition, continue to occur in areas where dams were constructed. Without proper maintenance and funding, the deterioration of aging dams will put populations at a greater risk as reservoirs fill with sediment and population growth increases near dams. Some areas will experience an increased flood risk as dams meet their life expectancy. There is a need to assess risk perception in those areas as climate change, maintenance protocols, and general safety become major issues within the foreseeable future.

The second chapter introduces the role of geographers and their contributions in the natural hazards field by first detailing the geophysical characteristics of flooding then moving forward with an increased recognition of the interaction between physical environments and human societies. Geospatial technologies have been instrumental on both the physical and human approaches to understanding flood risk perception, through advancements in modeling, socio-demographic data, and risk communication. Further topics include risk, vulnerability and behavior associated with natural hazards. Risk perception theories are presented under the umbrella of a social-ecological systems framework using cultural theory and the psychometric paradigm. Finally, a section on risk communication is included.

To better understand the study area, chapter three includes relevant aspects of the geography of Kansas with an emphasis on the characteristics that were used to identify at-risk dams and selection of case study dams. Research question 1 is addressed in this chapter. The fourth chapter, “Methods,” describes the explanatory sequential methods used for this research. The approach for this study includes mixed methods with a combination of mailed questionnaires and semi-structured interviews. The results of the research (RQ2 and RQ3 findings) are detailed in the fifth chapter, followed by a discussion of results in the sixth chapter. Chapter seven is the final chapter, with a brief summarization of the findings uncovered in this study, their implications, and observations regarding this research undertaking. In this chapter, the limitations of the research are explored, in addition to providing possibilities for future inquiry. Finally, appendices include supplemental information associated with study.

Chapter 2 - Background and Literature Review

Introduction

Geographers in the natural hazards field focused early research efforts on understanding the physical processes that contributed to hazardous events as a result of earth's dynamic systems. Over time, those efforts evolved into understanding the human-environment interactions and the complexity of societal issues associated with natural hazards and disasters. Many researchers credit Gilbert White's (1945) Human Adjustment to Floods as being the cornerstone to the evolution of natural hazards research by incorporating social components into natural hazards research (Montz and Tobin 2011). Natural hazards refer to the interaction between humans and extreme natural events that have the potential to constitute a threat to society (Montz et al. 2017), although human activities affect these events so that they may not all be completely 'natural.' For example, human-induced climate change is now associated with changes to wildfires, hurricanes, and flooding, though the proportion of an event due to human activities cannot readily be assigned. Climate change is projected to alter the frequency and magnitude of both floods and droughts, varying regionally across the globe (IPCC 2014). A natural disaster is a geophysical event that significantly impacts humans. Geospatial technologies have been instrumental in understanding the geophysical processes that occur during natural hazards through real time data and advanced modeling.

Research on risk perception, vulnerability, resilience, behavior, and communication are just as important as understanding the probability of risk itself (Slovic et al. 2000, Cutter et al. 2003, Burton et al. 1993). A social-ecological systems framework is used for this study, in conjunction with guidance from cultural theory and the psychometric paradigm to examine flood risk perception, and risk communication. Research using geospatial technologies, such as geographic information systems (GIS), allows researchers to combine social and demographic data to address human factors, such as vulnerability and resilience, throughout the existence of a natural hazard. Geospatial technologies help fill the communication gap by providing accurate and timely information. As those communication gaps are filled between experts and laypeople, there is a change in risk perception. With more information, people are able to make conscious decisions about their level of risk and make informed choices in the event of a hazard or disaster event.

Why Dams Matter

There have been relatively few efforts to understand the impact of dams reaching their designed life expectancies, and what this means for both upstream and downstream residents. Hydrological processes, such as drainage basins, precipitation runoff (single-event and continuous), evapotranspiration, interception, infiltration, and soil moisture, can impact the regular flow or levels of a river, despite the spatial location of a flood control structure (also referred to as a flood retarding dam). After a dam's construction, changes in the physical environment, increased population, nearby development, and the materials used to construct the dam may undermine the structural integrity and primary objective of the dam.

Dam breaks or failures are often a result of water overtopping the structures, excessive seepage through the surrounding ground, or a structural failure. Failures can occur with little to no warning, therefore threatening the safety of the structures and the people who rely on them (National Weather Service 2019). Dam failure, which may be a result of several factors, including earthquakes, poor maintenance, structural failure, and settlement or erosion of embankments, can create downstream flooding, regardless of recent rainfall events. Physical processes and maintenance status inevitably contribute to the success or failure of these structures. Over time, dam failures and increased risk will either result in a focus on new risk management strategies or will leave an unknowing population at even greater risk (Moser et al. 2014).

Since most dams are designed to be in use for 50-100 years and many have exceeded their design lives, there is a risk to people who live downstream, as well as risk to other infrastructure and to land uses like farming. Dams, reservoirs, and other water retaining structures will experience a reduction in storage capacity as reservoirs fill with sediment due to soil erosion caused by rain and wind runoff. (IPCC 2014). As dams age, they become more susceptible to failure as a result of structural deterioration, reduced water holding capacity of sediment-filled reservoirs, and increased development nearby (FEMA 2015). Older dams also experience increased stress from extensive plant root growth, animal burrows, and problems with filters and drainage systems (FEMA 2005b). Many dam owners plant trees on dams for aesthetics and can be resistant to removing trees, even if it is in the best interest of safety. In other cases, plants naturally colonize earthen dams that are not intensively maintained. Vegetation, particularly woody plants, on earthen dams can lead to negative impacts or possible dam failure from undesirable root penetration (Table 2.1) (FEMA 2005). Tree roots, which penetrate and destabilize earthen dams (particularly those not being properly maintained), can loosen embankment soil and create seepage. In particularly densely vegetated areas, the problem then becomes obscuring of the dam surface by plant cover (FEMA 2005a). Dam drainage systems are “graded and/or protected pervious aggregates in a dam designed to collect, filter, and discharge seepage through the embankment, abutments, or foundation” (FEMA 2005b). Drainage systems are designed to reduce the potential from internal erosion and soil beneath the structure.

Table 2.1. Dam Safety Problems Caused by Woody Vegetation (FEMA 2005b).

Problem	Cause
Impaired safety monitoring	Difficult to see areas of stress seepage, cracking, sinkholes, slumping, settlement, deflection Provides cover for burrowing animals
Loosen compacted soils	Uprooted trees creating large voids
Erosion	Decaying roots lead to seepage paths Undesirable vegetation can lead to embankment erosion
Damage to spillways	Fallen trees, Induced local turbulence in spillways from overtopping
Concrete damage	Roots wedged between open joints can lead to cracking, uplifting, or displacement

River-related infrastructure is also impacted both upstream and downstream of dams: aggradation upstream of the dam reduces the size of upstream bridge openings (the area between the bottom of a bridge and the stream bed). This can lead to bridges being overtopped by floodwaters (Annandale 2005). Conversely, degradation downstream can lead to scouring at downstream bridges and lead to failure due to undercutting of the structure (Annandale 2005).

Structural Deterioration

As Kansas dams age, the loss of structural integrity will mean that dams will no longer be able sustain intended storage capacities, nor provide sufficient flood control. FEMA has identified three major failure types associated with dams as structural, mechanical, and hydraulic. Structural failures as a result of foundation defects, settlement, and slope instability, or damage caused by earthquakes, have caused approximately 30 percent of all dam failures in the United States (FEMA 2015). Mechanical failures are a result of malfunction of gates, conduits, or valves that have the potential to cause upstream and downstream flooding. About 36 percent of U.S. dam failures are attributed to mechanical failures (FEMA 2015). Hydraulic failures account for approximately 34 percent of all dam failures in the U.S. and are a result of overtopping due to inadequate spillway designs, debris blockages of spillways, or settlement of the dam crest (FEMA 2015).

Reservoir Sedimentation

Reservoir sedimentation is a significant concern for water resource managers who are responsible for the nation's dams and reservoirs. The finest particles flowing into the reservoir with stream and overland flow inputs will settle closest to the dam, and eventually build up over time without human intervention. Sediment deposition occurs as a river's flow velocity is reduced with entry into a reservoir. Determining the useful life of a reservoir has historically been done through periodic hydrographic surveys and inflow-outflow approaches which are often time consuming and expensive (Goel et al. 2002). Current engineering and design standards focus on hazards through deterministic or probabilistic approaches, but do not take into account the performance of the infrastructure (NRC 2012). As sediment levels rise, the capacity of water storage in the reservoir is reduced, leading to both upstream and downstream impacts for flood management, infrastructure, reliability of water supply, and standard of living, such as economic production, quality of the environment, and recreation opportunities (Annandale 2005).

Dams designed for flood management can be adversely affected once the reservoir volume has been significantly reduced due to sedimentation. If deposition occurs upstream of the dam, stream geomorphology changes, resulting in higher flood levels upstream (Annandale 2005). Industrial production may decline in areas where water and power supply are reduced due to reservoir sedimentation (Annandale 2005), creating another hardship for at-risk populations. Assessing sediment deposition is important for the management and operation of reservoirs (Bhavsar and Gohil 2015), especially as reservoir sedimentation and lack of awareness become obstacles to protecting downstream populations.

Development near Dams

An increase in impervious surfaces, including roofs, paved streets, and sidewalks accompanying creation of upstream housing subdivisions and businesses, can increase the volume of runoff to a reservoir (FEMA 2015). Urban development upstream has the potential of seeming too unpredictable or too far removed from the actual responsibility (Griffin et al. 2008). Downstream, an increase in population means an increase in hazards. According to FEMA Acting Regional Director Tammy Doherty, "when a state designates a dam as 'high hazard' it has little to do with the inherent stability of the dam, but everything to do with the threat posed to downstream populations in the unlikely event of dam failure" (FEMA 2001). From an economic perspective, the attractiveness of settling in a floodplain, based on lower housing costs, and assumed safety from flooding has encouraged the formation of settlements as close to rivers as possible (Viglione et al. 2014.). Newly constructed homes with perceived "protection" from floods can attract residents to floodplain areas behind levees, often with an overestimation of safety from flood risk (Ludy and Kondolf 2012).

Residents' Dam Responses

Hazard research suggests that people make decisions based on their personal perceptions of potential risks (Paul 2011). A higher level of trust based on the presence of flood control structures reduces residents' preparedness and the amount of dread evoked by assumed flood risk

(Terpstra 2011). Risk perception arises from a combination of individual sensory experiences, previous experience, and personal attributes (Ludy and Kondolf 2012). Given personal experiences, proximity to the dam, and level of awareness of the probability of a flood event, individuals in the same community may assess flood risks differently (Messner and Meyer 2006). People who have previous experiences with floods are more likely to act protectively during a flood when the majority of inhabitants that live in a flood-prone area will underestimate their danger, sometimes under the assumption that floods would not re-occur for several years after the last event (Brilly and Polic 2005). Over time, the memory and experience of the flood tends to fade, and some individuals will no longer anticipate a second major flood event in their lifetime. The greater the spatial and temporal distance from a flood, the lower the perception of flood risk (Burningham et al. 2008).

Climate Change, Dams, and Risk in Kansas

Global climate change is altering precipitation patterns worldwide. Increases in the magnitude and frequency of heavy rainfall events are directly associated with worsened flooding. According to the United States Geological Survey (USGS), a flood is defined as “an overflow or inundation that comes from a river or other body of water and causes or threatens damage” (USGS n.d.). More specific definitions used by the U.S. Federal Emergency Management Agency (FEMA) describe flooding as a “general and temporary condition of partial or complete inundation of 2 or more acres of normally dry land area or of 2 or more properties from overflow of inland or tidal water; or unusual and rapid accumulation or runoff of surface water from any source; or mudflow” (FEMA n.d.). Increased annual seasonality results in higher peak stream discharges and changes in stream geomorphic form caused by channel widening and decreased vegetation density (Martin and Johnson 1987). The expansion of irrigated cropland in the central United States has contributed to large-scale precipitation increases, particularly during the summer months of June-August (Alter et al. 2015).

Realization of climate change predictions of more frequent and extreme weather events will contribute to the demands placed on current infrastructure (O'Neill et al. 2016) as the runoff from heavy rainfall increases flash flooding. In 2019, Kansas floods were driven by a March "bomb cyclone," with spring snowmelt and persistent rainfall contributing to the wettest May in recorded Kansas history, and the second wettest of any month on record for the contiguous United States (NOAA 2019). More than 90 percent of the state's monitored rivers were above flood stage (USGS 2019), damaging at least 11 dams in Kansas (KDEM 2019). Continued stress on water management systems will heighten chances of failure without proper maintenance and needed improvements in water, soil, and flood management systems (Rahmani et al. 2016).

Flooding along the Missouri River and its tributaries have occurred almost annually in its recorded history. Major floods in the 19th and 20th centuries contributed to the enactment of the 1936 Flood Control Act, which recognized flood control as a national priority. The act authorized the United States Army Corps of Engineers to construct flood control structures nationwide. Unprecedented and severe flooding in 1943 within the Missouri River Basin gained public and congressional attention, leading to the passing of the Flood Act of 1944 (which included the Pick-Sloan Missouri Basin Program). The Pick-Sloan Program provided for the construction of large and small dams along the Missouri River and its tributaries for the purposes of flood control, navigation, electricity, recreation, and irrigation. By the time of the 1951 flood, which during its peak pushed more than 512,000 ft/sec of water into the Missouri River, several proposed dams had yet to be built under the plan (Kollmorgen 1954). In response, the Army

Corps of Engineers, pushed for an uptick in the construction of Kansas dams between 1960 and 1982; this paralleled trends in the construction of dams across the United States (Kollmorgen 1954). The dams were built to address flood risk management during a time when precipitation averages were lower, sediment had not filled the bottom of the reservoirs, and the population in Kansas near dams was still relatively low. For the past 50 years, Kansas residents have lived without the fears of major flooding like what happened in the early 1950s (Perry 1994). Dams are filling with sediment (some at faster rates than others), downstream populations are increasing, upstream land uses/land covers have changed, and the changes in weather patterns have shifted enough to be important research topics. As many Kansas dams start to reach the end of their design life, societal concerns such as altered land use, population dislocation, unmet water and power needs, and flood risk exposure (Annandale 2005) can increase the risk, vulnerability, and adaptive capacity of populations located near these infrastructures. In 1993, when most Kansas dams were approaching their 20th year, the United States experienced the costliest river related flood at 20 billion dollars across 9 states adjoining the Mississippi River from June to August (Combs and Perry 2003, USGS 2006). Since then, above normal rainfalls between May and September have led to significant floods in 1994-5, 1998, and 2007. In 2008, Kansas experienced the largest streamflow peaks to occur in decades for many locations. With changes to dam, environmental, and social conditions, better understanding of residents' perceptions as addressed by this research will help to address whether there are important disconnects between conditions and perceptions in order to help improve communications, public knowledge, and safety.

Physical Geography of Floods

Within the water cycle, water exists across Earth subsystems, in terrestrial and water body locations (ice sheets, glaciers, groundwater, lakes, soil moisture, rivers), biotic – especially botanical – positions (with uptake and transpiration through plants), and in the atmosphere (water vapor and forms of precipitation). When water falls on land, its destination is determined by the watershed, a geographic area of land from which all water drains to a single outlet. An outlet may include a reservoir, mouth of a bay, or any point along a stream channel (USGS 2020). The term watershed may also be referred to as a drainage basin or a catchment and can be represented at various scales. The defining geographic characteristic of a watershed is its topography, but it is a dynamic system with inputs, outputs, and interactive ecosystem components. The streamflow and water quality of a river are affected by things happening in the watershed above the river outflow point. Land cover and land use in the watershed directly affect how much and how quickly water runs off the surface into downstream rivers and reservoirs.

A flood is considered a "temporary rise in water surface elevation resulting in inundation of areas not normally covered by water" (FEMA 2013). Flood characteristics include the magnitude, extent, and duration of a flood event (Nied et al. 2017) and can vary over time and space (O'Connor and Costa 2004). Terrestrial and atmospheric sources have the potential to release large flows of water, resulting in flooding within a watershed. Meteorological events, such as intense rainfall, storm surges, high tides, and rapid ice or snow melt are the most common reasons for flooding but can also be a result of dam breaches, breakup of glacial ice dams, releases from caldera lakes or ice-jam floods (O'Connor and Costa 2004). The five main types of flooding include river floods, coastal floods, storm surges, inland flooding, flash floods, and debris flows (NSSL n.d.), all of which have the ability to impact hydrological, agricultural, economic, social, and environmental systems (Rahmani et al. 2016). River flooding, the key type related to dam failures under investigation here, occurs when infiltration is low – perhaps reduced by saturation from prior snowmelt or rainfall – and surface runoff is increased by either natural or anthropogenic forces. Preceding weather conditions, amount and type of rain, temperature, soil moisture and texture, runoff, land cover, and topography all play roles in the intensity of flooding in a particular area and at different scales.

Scale and Spatial Variability in Flood Risk Forecasting

Flood risk forecasting is inherently difficult to model but necessary in providing time-efficient warnings to those at risk. Temporal scales provide a framework for considering natural and human processes in watersheds. As different hydrological processes are dominant over a wide range of scales, flood risk forecasting relies on different modeling approaches to attain the most reliable and accurate information for users. The four major scales are a) global, b) national (country), c) regional (watersheds or large cities), and d) local (town or specific river stretches) (de Moel et al. 2015). As changes within the environment take place (precipitation, drought, earthquakes, pollutants), watersheds can be affected at different scales. Magnitude and frequency relationships have important implications for changes in watersheds. The magnitudes of events in a system are usually linked to the frequency with which they occur; in general, higher magnitude events are relatively rare and low magnitude events are more frequent. The impact of disturbances (physical processes that contribute to flooding) in a region typically decrease as the scale of the catchment size gets smaller in scale. However, climate impacts occur at larger scales, affecting both small and large catchments in a particular region (Bloschl et al. 2007). Through analysis, a baseline for the average amounts of precipitation can be determined within the watershed. This type of information is important, not only to address current concerns (e.g., crop yields, infrastructure needs), but also for predictions about future hydrological events.

In order to understand the role climate variability and land use have on hydrologic responses as a function of spatial scale, the UNESCO Division of Water Sciences created a five-year research strategy to help basins address issues on change analysis, transitional climate regimes, catchment processes and flow paths, feedbacks, heterogeneity and scaling, and generalization and potential of typologies (Bloschl et al. 2007). As a part of their research strategy, the group focused on two main approaches, each with their own respective strengths and shortcomings, used for forecasting flood risk: 1) the "upward approach," also referred to as a reductionist or mechanistic approach (Romanowicz et al. 2008), and 2) the "downward approach" (Bloschl et al. 2007). The upward approach uses a model structure that links real time hydrological and meteorological data that includes processes such as rainfall, subsurface flow, and upstream/downstream level variances. The authors note that scale may be difficult to capture with this approach and the parameters are not identifiable. The downward approach uses trend analysis of long runoff data series and paired catchment studies (Bloschl et al. 2007) to understand the basin's response to climate change. In a paired catchment study, both catchments share similar physical (slope, soils, vegetation, etc.) or geographical characteristics (Brown et al. 2005). A study conducted in the Mahanadi River Basin, India, used the downward approach to characterize the impacts of climate change using long term data from the region and future flood condition predictions (2026-2055) as a way of identifying and prioritizing areas where flood adaptation and flood hazards potentials were like to increase as a result of the changing environment (Gusain et al. 2020). The downward approach is useful for capturing the summary of multiple controls but limits the user's ability to identify a specific cause (Bloschl et al. 2007).

Global Scale. Impacts can be difficult to verify at the global scale because of the temporal lag between the cause and the effect. Recent technological innovations have allowed researchers to collect a wider range of data and the computational capacity to scale up to larger scales to understand data-scarce regions (de Moel et al. 2015). Improved risk assessments on the effects of catastrophic flooding are needed at the global scale, particularly as changes occur in climates, population densities, and the global economy (de Moel et al. 2015). The DEM (digital elevation model) resolution of global data is usually in the range of 1-10 km and is used for estimates in global river flood models and ocean surge heights in coastal regions. Modeling at the global scale contributes to support of "climate change adaptation policies and helps develop robust public disaster relief funds" (de Moel et al. 2015). By modeling at broad scales, researchers are able to project changes in hazards or exposures to flood prone areas, particularly in coastal regions (de Moel et al. 2015).

National Scale. In the United States, the USGS uses the Hydrologic Unit Code (HUC) system to classify and define watersheds at different geographic scales. The watershed provides a logical boundary system and conceptual unit for ecosystem management because it is based on the geographic characteristics of the ecosystem's hydrology (NRC 1999). At the national scale, flood maps are usually generated for national programs, such as insurance programs, at a DEM resolution between 100 m and 1 km to alert the public to risks and flood management practices (Michel-Kerjan and Kunreuher 2011, de Moel et al. 2015). At this scale, simplified approaches allow for generic flood models and combined hydraulic simulations that can cover an entire country but may lead to inconsistencies in inundation modeling at coarse scales (de Moel et al. 2015) and provide insufficient detail for local decisionmakers and residents.

Regional Scale. Regional scale studies are based on the assumption of spatially uniform flood return periods and are used to evaluate management measures. Potential management actions include the development of retention areas, restoration of abandoned meanders, reforestation, and flood proofing (de Moel et al. 2015). These measures are meant to reduce flooding but may not be completely effective: the regional modeling done during the 1993 flooding in the U.S. Midwest found that models consistently under-forecasted the intensity of flooding because they did not take into consideration broad-scale anomalies of atmospheric circulation patterns and nonlocal conditions (Dirmeyer and Kinter III 2010). In other instances, large scale patterns may overestimate flood risk. This can be avoided by using continuous rainfall-runoff data, driven by climate model scenarios, which provides a modeled flood event that is consistent for the whole catchment (de Moel et al. 2015).

Local Scale. At a local scale, land cover effects are very specific to the region. There is a need to understand the indirect economic effect of a flood event, which includes our understanding of the effects on critical infrastructure and the total effects of flooding, using data in the range of 1-25 m resolution (de Moel et al. 2015). Flood risk assessments done at the local level are done with detailed data (elevations, hydraulic structures, building types and uses, and the cost effectiveness of flood reduction measures) (de Moel et al. 2015). At smaller scales it is easier to identify the impacts of land use activities as well as sediment-related processes (Bloschl et al. 2007). Measuring at such a fine scale provides more detailed information and allows more effective preventative measures to be taken in the event of a flood event.

Risk and Vulnerability

Risk is defined as the probability of occurrence of a condition or event (Mileti 1999, p. 106). In terms of natural hazards and disasters, risk is based on the probability or frequency of occurrence of a hazard event going beyond some threshold magnitude (IPCC 2014), such as death or injury to humans and/or the expected economic damage caused within a natural environment (Paul 2011). Measuring risk is commonly done quantitatively through technical and economic analysis (Baan and Klijn 2004). Measuring the consequence of a natural hazard is generally expressed using three factors which include loss of life, human injury, and economic damage to the (mostly built) environment, reported in US dollars (Paul 2011) or another appropriate monetary unit. Qualitative ranges can be used to indicate the likelihood of risk by using terms such as "certain," "likely," "possible," "unlikely," "rare," or "extremely rare." The most common definition of risk can be expressed using the following equation:

$$\text{Risk} = (\text{Likelihood of Hazard Occurrence})\ (\text{Consequence})$$

It is important to note that, while this is the most common definition used by risk managers, there are multiple definitions for risk which take into consideration functions of hazard probability, probability of occurrence of an extreme event, vulnerability, magnitude, exposure, response, resilience, and preparedness (Paul 2011). Several definitions of risk depend on the probability of occurrence of an extreme event. Determination of hazard probability requires long-term data trends regarding events. Data may extend over a century and are generally only accessible in developed countries. Shorter time periods of record may provide unreliable estimates of probability in certain regions and for particular hazards (Paul 2011). Even data records of a century or more may result in misleading estimations of event probability (e.g., a flood of a particular magnitude), and climate change is likely to further complicate determination of the likelihood of a particular hazard.

Hazards are conceptualized by Mitchell (1990) as a function of risk (the probability of an adverse effect), exposure (size and characteristics of an at-risk population), vulnerability (potential for loss), and response (mitigation measures that are in place). Some researchers risk may increase or decrease based on the respective trend of the hazard event, vulnerability, and exposure (Paul 2011).

Magnitude

Some attempts to measure risk remove the probability of hazard and consequence, and instead focus on occurrence of an extreme event multiplied by the magnitude, measuring the probability and severity of harm (Paul 2011). Magnitude is used to describe the size, strength, or force of an extreme event and is generally associated with higher fatalities, injuries, and damages to property (Paul 2011) based on their characteristic timescales (IPCC 2012). The 2012 Intergovernmental Panel on Climate Change (IPCC) report indicated that the frequencies and magnitudes of some types of extreme weather and climate events have increased, subsequently causing an increase in populations with consequences for disaster risk. Examples from the report include: a) an increased magnitude and frequency of floods at regional scales due to spatial and temporal limitations of gauge stations, projected increases in heavy precipitation leading to increased runoff, early spring peak flows in snowmelt, and changes in land use, b) an increase in the frequency and magnitude of warm daily temperature extremes and decreases in cold extremes during the 21st century based on anthropogenic influences, such as emissions. Other examples of magnitude include the severity of windspeed thresholds during a tropical cyclone or tornado and the seismic rating of earthquake events. Increased magnitude or rate of climate change will increase the likelihood of adaptation limits. Transformational adaptation may be required in a system where the magnitude of an event has led to losses and damage that are no longer recoverable (IPCC 2014).

Vulnerability

The development of vulnerability science is intended to understand "circumstances [that] put people and places at risk and those that reduce the ability of people and places to respond to environmental threats" (Cutter 2003, 6). Vulnerability scientists have identified four major responses to vulnerability: a) reducing exposure to hazards, b) minimizing destructive consequences, c) improving capacity to cope during a hazard event, and d) reinforcing potential recovery (Paul 2011). Vulnerability is often defined as the "starting point," used to describe the estimated or residual impact of an event by considering the system's exposure and/or sensitivity to a hazard and its ability to recover after the event (Smit and Wendel 2006), or simply as the "propensity or predisposition to be adversely affected" (IPCC 2014). In essence, vulnerability is a measure of an entity's inability to deal with a natural hazard or disaster (Paul 2011), using either:

Risk = (Hazard Probability) (Vulnerability), or

Risk = (Hazard Probability) + (Vulnerability)

Due to the wide range of disciplines invested in understanding vulnerability, two broad approaches are to focus on either social vulnerability or biophysical vulnerability. Vulnerability varies in multiple scales and stresses, ranging from a single individual to society as a whole; by phenomena of interest (physical, biological, social, etc.); and temporally, from an instant to century (Smit and Wendel 2006). Differences in social, economic, cultural, political, institutional, or otherwise marginalized groups shape different vulnerability, adaptation and mitigation responses during a natural hazard or climatic event (IPCC 2014). At the individual, household, and community levels, vulnerability is related to demographic characteristics, including level of education, income, race, gender, age, and any past disaster or hazard experience (Cutter et al. 2003, 2016; Paul 2011). A group's vulnerability can also vary based on their dependency on others (particularly for children and the elderly), remoteness, and their own personal choices and decisions in response to a hazard (Klienenberg 2002, Pelling 2003, Paul 2011).

Social vulnerability is determined by socio-economic and demographic factors whereas biophysical vulnerability is the combined vulnerability of a system as a function of hazard, exposure, and sensitivity (Brooks 2003). Additional types of vulnerability include individual/household vulnerability (Shah et al. 2018), institutional vulnerability (Lopez-Martinez et al. 2017), economic vulnerability (Felsenstein and Lichter 2014), environmental vulnerability (Houston et al. 2020), system vulnerability, and place vulnerability (Borden et al. 2007, Cross 2001, Paul 2011). Social vulnerability factors are characteristics that may increase an individual's or a population's vulnerability to a hazard event (Cutter at al. 2012) (Table 2.2). Any of these characteristics may increase the harm felt by persons, even as compared to others being affected by the same magnitude or severity of, for example, a flood or storm inundation.

Table 2.2. Increased Social Vulnerability Based on SoVI Factors (Cutter et al. 2003).

Social Vulnerability Factors	**Conditions that Increase Vulnerability**
Socio Economic Status	**Low Income/Status** – Inability to absorb loses or enhance resiliency as effective as wealth enable communities (insurance, social safety nets, and entitlement programs)
Gender	**Women** – Sector specific employment, lower wages, family care responsibilities
Race and Ethnicity	**Nonwhite/Non-Anglo** – Language and cultural barriers may affect post disaster funding and residential areas win high hazards locations. Social, economic, and political marginalization associated with racial disparities
Age	**Elderly** – Mobility constraints/concerns **Children** – Mobility constraints/concerns; financial strain on parents during loss of daycare/school facilities
Commercial and Industrial Development	**High Density/Value** – Indicator of economic health of community
Employment Loss	**Employment Loss** – Unemployed workers contribute to slower recovery from disaster
Rural/Urban	**Rural** – Lower incomes, more dependence on locally based resources (farming, fishing) **Urban** – High density areas restrict evacuation routes
Residential Property	**Mobile home** – Easily destroyed and less resilient than expensive homes
Infrastructure and lifelines	**Loss of extensive infrastructure** – (sewers, bridges, towers, water, communication, and transportation) Create financial burden on smaller communities
Renters	**Renters** – Transient or financially unable to purchase a home often lack access to financial aid information during recovery. Renters may lose housing when lodging becomes uninhabitable or too costly
Occupation	**Clerical, Laborer, or Service Sectors** – Resource jobs may be impacted by hazard event. As disposable income fades, the needs for services declines
Family Structure	**High Birth Rates, Large Families, Single Parent Households** – Family and financial strain to maintain work responsibility and family care
Education	**Little Education** – Constrains ability to understand warning information and access to recovery information
Population Growth	**Rapid Growth** – Lack of available/quality housing, and social services
Medical Services	**Distance from medical services** – Lengthens immediate relief and long-term recovery from disasters
Social Dependence	**High Social Dependence** – Individuals are already struggling economically and socially; may require additional support after a disaster
Special Needs Populations	**Large Special Needs Population** – Difficulty to identify in the communities and are mostly ignored during recovery

Flood risk reduction programs rely heavily on cost-benefit analyses to determine property damage, and less on the socio-spatial impacts on affected communities (Cutter et al. 2003). Property losses are typically greater in urban areas due to the volume and value of structures in an urban environment, however there may be a greater sense of loss and longer recovery time in less resilient rural places (Cutter, Ash, and Emrich 2016).

Using a multidimensional, scale- dependent, and spatially reliant algorithm, Cutter et al. (2003) developed the Social Vulnerability Index (SoVI), which uses multiple variables (including race, gender, socio-economic status, employment, and special needs) to capture the dynamic and multidimensional nature of vulnerability within and between communities (Cutter et al. 2012). The SoVI algorithm has been widely used in government agencies in the United States[2] and internationally (Holand et al. 2010, Chen et al. 2013, Guillard-Goncalves et al. 2014, Hummel et al. 2016) for hazard planning, decision making in disaster recovery, and resource allocation.

Flood Risk and Vulnerability

Flood risks can be broken down between the threat of flooding and the vulnerability to a flood (Wasson 2016). Flood hazards are projected to increase with climate change, leading to greater exposure and vulnerability (IPCC 2014). Measuring flood risk is commonly done through technical and economic analysis (Baan and Klijn 2004). Flood risk is assessed by first estimating the potential danger of flooding. The basis of each assessment is done through

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[2] United States Army Corps of Engineers, Center for Disease Control, Hazards and Vulnerability Research Institute for the Florida Department of Health, Impact Assessment and Recovery Action Plans and for state, county, and regional hazard mitigation plans in several states).

observational data (recorded flood events, time series of precipitation, river discharge, water levels, etc.), which can also be used as inputs into hydrological and hydraulic models that represent flood processes in catchments and river systems (de Moel et al. 2015). Operational and probabilistic flood forecasting approaches are used to inform the public about flood threats. Operational or real-time forecasts use meteorological forecasts and hydrological modeling to determine flood threats from hours to months, and are used for publicly available warnings (television, radio, social media, etc.), evacuations, and recovery plans for the public. The estimation or probability of floods is the second type of flood forecast used as an input for infrastructure design (such as the lifetime of a dam), flood zone planning, and evacuation planning. This type of potential flood assessment may last from years to several decades into the future (Wasson 2016).

As a general rule, people that perceive low flood risk are less prepared to deal with flood events and experience above average levels of damage, increasing their vulnerability (Messner and Meyer 2006). For those located below a dam, their established trust in the dam's ability to regulate flood events greatly influences their risk perception (Ludy and Kondolf 2012). This raises the question of whether and how much these individuals are aware of the risks that are associated with dam failure. Increased flooding risk and a lack of transparency contribute to the growing number of Americans purchasing their homes in floodplains, particularly those in the middle and lower classes. Bills advocating for a nationwide flood disclosure system have failed in multiple states, with the threat of decreased property values and the hope that flood risk will go away (Hersher 2020). Kansas, along with 20 other states, has no statutory or regulatory requirements for a seller to disclose a property's flood risk, past flood history, or potential for future flooding to a potential buyer

(NRDC 2021). Apartment dwellers, who may be less familiar with flood insurance risk than homeowners, are part of an even larger number of states that are not required to disclose flood risk information to tenants (Dwyer 2020).

Risk Perception

Hazard research suggests that people are able to make decisions based on their personal perceptions of potential risks (Paul 2011). Risk perception is defined as a "subjective assessment of the probability of a specified type of accident happening and how concerned we are with the consequences" (Sjoberg 2004, 8). People frequently have perceptions that differ from actual (statistical) risk, and perceptions may also change over time and with varying experiences. Overall, risk perception is found to be similar in men and women, despite women more commonly being identified as "risk avoiders" and men as "risk takers" (Cutter et al. 1992).

A lack of necessary and/or accurate information may prevent people from properly identifying and reducing risks (Paul 2011). Early theories of risk perception emerged in the mid-1960s and have continued to be of interest to social scientists, policy makers, and others, as scientific experts and the general public have struggled with the idea of accepted and acceptable risk (e.g., Starr 1969). Accepted risks are generally those risks that are part of a lifestyle choice and are viewed as consequences of living in hazardous environments (Paul 2011). An example of accepted risk is when an individual chooses to locate a full-time or vacation home 'on the beach' although storm surges or tsunamis may be expected. The resident takes the chance that no problems will arise, and there is less of a chance that risk management is being planned by residents.

Acceptable risk is defined as the level of risk for which an individual deems the cost of reducing risk not worthwhile compared to the advantages of increased safety (Slovic et al. 2000). This measure may be skewed by income or ability to reduce risk. In Starr's (1969) Social Benefit versus Technological Risk, he asks 'how safe is safe enough?' by proposing the idea of 'acceptable' risk-benefit ratios using quantitative techniques. Starr found that 1) the acceptability of risk was proportional to real and perceived benefits, 2) the public was willing to accept voluntary risks (recreational activities) over involuntary risks (food preservatives) which provided the same level of benefit, 3) the more people were exposed to a risk, the more accepted the risk was, and 4) tolerable accepted hazards were ranked similar to the level of risk from disease. For reference, Starr suggested the lowest class of risk is set by the risk of death from natural events like lightening, flood, and earthquakes (1 death/year per 1,000,000 people) and the highest class of risk was determined by the normal US death rate from disease (about 1 death/year per 100 people). Based on this scale, an involuntary risk would be considered high if it approached the disease rate, excessive if it exceeded it, moderate if it was 10-100 times less than the disease rate, and low if it approached the natural hazards level.

Flood Risk Perception

Given personal experience, proximity to a dam, and knowledge about the probability of a flood hazard event, individuals in the same community may assess flood risks differently (Messner and Meyer 2006). Flood risk perception is influenced by the combination of individual experience, previous experience, and personal attributes (Ludy and Kondolf 2012). Risk perception also has a spatial component, where perceptions and attitudes of laypeople perceive higher risk the closer they are to the hazard, also known as "dread risk" (Slovic 1990). Attempts to measure risk are as varied as the definitions they are meant to address. Flood risk perception can be very diverse within a single community, even among similar groups. Even experts may view floodplains differently: those interested in flood protection measures and those interested in expanding economic development are likely to differ (Messner and Meyer 2006). Likewise, some individuals may be sufficiently concerned about flood risks to the point of investing in private measures to protect their belongings, whereas others may leave flood risk mitigation to public policy (Messner and Meyer 2006).

People who have previous experiences with floods are more likely to act protectively during a flood event, but the majority of inhabitants who live in a flood-prone area will underestimate their danger, sometimes under the assumption that floods would not recur for many years (Brilly and Polic 2005). In a study conducted on the residents' perceptions of flood risks in the flood-prone area of Celje, Slovenia, the researchers found that flood risk awareness was higher in the city than in areas of Slovenia where flooding is less common (Brilly and Polic 2005). A study done in the Netherlands on flood risk perception found that individuals in low-lying areas generally have perceptions of higher flood risk and rural populations were more aware of the risk of flooding than urban populations; previous experience with flooding increased formation of perceived risk (Botzen, Aerts, and van den Bergh 2009).

It is evident that flood experiences influence perceptions of future flood probability. As a general rule, people who perceive low risk are less prepared to deal with natural hazard events and may experience above average levels of damage, increasing their vulnerability (Messner and Meyer 2006). Trust in hazard-averting infrastructure greatly influences an individual's risk perception (Ludy and Kondolf 2012, McPherson and Saarinen 1977), with lowered perception of risk when infrastructure is trusted for protection.

Theoretical Premise for Understanding Risk Perception

An extensive understanding of risk perception has significantly contributed to risk management literature and risk communication strategies (Birkholz et al. 2014). To better understand the complexity of conceptualizing risk perception, rationalism (an individual's approach to weighing benefit vs. costs) and constructivism (individual perception influenced by socio-political factors) approaches have been used to interpret evidence and develop further theories (Rana et al. 2020). In social science studies, risk perception has largely been explained by the integration of these two approaches through the psychometric paradigm (rationalism) and cultural theory (constructivism). According to the psychometric paradigm, an individual's perception of risk varies based on a combination of perceived risk characteristics and behaviors, referred to as the affect heuristic (Paek and Hove 2017). Cultural theory argues that perceptions of nature are socially constructed (Bellamy and Hulme 2011) and can subsequently be used to further explain how relationships in social-ecological systems can be categorized in a way to understand risk perception. For the purposes of my research, the combination of the psychometric paradigm and cultural theory is well suited to understanding flood risk perception in ten different locations of Kansas, with varying spatial and demographic characteristics.

Psychometric Paradigm

The psychometric paradigm is a rationalism approach that considers an individual's mental construct for evaluating risk perception by contrasting acceptable risk and benefit tradeoffs (Rana et al. 2020). In this approach, risk is inherently subjective, defined by individuals who may be influenced by a multitude of factors (psychological, social, institutional, and cultural) (Slovic 1990). The psychometric paradigm can be generalized into two main assumptions, 1) that perceived risk can be measured and predicted, and 2) that individuals and groups define risk differently, particularly between experts and laypeople (Slovic 1986). The cognitive variables that affect risk perception are measured using nine factors to gauge subjective risk judgement: voluntariness, immediate effect, knowledge of risk by those exposed and by experts, controllability, familiarity, catastrophic potential, dread, and likelihood of fatality. The psychometric paradigm allows researchers to compare risk characteristics that oppose each other with various hazards (Table 2.3) as a way to understand how an individual weighs the trade-off between perceived risk and perceived benefit (Raaijmakers et al. 2007).

Table 2.3. Psychometric Paradigm - Comparison of Risks (Adapted from Slovic 1986 and Raaijmakers et al. 2007)

Risk Perception Factor	**Less threatening vs More threatening**
Voluntariness	Voluntary (freedom of choice) vs Involuntary
Immediate Effect	Delayed vs Immediate
Knowledge (Awareness)	Known to Science vs Not known to Science
Controllability (Preparedness)	Controllable vs Uncontrollable
Familiarity	Old vs New
Catastrophic Potential	Chronic vs Catastrophic
Dread (Worry)	Known exposure vs Unknown exposure
Likelihood of Fatality	Not fatal vs Fatal

In risk-focused psychometric paradigm work, emotions such as dread, involuntariness, and controllability are considered essential in rationalizing riskiness (Slovic, Fischhoff, and Lichtenstein 2000). Psychometric methods, such as the measurement of an individual’s cognitive, behavioral, and personality constructs, have also been used to explore underlying social dimensions such as trust, blame, and accountability (Marris, Langford, and O’Riordan

1998). In terms of annual fatalities from a given cause or risk, experts tend to respond based on technical estimates, whereas laypeople's additional concerns over controllability, future threats, and catastrophic potential contribute to their sometimes very different annual fatality estimates (Slovic 2000). Due to the social context of risk perception, it is without doubt, that some issues tend to become politicized, resulting in the allocation of blame and the distribution of power (Tansey and O'Riordan 1999).

Cultural Theory

Cultural theory, as described by Mary Douglas (1978), is used to understand how risk is perceived through personal experience, cultural biases, and social relations. Social relationships may look different today than 20 years ago, but they still share the same characteristics where a group is defined by shared expectations and values of each other, otherwise referred to as cultural bias. A combination of social relations, and cultural bias was used to define a 'way of life' to explain why individuals and groups perceive risk differently (Thompson et al. 1990). To visualize the concept of cultural theory, Douglas (1978) classified cultural bias into a two-dimensional graph with a horizontal and vertical axis using "grid" and "group" characteristics. Ideally, individuals could be categorized into generalized groups based on their similar characteristics. On the horizontal axis, group characteristics range from one extreme, individual choice, to the other, collective or group preference. On the vertical axis, grid characteristics indicate whether an individual's life will be circumscribed by outside social influences or not. Based on this understanding, four broad groups emerged based on an individual's attitudes and actions (Douglas and Wildavsky 1982): individualistic, egalitarian, hierarchical, and fatalistic. In some research, a fifth way of life is presented at the intersection of the horizontal and vertical axes to represent individuals who were removed from societal influences, referring to this way of life as autonomic.

Myths of Nature

Cultural theorists adapted the four primary worldviews to include perceptions of the environment known as ‘myths of nature.’ Each myth represents a different way of viewing the natural world in congruency with an individual’s primary way of life: nature perverse/tolerant (hierarchy), nature benign (individualistic), nature ephemeral (egalitarian), or nature capricious (fatalistic) (Holling 1986, Thompson et al. 1990; Bellamy and Hulme 2011). These idealized categories are used to understand how societies (and individuals) evaluate and respond to environmental risks. Identified social type groups (fatalist, hierarchist, individual, and egalitarian) are further defined by how individuals make decisions based on their environmental views and perceptions of risk (Figure 2.1).

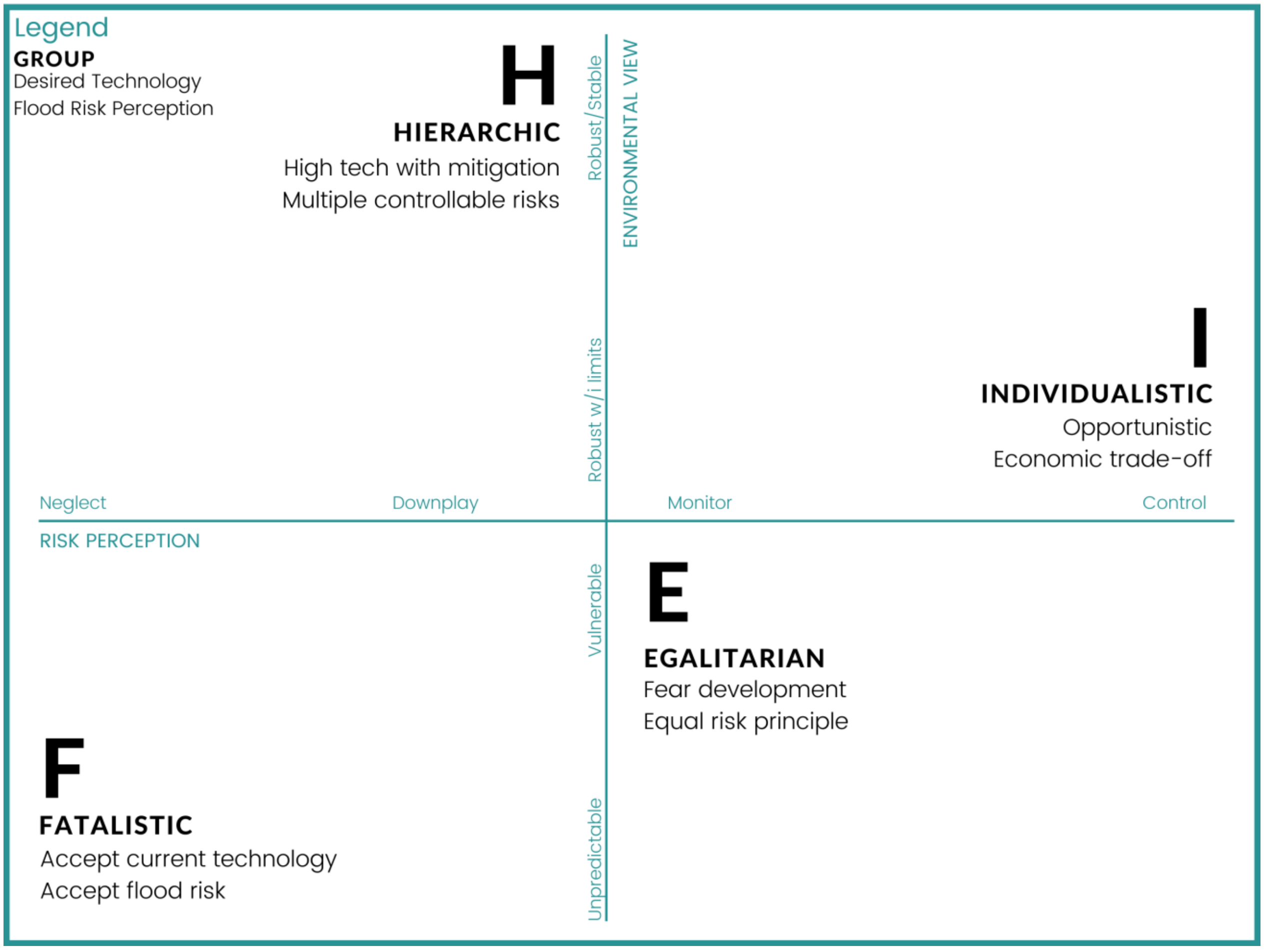


Figure 2.1. Flood Risk Perception using Cultural Theory worldview (adapted From Douglas 1970; Hoekstra 1998, Ridolfi et al. 2019, and Thompson et al. 1990).

Hierarchists, who are characterized as focused on strong social structure, are more likely to agree with experts who deem environmental risk as acceptable (Bellamy and Hulme 2011). Hierarchists often view nature as unstable with scarce resources, which need to be regulated and controlled in order to meet the needs of humans (Steg and Sievers 2000). People that are more self-focused are considered individualistic. This group perceives risk as an opportunity for private benefit and are therefore less likely to be concerned with anthropogenic influences on the environment. From a “nature benign” view, nature is seen to be at a stable equilibrium with an abundance of resources (Steg and Sievers 2000).

Unlike rule-abiding hierarchists, egalitarians are less likely to follow rules or follow leadership because of their strong views on equality or an increase in inequalities among the community. Egalitarianism, as defined by Merriam-Webster (2021), is a belief in human equality and advocacy for the removal of social, political, and economic inequalities among people. Skeptical of institutions and authorities misusing their authority, egalitarians support social equality and more closely follow the principles of left-wing politics (Oltedal et al. 2004). An egalitarianist outlook may find difficulty where fairness is often unbalanced. Egalitarians view nature as fragile/vulnerable to human intervention and will oppose risks from pollution and new technologies that might change the state of nature by inflicting irreversible danger to society or for future generations (Oltedal et al. 2004). Risk is often seen as an imminent catastrophe (Bellamy and Hulme 2011).

Fatalistic individuals are opposite to egalitarianists, viewing risk as unpredictable and as a matter of fate; where humans are untrustworthy, and there is no need to manage outcomes because everything is a function of change (Bellamy and Hulme 2011). Fatalists are considered nature capricious, tending to manage environmental risks through coping and little concern for the future. They hold firm to the belief that what you do not know cannot hurt you (Steg and Sievers 2000). The value systems as expressed through cultural theory contribute to a greater understanding of how individuals perceive risk, respond to risk, and essentially how risk management strategies will be developed and put into action (Ridolfi et al. 2019).

Flood Risk Perspective through Cultural Theory

Using cultural theory's "myths of nature" concept, socio-hydrologists have been able to explore how hydrological extremes affect societal responses from a flood-risk perspective.

Societies have learned to adapt to hydrological events through the use of soft- and hard-adaptation measures (Ridolfi et al. 2019). Soft-adaptation measures include community education, early warning systems, and changes in land use planning (Ridolfi et al. 2019). An egalitarian culture is a risk-monitoring society and tends to respond to risk with a community-based approach that involves bottom-up strategies to adopt soft measures resulting in greater awareness and preparedness for the entire society (Ridolfi et al. 2019).

Control measures like levees and dams are considered hard-adaptive measures. Hard measures are designed to reduce hydrological risk, in terms of frequency and magnitude of hydrological events (Di Baldassarre et al. 2017). Hard-adaptive measures are well accepted by hierarchists who support the top-down approach to environmental risk management. However, as time passes, the implementation of hard adaptive measures affects awareness. White (1945) referred to this as the levee effect: a lack of awareness develops over time as hard-adaptive measures prevent memorable flood events (Ridolfi et al. 2019). Fatalists and individualists are less likely to adopt either measure. In terms of preparedness, the former does nothing -- based on the rationality that managing risk is impossible -- while the latter does not see the need for collective action (Ridolfi et al. 2019).

Researchers continue to call for the re-invigoration of flood risk perception research, to understand how risk perception influences vulnerability, capacity, and resiliency of hydrological events (Birkholz et al. 2014). The quantitative and rationalist approach of the psychometric paradigm focuses on individual assessments of risk while the constructivist approach of cultural theory argues that risk perception is socially constructed and produced throughout organizations and individuals (Birkholz et al. 2014). However, it is the integration of both constructivist and rationalist approaches, such as the psychometric paradigm and cultural theory of risk, that are fundamental in broadening and enriching the field of risk perception.

Social-Ecological Systems (SES) Framework

A social-ecological systems framework is used in conjunction with cultural theory and the psychometric paradigm to contribute to the understanding of human-environment interactions with ecosystem services. An SES is composed of highly complex and integrated ecological and social systems, including economic portions of social systems. An inherent key link between human needs and ecosystem functions is water, which has largely been controlled by the construction of dams in the United States (Hammersley et al. 2018). Dams and resulting reservoirs create a system where they are influenced and affected by ecological, social, and economic processes (Figure 2.1). The resulting infrastructure puts water to work: generating power, enhancing navigation, expanding irrigation, and controlling floods (Trebitz and Wulfhorst 2020). The aesthetic appeal of waterfront property drives up property value and the addition of a major water source supports the local economy, particularly in rural areas that depend on irrigation, household, and other stored water uses, and that may gain revenue from water-based recreation activities at the dam and associated water bodies.

Land use changes threaten the balance of a social-ecological system, where communities are directly exposed to the negative consequences of those land use changes (Withanachchi et al. 2018), such as soil degradation and erosion. Other environmental impacts include disrupting biodiversity within the riparian system, shifting the landscape, increased sedimentation in the stream bed, and altering the flow of the river. Over time, dams become less stable; their aging infrastructure deteriorates, reservoir sedimentation increases, and outdated technology becomes more costly to repair. As dams reach their life expectancy, the system becomes more vulnerable to other disturbances such as climate change and increased demand on water supply (Hammersley et al. 2018). Governance networks, including watershed district members, federal, state, and other water resource stakeholders must work together to find common goals and strategies for identifying and implementing social measures related to the function and use of dams in their areas (Trebitz and Wulfhorst 2020).

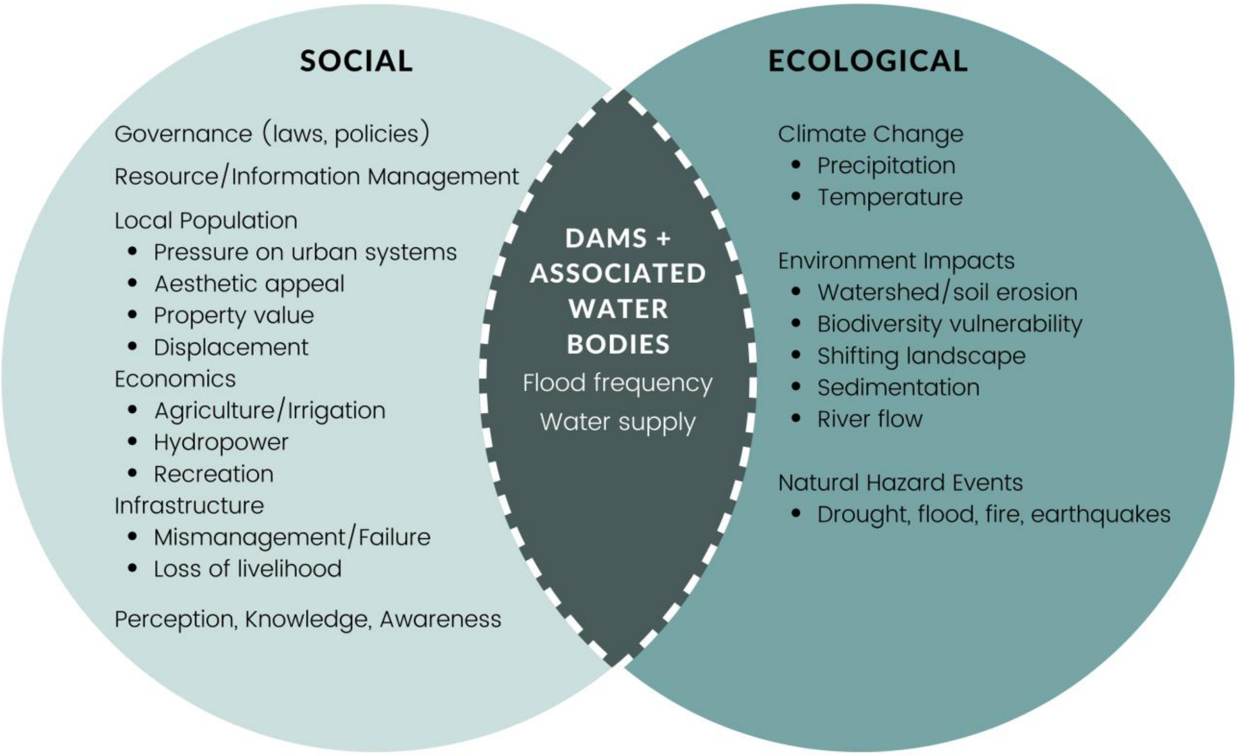


Figure 2.2. Social-ecological system components of dams and associated water bodies.

Uncertainty

Due to the multiple public and private actors that have influence in the decision-making process, there is a need to understand uncertainties when developing, implementing, mobilizing, and evaluating changing policies (Dewulf and Biesbroek 2018). The interaction of multiple sources of uncertainty adds to the complexity of policy making where multiple risks are realized at once (Koppenjan and Klijn 2004, Jensen and Wu 2016). Distinctions in uncertainty are critical for decision makers to assess different challenges, such as the phenomena of interest, scale, and strategy (Jensen and Wu 2016) when it comes to policy making. Uncertainties can be distinguished as: 1) *epistemic*, uncertainty as a result of imperfect knowledge of a system; 2) *ontological*, uncertainty in the variability and unpredictability of the system; or 3) *ambiguous,* where decision makers may not have a complete understanding of the multiple stakeholders invested in the policy process (Dewulf and Biesbroek 2018, Jensen and Wu 2016).

Where epistemic uncertainties benefit from technological innovations and further research, little can be done to regulate the inherent variability of ontological uncertainties. Ambiguity is most likely to be reduced by methods that support joint decision making. To further classify uncertainty with a broad range of social and behavioral uncertainties, researchers Jensen and Wu (2016) include *objects of uncertainty*, as proposed by Koppenjan and Klijn's work on governance processes (2004), as part of their three-by-three matrix to build a more comprehensive framework for understanding and addressing uncertainties in decision making. The objects of uncertainty include: *substantive*, the substance, content or knowledge of environmental issues, *strategic*, choices made by actors involved in the governance process, and *institutional* uncertainties, the formal and informal rules of the game that apply in environmental governance.

Uncertainties in Flood Risk

There have been significant technical advancements in climatic and physical data collection and modeling to understand flood risk, with little attention being made to understand human and behavioral uncertainty (Wasson 2016). Long term flood forecasting is inadequate when predicting and helping societies prepare for future events, particularly low-probability, high impact events such as dam failure, leaving societies at risk (Jensen and Wu 2016). Without also taking into consideration social, economic, and political sources of uncertainties, policy makers will have a limited understanding of vulnerability in relation to flood management (Wasson 2016). Without the proper resources, individuals who perceive a greater risk may not be in the position to make significant changes, such as relocating their family, home, or job.

Table 2.4. Nine types of uncertainty in flood risk near dams (adapted from Dewulf and Biesbroek 2018).

Object of Uncertainty	Epistemic (Lack of Knowledge)	Ontological (Unpredictability)	Ambiguity (Different Frames)
Substantive (Substance of the issue)	Where are undocumented flood zones downstream of dams? Are people aware or concerned?	How extreme will flooding/rainfall events be?	Is this a climate change, population increase, or water supply/demand problem?
Strategic (Interactions of actors)	Who is responsible for dam maintenance, or dam failure alerts?	(Unpredictability of actors)	Is dam failure a genuine concern?
Institutional (Rules of the game)	What are the requirements for dam maintenance?	How will climate change, dam aging process affect flood risk?	Is there a public threat vs. private property rights?

Flood Risk Management and Communication

Risk management is the implementation of risk reduction measures through mitigation and preparedness to minimize destruction from disasters (Paul 2011). The essential processes to risk management include 1) identifying the exposure, 2) identifying options that will reduce potential losses, 3) evaluating the efficacy of available options for reducing hazard losses, and 4) choosing and implementing the best options for a particular area (Paul 2011). The USACE defines flood risk management as the reduction of the flood risk through resiliency structures and other approaches to reduce the risk of loss of life, long term economic damages to public and private sectors, and to improve the natural environment (USACE 2021).

Variations in the physical area, population, and potential damage to property in the event of a hazard are important for determining the level of severity and type of physical and/or financial exposure an area might experience. Physical exposure refers to areas that would be at risk given the magnitude of a natural hazard where financial exposure refers to the economic damage an area would experience because of damage to property, infrastructure, or income loss (Paul 2011). Technological developments have been instrumental in improving risk management in support of preparedness and mitigation measures, through applications such as remote sensing, global positioning systems (GPS) and geographical information systems (GIS) (Smith 2013).

Ideally, risk management should address the highest levels or risk, based on detailed risk assessment including the ‘relative significance of losses from high and low frequency events’ (Smith 2013). Criticisms of risk management are often based on the lack of comprehensive conception using multidisciplinary approaches, lack of unity between science and political decisions (Cardona 2004), avoidance, and/or denial (Seebauer and Babcicky 2017). Risk management should be a complex process that includes the cooperation of risk managers, all levels of government, and the community to incorporate economic, social, political, technical, and perceptual factors as a way to decrease potential losses as a result of disasters (Paul 2011).

Risk Communication

As long as there is socioeconomic, geographic, and psychological diversity, the importance of risk communication is essential. Risk communication is based on the assumption that uninformed people will make decisions that impact them negatively based on consequences they were unaware of (Mileti 1999). The lack of consideration of risk communication between experts and the general public has created a disparity between the potential severity of ineffective dams and their impact on downstream populations. Hazard responses are often unique to a community, where message acceptance and protective action may differ from location to location based on existing habits, social expectations, and the role of decision making by local organizations and government officials (Mileti 1999).

Bridging the gap between risk analysis and risk perception allows decision makers and individuals and freedom to responsibly choose the best method in addressing vulnerability, risk and adaptive capacity at the local level. While dam programs recognize the importance of relationships with the public as ways to improve community resilience (National Research Council 2012), there is still a significant gap in the risk communication between policy makers and the general public. In an Austrian study on the trust and communication in flood-prone households, researchers found that citizens responded differently when receiving flood risk information from local governments, volunteer relief services, and their neighbors. Flood risk communication has typically been handled by local governments, which have created narratives that rely heavily on public flood protection.

Current resistance for additional funding and personnel to properly maintain flood protection infrastructure and measures, at all scales, can leave some communities with insufficient protection (Seebauer and Bibcicky 2017). Seebauer and Bibcicky (2017) found that older volunteers were among the most trusted of the information sources studied and perceived as the most competent. Developing these types of relationships are crucial to providing awareness as a means of avoiding major disasters. Hu and Morton (2011) state that understanding the general knowledge of a population’s awareness and beliefs about water aids in decision making through the use of local knowledge and experience.

Summary

Individuals are able to assess their own risk based on experience and their ability to react, adapt, or overcome a potential high-risk event. However, research has shown that individuals are often influenced by social, political, cultural, and economic factors when making decisions about responding to natural hazards in their community. The development of infrastructure to protect individuals from natural hazards has created a sense of security, although specific structures will soon meet the end of their designed life expectancies and physical environmental conditions may also be changing in ways that can reduce effectiveness of existing infrastructure. As people are removed both spatially and temporally from a high-risk event, the literature suggests that individuals become less concerned about the need to prepare for a potential hazard or disaster. People who live further from a dam are less likely to be concerned with the dam failing, while people who live closer to the dam are more likely to have an increased risk perception of the potential for a dam failure. Temporally, this means that the longer an individual or group goes without experiencing a high-risk event, the less likely they are to make preparedness efforts to protect themselves against a future high-risk event.

Yet, climate change, urban development, and the structural demands placed on Kansas dams are contributing to a critical situation that will soon face a number of Kansas residents who reside near aging dams. Current approaches to risk management and communication are rooted in cost/benefit scenarios, with little attention being focused on the views and perceptions of residents who are facing potential and dam failures and their associated risks. Using an SES framework to examine flood risk perception, and risk communication in conjunction with GIS technology, decision makers and researchers have the opportunity to fill gaps in risk communication and advance their understanding of risk perception in regard to aging dams.

Chapter 3 describes the Kansas study region and procedures for selection of specific study locations. Characteristics of these areas are further described, leading to an explanation of research methods for exploration of flood risk perceptions in the following chapter.

Chapter 3 - Kansas, Risky Dams, and Study Sites

Introduction

Due to the multi-faceted water resource management challenges in combination with the significant number of active dams in Kansas, this research is unique as an addition to the body of knowledge related to risk perception near aging dams. Unlike the major dam failure that displaced nearly 200,000 people in California, there are more are 6,000 dams in Kansas to provide flood control for hundreds of thousands downstream residents, over 45 million acres of farmland, and changing climatic conditions. Not only does Kansas have the second largest number of dams in the United States, the majority of dams, like most of the United States, were constructed during the same time period. As a result, most Kansas dams will be in danger of potential failures occurring somewhat simultaneously. This exploration of residents' views of the potential for dam failures and perceptions of associated risks in Kansas focuses on rural, at-risk populations that live downstream of medium-sized dams, which are often neglected and can contribute to a lack of understanding by some residents.

Kansas has a history of climate variability, with multi-year droughts and extreme flooding, which has presented water resource management challenges. Understanding the effects of precipitation and flooding in Kansas is essential to understanding water management. The characteristics of the state's physical geographic landscape create variations in which dams are engineered and used across the state. This chapter begins with a review of background information about the state of Kansas, focusing on relevant climatic and social conditions. Climate, particularly precipitation patterns with respect to amounts, seasonality, and intensity, is especially important to the status of streams, impoundments, and dams/dam stability. Following the general background material, dam history and conditions are described. Next, identification of the riskiest intermediate-sized dams of eastern Kansas is described, in order to address Research Question 1. Lastly, the specific study sites and their selection are explained.

Social Conditions

As part of coupled human-natural systems, water resources are impacted by climate change, land use/land cover, and human activities, such as water management, irrigation, conservation, usage, and water pollution (Yin et al. 2021). Understanding the role of humans in water systems is necessary in order to address water resource problems (Sanderson et al. 2017).

Kansas has over 81,000 square miles of land area (Census QuickFacts) that are annually influenced by severe storms, high winds, and flooding. A community's ability to respond to hazardous events is determined by factors such as socioeconomic status, age, race, gender, disabilities, linguistics barriers, and special needs. These factors are indicators of social vulnerability, or the potential of loss for a particular group or individual in the face of disruption (particularly a hazard event). Social vulnerability can be measured to graphically illustrate where an uneven capacity for preparedness and response to environmental hazards exists at the county or tract level using the Social Vulnerability Index (SoVI) (Cutter et al. 2003).

Location and Hazard Attention

The focus on natural disasters/hazards and their association with risk perception has largely been centered on urban or densely populated areas in cities and along coastal areas, in part because of the perception that highly populated areas have an increased risk of a disaster event, or at least an increased risk of significant losses. Coastal areas receive a great deal of attention as they are affected by the changing frequency and magnitude of hazards, such as tropical storms, which threaten more than 29 percent (approximately 87 million people) of the U.S. population (US Census 2021). Extensive resources to create Risk Mapping, Assessment and Planning (Risk Map), Flood Insurance Studies, and Flood Insurance Rate maps have been updated and made digitally available for densely populated areas in coastal regions of the United States (FEMA 2021). However, the rural and agriculture regions of the Great Plains continue to experience persistent losses from seasonal flooding and severe weather, affecting long term resilience and future sustainability (Cutter et al. 2016). Updated and digitized flood maps are still missing or unavailable for large portions of the rural, central part of the United States (Figure 3.1). In Kansas, only 54 out of 105 counties have effective Digital Flood Insurance Rate Maps (DFIRMs) as of July 5, 2023 (KDA Floodplain Viewer 2023).

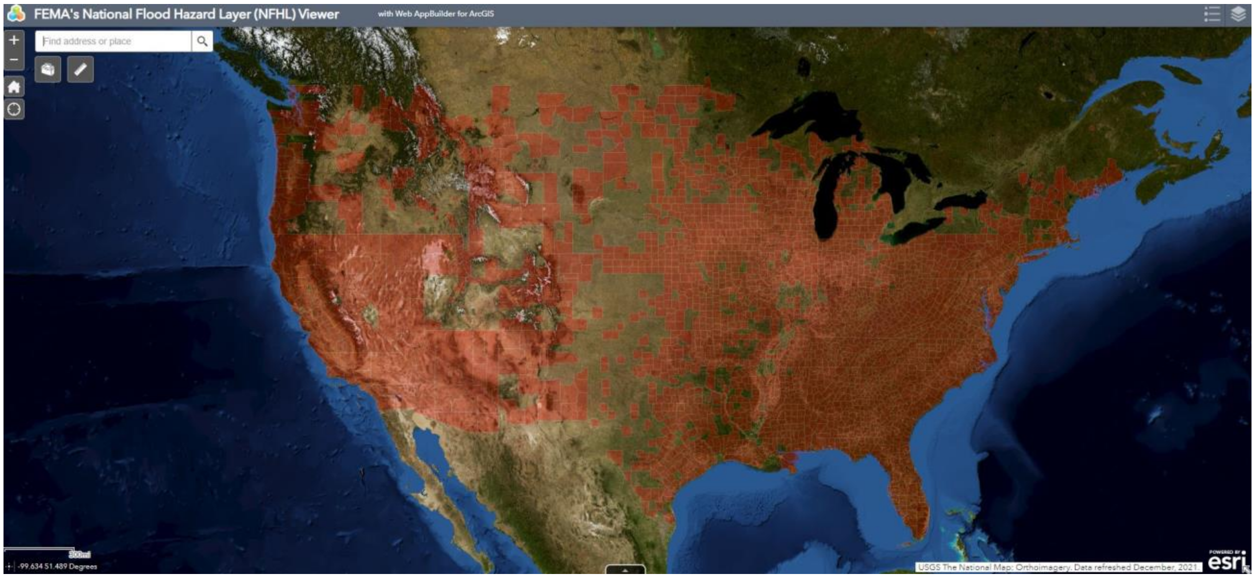


Figure 3.1. FEMA's National Flood Hazard Layer (NFHL) Viewer.

Rural areas are less likely to receive the same amount of attention as urban locations and have different challenges than urban areas after a natural hazard or disaster event (Cutter et al. 2016). Often seen as inherently resilient and self-sufficient, rural areas are expected to rebuild after a natural disaster by themselves, leading to federally funded hazard mitigation being disproportionately focused on urban areas (Seong et al. 2022). Rural areas that struggle to maintain government and business operations also struggle to maintain the management and business operations of their dams and reservoirs. In many cases, watershed districts and dam managers are volunteer based with aging board members that admittedly are concerned about the younger generation taking over.

As climate change is expected to impact extreme weather events, natural hazards threaten people in both urban and rural areas but in different ways. Climate change will affect rural livelihoods and incomes that are dependent on natural resources and heavily reliant on infrastructure (dams, roads, irrigation systems, etc.) to a greater extent than direct effects on metropolitan livelihoods (IPCC 2014). The most common feature of rural counties in the Great Plains is their economic dependence on agriculture (Ojima et al. 2012). Rural populations associated with the agriculture sector are particularly vulnerable to weather and climate extremes that can affect crops, soil, livestock, and the infrastructure that supports agricultural output (Ribeiro et al. 2020).

The United States Department of Agriculture's Economic Research Service (USDA ERS) developed a multi-level classification scheme to distinguish metropolitan and nonmetropolitan counties by their degree of urbanization and adjacency to a metro area, referred to as the Rural-Urban Continuum Codes (RUCC) (Table 3.1). The RUCC has been updated every decade since its development in 1974 to aid researchers investigating trends in nonmetro areas affected by population density and nearby metro influence (USDA ERS 2020). Flooding due to the failure of a single dam has the potential to influence upstream and downstream residents at different scales, contributing to their understandings and personal perceptions of flood risk in their area.

Table 3.1. USDA ERS 2013 Rural-Urban Codes.

Code	Description
Metro counties	
1	Counties in metro areas of 1 million population or more
2	Counties in metro areas of 250,000 to 1 million population
3	Counties in metro areas of fewer than 250,000 population
Non-metro counties:	
4	Urban population of 20,000 or more, adjacent to a metro area
5	Urban population of 20,000 or more, not adjacent to a metro area
6	Urban population of 2,500 to 19,999, adjacent to a metro area
7	Urban population of 2,500 to 19,999, not adjacent to a metro area
8	Completely rural or less than 2,500 urban population, adjacent to a metro area
9	Completely rural or less than 2,500 urban population, not adjacent to a metro area

Compared to their urban counterparts, rural areas may have a lack of human and financial resources (Tootle 2007) to maintain and/or respond to hazardous impacts. Access to public services and emergency response systems decline and become less effective as populations get smaller and further removed from metro areas (Ojima et al. 2012). This concern is exacerbated during disasters and natural hazard events. Rural areas are typically lower income and are likely dependent on locally based resources (Cutter et al 2003). Social capital plays an important role in rural areas particularly in regions that may experience potentially devasting impacts for an agricultural-based economy and the local population. Risk perception may be a contributing factor for adequate (or inadequate) preparedness in rural areas.

Hydrologic effects of dams

By comparing dams' storage capacity to their watershed sizes, the potential change and magnitude of river flow and potential for ecological disruption can be determined (Graf 1999). The most significant effects are related to annual maximum and minimum flows (Graf 2006). With a reduction of maximum flows, the beneficial effects of flooding are removed, and ecological processes are greatly reduced (Gregory et al. 2002). Flowing water, riparian and floodplain habitats, and lotic organisms are lost to standing water and lacustrine habitats, and lentic organisms after a reservoir is filled with deep water having low flow velocity (Juracek et al. 2015). The reservoir storage created by the installation of dams can serve as an indicator of the hydrologic impact on stream flow and downstream effects, while considering other changes due to evaporation or seepage losses (Graf 1999). Connectivity between upstream and downstream reaches are lost after a dam has been completed, removing the physical integrity of the river system (Juracek et al. 2015). Downstream effects from reservoirs can be attributed to the change in surface flow (Graf 1999), which will vary based on the purpose of dam (Juracek et al. 2015).

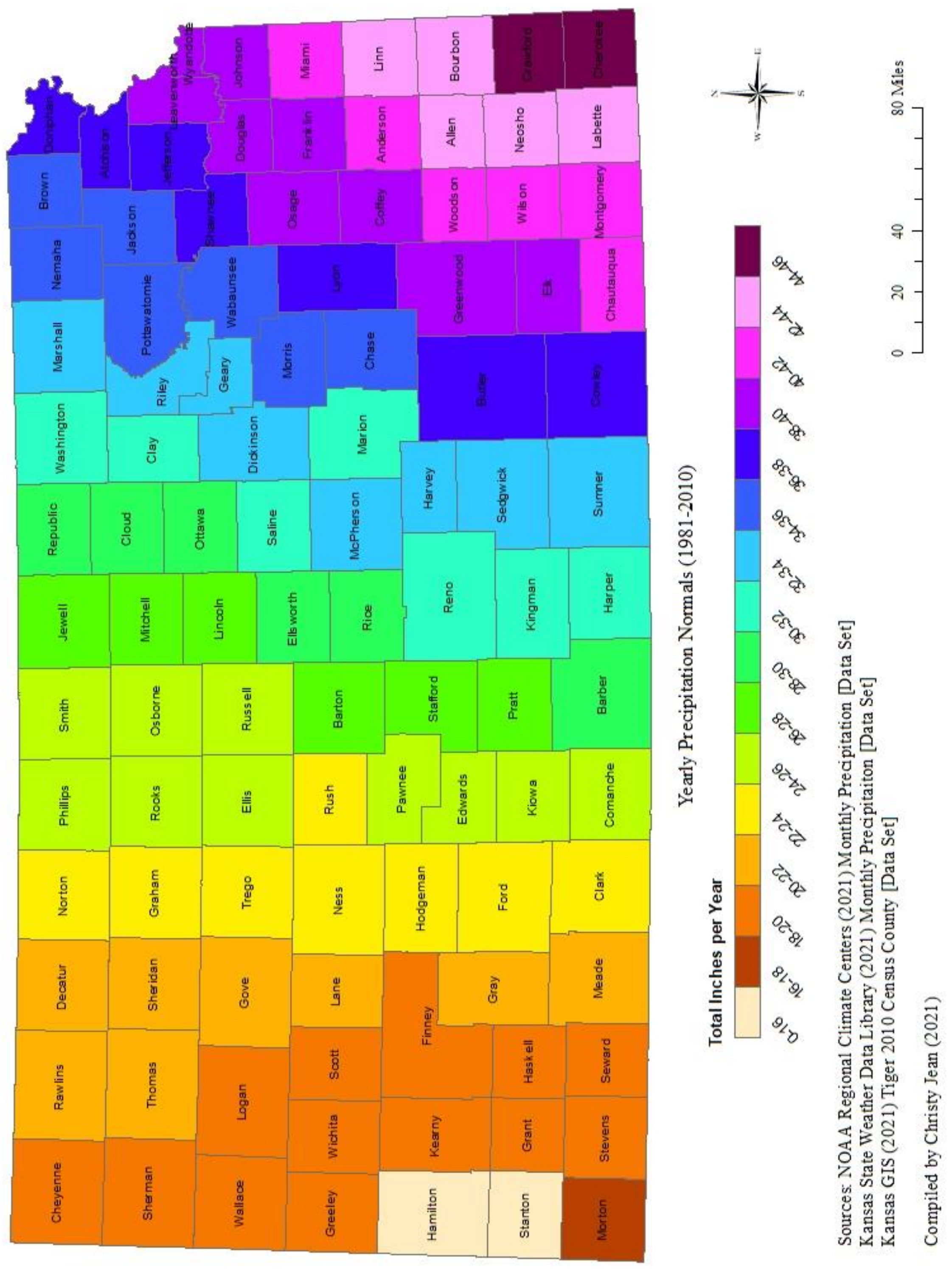
One measure used to indicate downstream hydrology effects is the dam's storage capacity compared to the annual water yield upstream of (capacity/yield ratio) (Graf 2006). Large amounts of storage typically reduce annual maximum flows, while low amounts of storage have less control over changes in downstream flow (Graf 2006). Peak flows are also a major concern as this contributes to runoff experienced during intense rain events. In a US Geological Survey analysis conducted by Rasmussen and Perry (2001), peak flows were evaluated on selected streams in Kansas. The results of the trend analysis found that 43 percent of streams showed a change in their peak flow over the entire available period of record (with a record length of more than 38 years), with 30 percent decreasing trends and 13 percent increasing trends. In most cases, decreasing trends in peak flow are attributed to ground water withdrawals and the construction of water retaining structures, such as dams, ponds, and terraces (Rasmussen and Perry 2001).

An analysis of the hydrologic and geomorphic changes on the Kansas River between 1985 and 2009 was conducted by the Army Corps of Engineers to determine changes in flow volume, flow duration, hydrologic impacts from federal reservoir, stage-discharge relationships, sedimentation levels, changes in the width of the channel, and the correlation between morphological changes and dredging activities (USACE 2010). The report listed an increase in total volume of flow with little to no change in the average annual flow but indicated that floods and low flows are less severe than they were prior to the dam building era. It also found that stage-discharge relationships have dropped in three out of five locations along the river. To gage information about the flow of any given river or stream over a period of time and through a multitude of stages, the USGS measures physical discharge moments to create a rating curve.

The rating curve provides a graphic representation of the relationship between stage (low flow to flood stage) and streamflow (measured in cubic feet per second). "A rating curve often changes after a flood when the physical force of high-water movement can change the dimension of the streambed or stream channel" (USGS 2011). A drop in the state-discharge measurements (or rating curves) generally occurs in response to major flood events when the channel has widened and the water level in the channel has dropped (USACE 2010). The report also found that degradation has occurred throughout the river, especially following floods, and most reaches along the river have experienced narrowing as a result of the 1993 flood (USACE 2010).

Mid-Continent Climate Variability and Change

While dams affect hydrological conditions, weather and climatic conditions also affect hydrology and the functioning of dams. Annual changes in atmospheric Hadley circulation (north-south circulation of warm, moist air) and mid-latitude westerlies (west to east winds) produce strong seasonal differences that affect midcontinent weather and climate conditions. The magnitude and frequency of severe weather events, such as blizzards, thunderstorms, tornadoes, dust storms, heat, and rain in the midcontinent are a result of the shifting patterns in the Earth’s atmospheric circulation system (Harrington and Harman 1991). Parts of the northeastern and midwestern US are experiencing more intense and frequent heavy precipitation – key factors that affect the risk of floods and flash floods (USGCRP 2018). The land-locked location of Kansas and its spatial relationship to moisture flow from the Gulf of Mexico causes significant variation in the annual precipitation gradients across the state. Northward advection of moisture originating in the Gulf of Mexico, generally extending westward to around 100°W longitude (the 100th meridian), and the occasional remnants of hurricanes from the Gulf contribute to the numerous floods that affect central and eastern Kansas (Clement, Bark, and Stiles 1991). Moist air riding northward on the low-level jet makes its greatest impact between May and July, when Kansas receives the bulk of its precipitation (Howard and Harrington 2012). An average annual precipitation of 0-16 inches in the most western part of the state to 44-46 inches along the eastern border exhibits a strong west to east gradient (Figure 3.2).



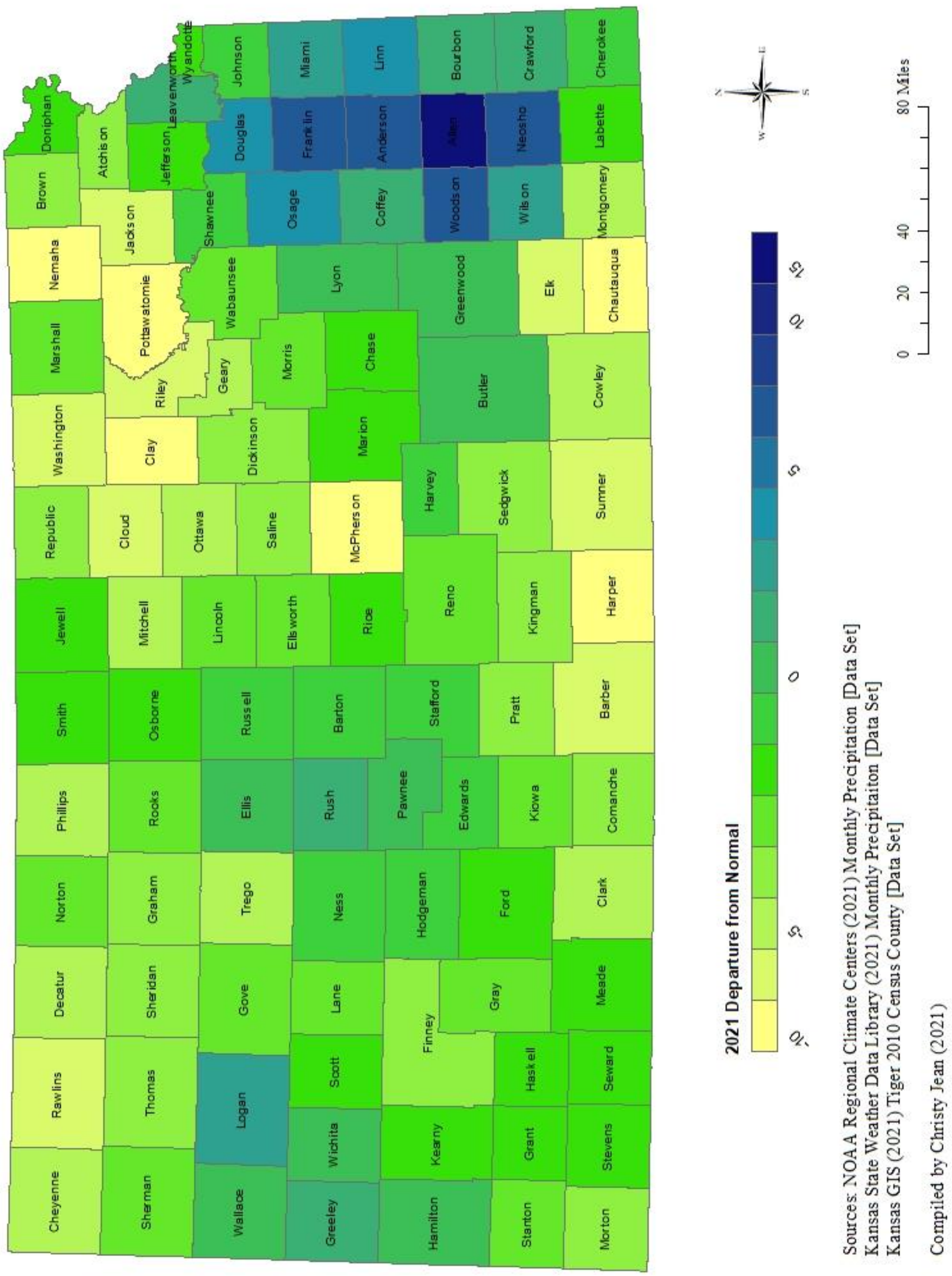
Sources: NOAA Regional Climate Centers (2021) Monthly Precipitation [Data Set]
Kansas State Weather Data Library (2021) Monthly Precipitaiton [Data Set]
Kansas GIS (2021) Tiger 2010 Census County [Data Set]

Compiled by Christy Jean (2021)

Figure 3.2. Average Annual Precipitation in Kansas, 1991-2020.

Moisture-carrying winds from the Pacific Ocean are generally depleted after crossing the western third of the country and multiple mountain ranges, leaving western Kansas noticeably drier, with significantly smaller and fewer extreme rainfall events compared to the east (Rahmani et al. 2016), where more moisture from the Gulf of Mexico arrives with advection northward. The moisture from the Gulf of Mexico (mT, or maritime tropical, air) is responsible for the majority of the state's precipitation, particularly in the south and east. As a result of advected moisture and relatively high humidity, this region of Kansas experiences frequent and heavier rainfall (Goodin et al. 1995). This is due in part to frontal uplift and summertime heating and convection. In fact, flood-producing rains are the cause of at least one Kansas stream to experience severe flooding during an average year (Clement, Bark, and Stiles 1991).

Based on recent trends, Kansas is likely to experience the wet season earlier in the year, with more frequent and more intense 24-hour rainfall totals in the near future (Rahmani et al. 2016). Even in the past, most parts of the state have experienced a downpour of 5 inches or more, generally in September, July, and/or June (Flora 1948). An analysis of precipitation seasonality by Dye, Howard, and Harrington (2018) suggests that Kansas is experiencing a transitional period where extreme daily precipitation amounts continue to trend upward across the state, with the greatest increases occurring in eastern Kansas. This study also found considerable increases in precipitation during the spring months in both the percentage of annual precipitation and total amount of precipitation. Since 1895, the percentage of annual precipitation received in spring and the total amount of precipitation have increased substantially, particularly in the eastern half of the state (Dye, Howard, and Harrington 2018). For example, data collected from the NOAA Regional Climate Center and Kansas Weather Data library from 2021 indicate increased precipitation totals, most notably in the eastern half of the state, when compared to a recent 30-year average 1991-2020) (Figure 3.3).



Sources: NOAA Regional Climate Centers (2021) Monthly Precipitation [Data Set]
Kansas State Weather Data Library (2021) Monthly Precipitaiton [Data Set]
Kansas GIS (2021) Tiger 2010 Census County [Data Set]

Compiled by Christy Jean (2021)

Figure 3.3. 2021 Departure from Average Annual Precipitation in Kansas.

In addition to more excessive spring precipitation, Kansas experiences sweltering heat; long periods of drought; and hot, dry, and windy events (HDWs). A HDW event−the combination of high temperature, moderate high wind spends, and low relative humidity−can increase evapotranspiration, burn vegetation by heat or condition-related fire, and influence the onset of drought (Tavakol et al. 2020). When two more or more extreme events, for example HDWs and long periods of drought, occur simultaneously or successively, this is called a compound event. As temperature levels change, the probability or severity of compound events is more likely (Tavakol et al. 2020). Significant events like the Dust Bowl during the 1930s and centuries-past droughts (Woodhouse and Overpeck 1998; Cook, Ault, and Smerdon 2015; Carter, Shinker, and Preece 2018) are examples of the potential magnitude of extreme droughts and their effects. The longest recorded drought in recent history occurred in the 1950s and more recently severe droughts impacted large portions of the Great Plains in the early 2000s. Effects from the La Niña phase of the El Niño Southern Oscillation (ENSO) conditions in the Pacific Ocean, as well as the Pacific Decadal Oscillation and the Atlantic Multi-Decadal Oscillation, have been strongly associated with the natural variability that causes drought in much of the United States (Ojima et al. 2012).

The major impacts of drought directly affect the performance of dams and reservoirs. Temperature, precipitation, and potential evapotranspiration (PET) determine plant growth/cover and surface stability of the region (Ojima et al. 2012). Vegetation plays a natural role in slowing water flow over the surface, increasing infiltration, and serving as a source for soil water storage. As vegetation dies during a drought, there is a decrease in infiltration and an increase in the amount and speed of surface runoff. The threat of bigger and more intense rainstorms could prove disastrous if immediately following a drought. Erosion, surface runoff, and flooding may have a direct effect on the structural integrity and how well aging dams can meet their design purposes.

Increased precipitation and shifting rainfall patterns are likely to affect the performance of dams and reservoirs, leading to overtopping, excess weight, damaged spillways, and significant erosion. During a heavy rainfall, increased stream flows result in higher reservoir levels, which may cause water to go over the dam itself, referred to as “overtopping.” Overtopping is particularly dangerous for earthen and concrete dams, that are not designed to withstand uncontrolled flows on their downstream slopes. Significant erosion due to overtopping is a result of the increased water velocity cutting away into earthen embankment or eroding the foundation material of the concrete dam. The weight of the water from increased reservoir levels also puts additional weight and pressure on the dam causing structural and hydraulic stresses which may lead to the instability of the dam. Gates or spillways designed to divert routine rainfall events may experience extensive damage, failure or may be incapable of safely storing or moving excess water. When the reservoir storage exceeds capacity, the overflow of water can cause erosion below the spillway, threatening the structural integrity (White et al. 2019). Heavy rainfall on saturated soils results in excessive ruff-off which can lead to damaged spillways and complicated reservoir operations as dam managers try to adjust for effective reservoir releases without causing additional damage to the dam or increasing risk to downstream residents (White et al. 2019).

Dams in Kansas

As seen from a bird's eye view, dams and impoundments stipple the Kansas landscape (Figure 3.4), creating an image that depicts the result of over 100 years' worth of dam construction. According to the Kansas Department of Wildlife, Parks and Tourism (KDWPT) (2017), there are over 10,000 miles of streams and rivers that flow through Kansas, fragmented by 6,398 dams[3], the second largest number of dams in the United States behind the much larger state of Texas (FEMA 2015). Kansas watershed projects have been responsible for reducing floodwater damage, combined with a focus on protecting and enhancing the state's natural resources. As a natural resource, water is essential for maintaining and developing the economy, supporting growing populations, and contributing to the sustainability and diversity of lands used for agriculture, livestock, and wildlife conservation. Most dams in Kansas are small earthen private dams built for the purposes of flood control, fire protection, fish and wildlife conservation, recreation, creation of small stock ponds, debris control, and/or irrigation.

The demand to protect growing urban populations, rural farmlands, and communities in flood-prone areas resulted in enactment of the U.S. Flood Control Act of 1936. The Act made flood-control a federal issue and responsibility was assigned to the Army Corps of Engineers, which had been involved with water resource projects since 1824 (Arnold 1988). For the first time in history, the federal government agreed to a flood

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[3] Each dam is given a National Inventory of Dams Identification (NIDID) number. In some cases, a levee or dike may be constructed in association with the dam. In six instances, the same NIDID is used among the 6,403 listings. For example, Glen Elder Dam (NIDID KS00021) has two dikes associated with the dam, the Downs Protective Dike and the Cawker City Dike. The dikes and the dam have different reported heights, but the storage for all 3 structures is the same (in ac-ft.) in the NID database. In the few instances where this occurs, the storage and structure are only calculated once.

control program which would address flood destruction across the United States. Following the 1936 Act, reservoirs, levees, and channelization projects were constructed nationwide (Arnold 1988). Many local grassroots organizations were also formed between the 1930s and 1950s to aid in the development and construction of dams. The development of the Kansas Watershed District Act of 1953 (K.S.A. 24-1201 through 24-1237) led to the formation of Watershed Districts, which played an instrumental role in developing some of the larger dams across the state.

Figure 3.4. Aerial image of Kansas impoundments (Photo: Arnaud Temme). Blurred white patches toward upper left are clouds; others are small impoundments.

The demand to protect growing urban populations, rural farmlands, and communities in flood-prone areas resulted in enactment of the U.S. Flood Control Act of 1936. The Act made flood-control a federal issue and responsibility was assigned to the Army Corps of Engineers, which had been involved with water resource projects since 1824 (Arnold 1988). For the first time in history, the federal government agreed to a flood control program which would address flood destruction across the United States. Following the 1936 Act, reservoirs, levees, and channelization projects were constructed nationwide (Arnold 1988). Many local grassroots organizations were also formed between the 1930s and 1950s to aid in the development and construction of dams. The development of the Kansas Watershed District Act of 1953 (K.S.A. 24-1201 through 24-1237) led to the formation of Watershed Districts, which played an instrumental role in developing some of the larger dams across the state.

People have constructed dams for millennia, but it wasn't until the latter half of the 20th century, when water management became a global concern as populations and affluence increased, that dam construction rapidly increased globally (Stanley and Doyle 2003). Most dam construction in Kansas occurred from the 1960s into the early 1980's (Figure 3.5), as changes in federal policies prompted water management activities. Kansas, like most of the United States, is now seeing the hydrological, ecological, and social costs associated with dams now that the dam building era is over, and the effects of dam construction are becoming more evident.

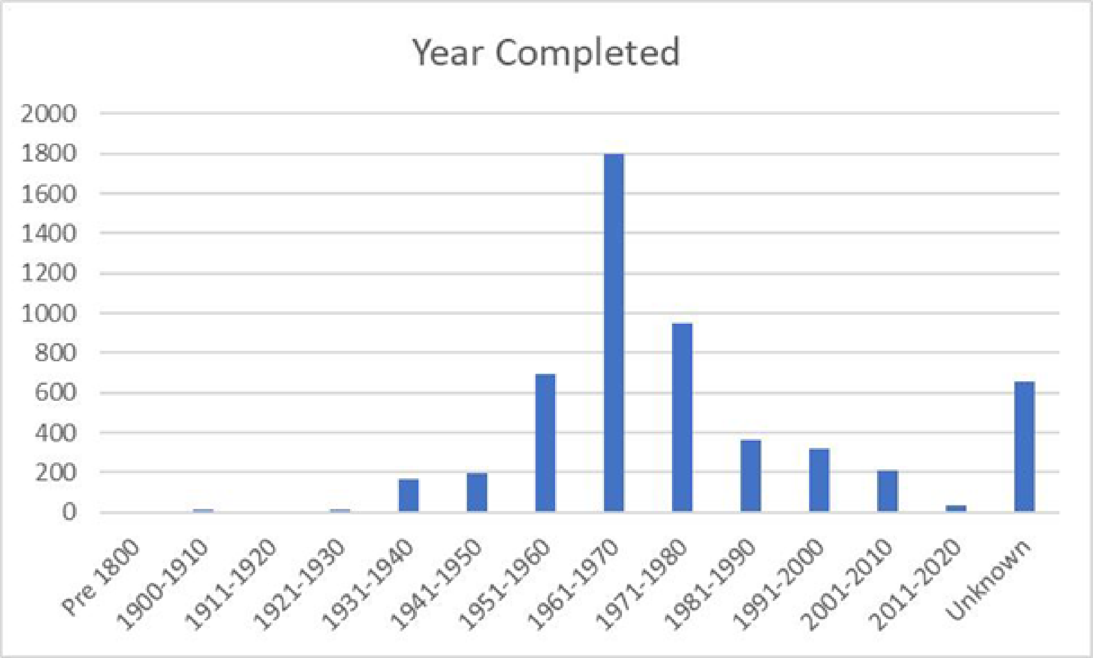
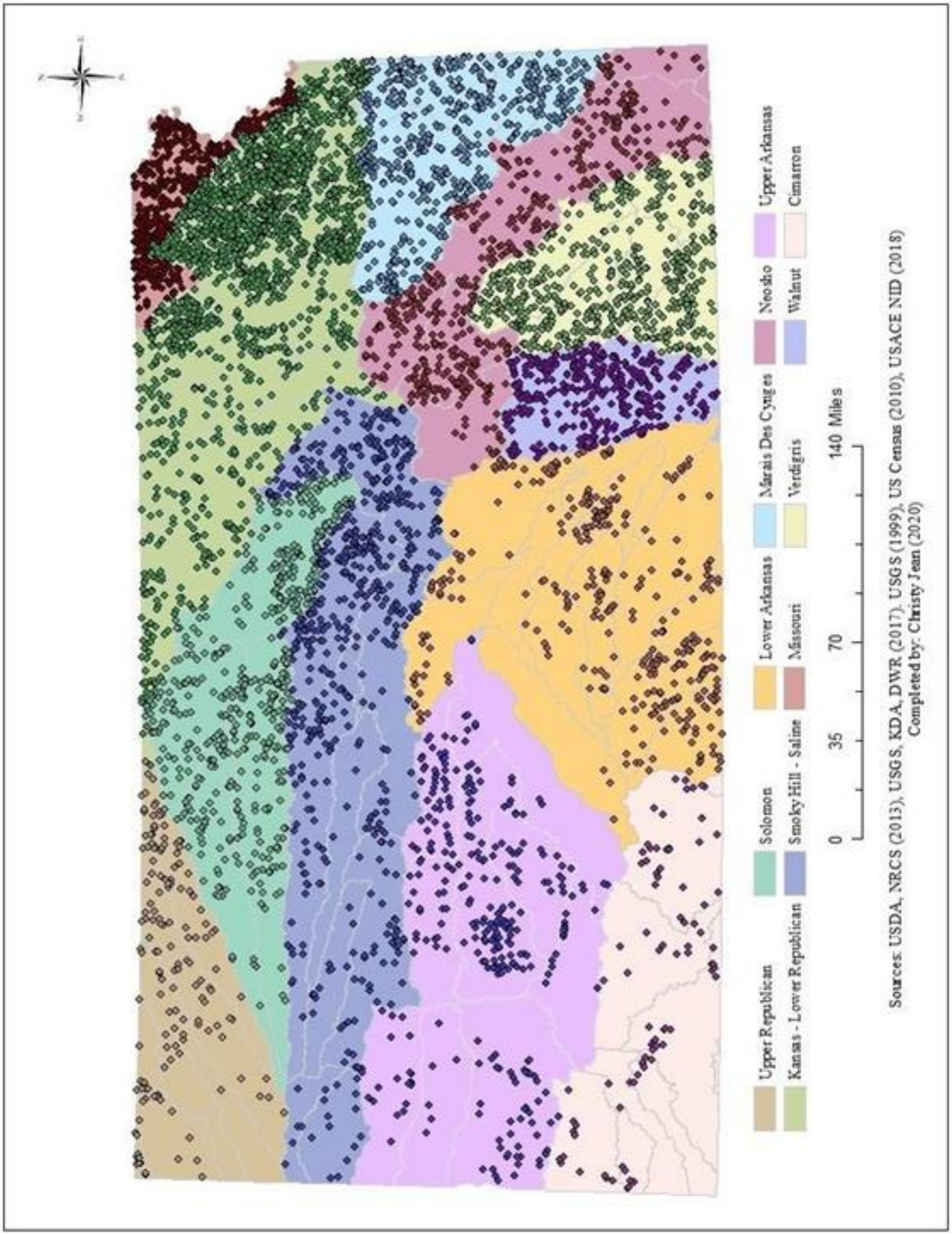


Figure 3.5. Dam Construction by Year Completed (Source: USACE NID 2019. Incomplete data does not account for the construction dates of at least 653 dams in Kansas.

Similar to a variable national distribution of dams, Kansas displays unequal distributions of dam density and river fragmentation across the state (Figure 3.6). Higher ratios of number of dams to river miles indicate greater river fragmentation. Kansas is divided into 12 drainage basins where the greatest density of dams is in the eastern half of the state. The drier western half has dams with greater average storage. The highest number of dams are in the Kansas- Lower Republican basin with a total of 1,724 dams registered through the NID database (Table 3.2). The lowest number of dams by basin are in the Cimarron watershed, as one might expect given the low average precipitation in the western half of the state and thus fewer perennial streams. The highest ratio of dams to river miles occurs in the Solomon basin.



Sources: USDA, NRCS (2013), USGS, KDA, DWR (2017), USGS (1999), US Census (2010), USACE NID (2018)
Completed by: Christy Jean (2020)

Figure 3.6. Geographic distribution of Kansas dams. (Source: USDA NRCS 2013; map by author).

Table 3.2. Dams, area, reservoir storage capacity, and relations to population in Kansas river basins.

Basin	Watershed Area (m^2)	Dams	Dams/ Watershed Area (m^2)	Storage (ac-ft)	Storage (ac-ft)/ Watershed Area(m^2)	Persons/ Dam	Storage (ac-ft)/ Person
Upper Republican	15,949.34	149	0.01	212,223.42	13.31	178	8.01
Solomon	6,859.97	515	0.08	48,284,662.92	7,038.61	71	1,313.62
Smoky Hill - Saline	11,625.68	615	0.05	2,062,900.39	177.44	258	12.98
Upper Arkansas	12,498.02	321	0.03	300,519.98	24.05	411	2.28
Cimarron	14,122.63	86	0.01	34,638.73	2.45	655	0.61
Lower Arkansas	14,164.75	343	0.02	689,710.03	48.69	1,978	1.02
KS - Lower Republican	17,672.39	1,954	0.11	7,454,654.80	421.82	600	6.36
Missouri	4,663.82	484	0.10	92,783.62	19.89	275	0.70
Marais Des Cygnes	7,521.71	538	0.07	1,118,011.57	148.64	259	8.04
Neosho	9,319.19	488	0.05	2,214,191.60	237.59	350	12.96
Verdigris	6,371.51	521	0.08	2,796,040.81	438.83	122	44.15
Walnut	2,949.64	381	0.13	585,962.20	198.66	345	4.46

Determination of Risk Levels

As part of research objectives 1 and 2 (to contribute to the understanding of flood risk perception where only part of the population is at actual foreseeable risk and to compare how perceptions relate to physical risk situations, respectively), the selection of study sites is based on Research Question 1: Which intermediate-size dams in eastern Kansas are most at risk to dam failure. This section details how geographic distribution, criteria, and selection of Kansas dams were used to answer RQ1.

Geographic Distribution

Given the geographic distribution of dams, precipitation gradient across Kansas, and the variances in height, storage, and primary purpose of each dam, we are able to look at how Kansas dams and their potential hazard impacts vary spatially across the state. The significant number of dams in Kansas, given their age of construction and climate variability, allows researchers to examine how flood risk perception may vary spatially.

Kansas is divided between two major watersheds: the Missouri River drainage basin and the Arkansas River drainage basin. T he Missouri River drainage basin is a 580,000 square mile watershed that encompasses 40,000 square miles of the northern half of Kansas (Schoewe 1951) and includes six major Kansas watersheds: the Upper Republican, Solomon, Smoky Hill-Saline, Kansas-Lower Republican, Missouri, and Marais Des Cygnes. The remaining six major watersheds in Kansas are part of the Arkansas-White-Red River drainage basin located in the southern half of the state and include the Upper Arkansas, Cimarron, Lower Arkansas, Neosho, Verdigris, and Walnut watersheds. With a total drainage area that exceeds any state east of the Mississippi River (Flora 1948), the Kansas River and Arkansas River watersheds experienced significant flood conditions prior to installation of flow controls.

Defining at-risk dams

In an effort to understand how flood risk perception varied across the state, the study areas were determined based on the following factors: a) characteristics of the dam, b) proximity of the dam to residents of the area, c) characteristics of nearby communities that are most likely to be impacted by the dam and d) climate predictions. These factors were used to address RQ1, identification of which intermediate-size dams in eastern Kansas are most at risk of dam failure. Identifying the characteristics of the population is important, based on literature that suggests socio-economic factors and cognitive processes can influence the response and impacts on at-risk populations (Cutter et al. 2003, O'Neill et al. 2015). The literature identifies high risk groups (elderly, young children, minorities, women, etc.) and those living in flood prone areas to be at a greater risk during a hazard because of increased vulnerability and longer recovery time. According to the findings, it is hypothesized that the relationship between socio-economic factors and proximity to the aging dam will influence flood risk perception.

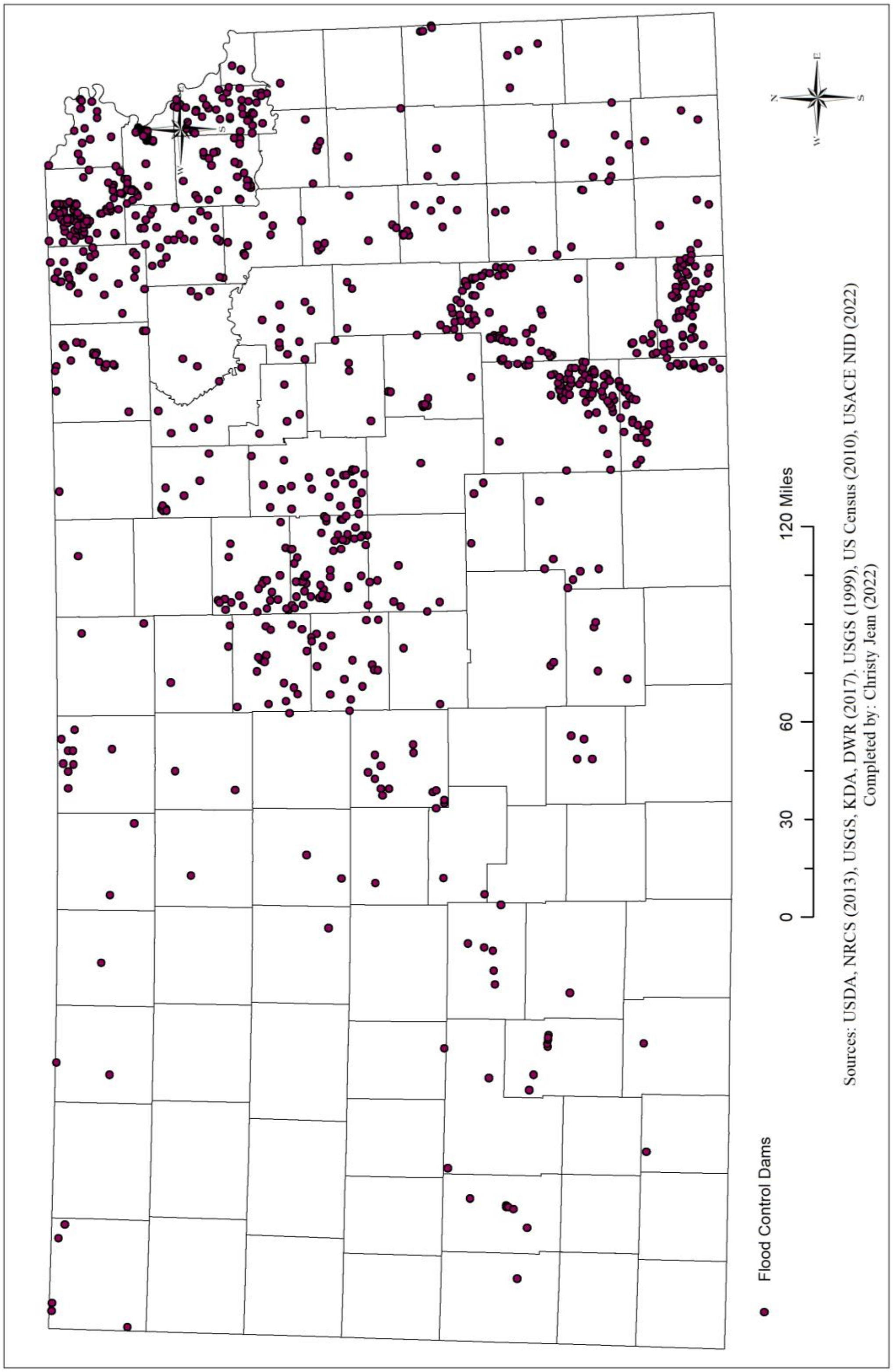
Assessment of Dams' Status

A total of 6,395 dams were examined during this study. Within the twelve watershed basins, 63% percent of those dams were constructed prior to 1970 (Table 3.3). Dams constructed prior to 1970 with a listed purpose of flood control account for 21% of the total number of dams. The identification of flood control dams within this group of dams constructed prior to 1970, were necessary in addressing RO2, to compare how perceptions relate to physical risk situations. Flood control dams are designed to reduce the risk of downstream flooding by releasing controlled amounts of impounded water, with the intention of lessening harm to communities, physical infrastructure, economic, and social activities. Notable clusters of pre-1970 flood control dams occur in the eastern half of Kansas (Figure 3.7), and more specifically within the eastern extents of the Smoky Hill-Saline, Walnut, Verdigris, Kansas-Lower Republican, and

Cimarron watershed basins (Figure 3.8). These findings indicate that, based on dam age alone, there are 4,046 (63%) dams that will have exceeded the 50-year expected design life as of 2020.

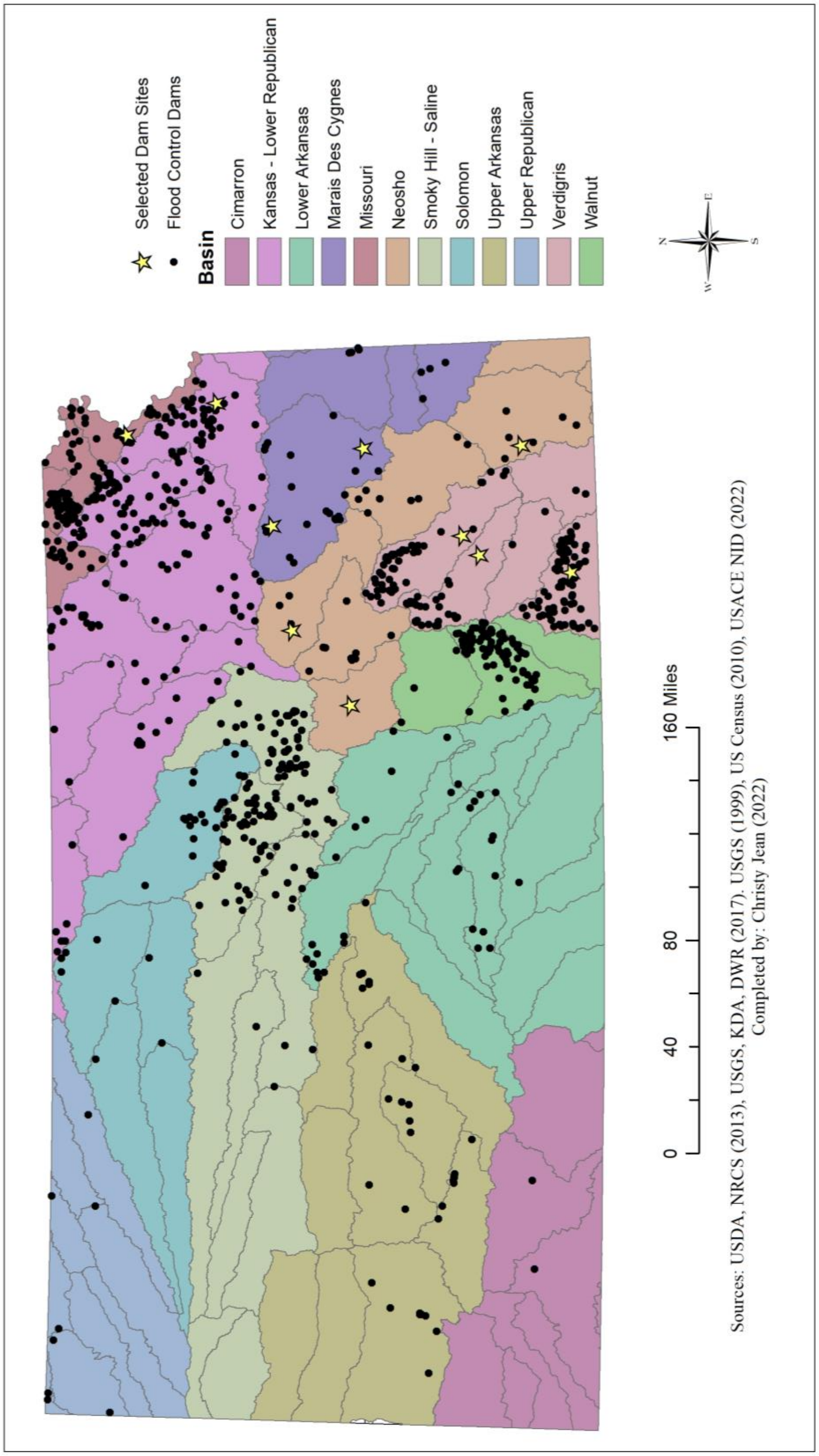
Table 3.3. Percentage of dams constructed prior to 1970 by watershed basin.

Watershed Basin	Total Number of Dams	Dams (Pre-1970)	Percentage	Flood Control (Pre-1970)	Percentage
Cimarron	86	64	74%	2	3%
Kansas – Lower Republican	1955	1084	55%	206	19%
Lower Arkansas	343	269	78%	30	11%
Marais Des Cygnes	538	293	54%	31	11%
Missouri	484	307	63%	122	40%
Neosho	488	235	48%	32	14%
Smoky Hill - Saline	615	470	76%	125	27%
Solomon	515	424	82%	30	7%
Upper Arkansas	321	202	63%	32	16%
Upper Republican	149	134	90%	8	6%
Verdigris	520	336	65%	150	45%
Walnut	381	228	60%	82	36%
Total	**6395**	4046	**63%**	850	**21%**



Sources: USDA, NRCS (2013), USGS, KDA, DWR (2017), USGS (1999), US Census (2010), USACE NID (2022)
Completed by: Christy Jean (2022)

Figure 3.7. Flood control dams constructed prior to 1970.



Sources: USDA, NRCS (2013), USGS, KDA, DWR (2017), USGS (1999), US Census (2010), USACE NID (2022)
Completed by: Christy Jean (2022)

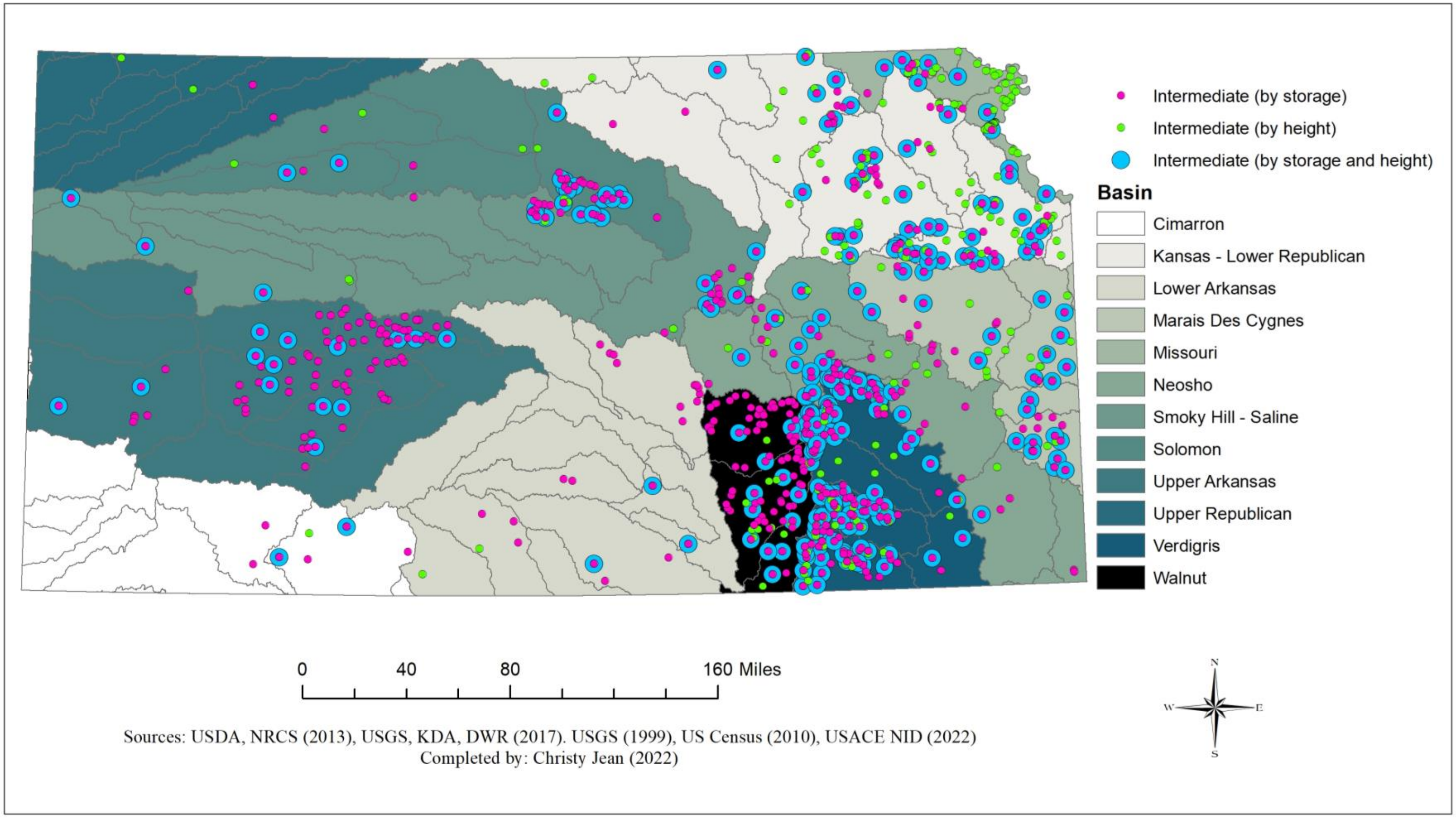
Figure 3.8. Flood control dams constructed prior to 1970, indicating watershed basin locations.

For this study, intermediate size also is a characteristic seen as relevant to risk and risk perception. Intermediate-size dams were mapped within Kansas watersheds to illustrate their distribution by storage and by height, with some overlapping in both categories. These dams account for 89% (758) of dams constructed before 1970 and used for flood control. Among pre- 1970 intermediate size dams, there are a total of 552 (73%) dams classified as intermediate size by storage (ac-ft), a total of 453 (60%) classified as intermediate by height, and a total of 247 that are both considered intermediate sized based on storage and height (Table 3.4).

The results of mapping indicated that Walnut and Verdigris watersheds had clusters of intermediate size dams similar to the pre-1970 dam clusters (Figure 3.9). Additional clusters in the eastern extents of the Upper Arkansas and Smoky Hill-Saline watershed basins indicate these regions also have a high number of intermediate size dams that would put downstream communities at risk. A fairly even distribution of pre-1970 flood control intermediate sized dams pattern the northeastern corner of Kansas which includes the watershed basins of the Kansas-Lower Republican, the Marais Des Cynges, and the Missouri. The highest percentages of pre-1970 flood control intermediate dams are in the Verdigris watershed basin. Other factors used to evaluate high risk dams included population (by tract), average annual precipitation, rural-urban continuum codes, and the social vulnerability index (Figures 3.10-3.13)

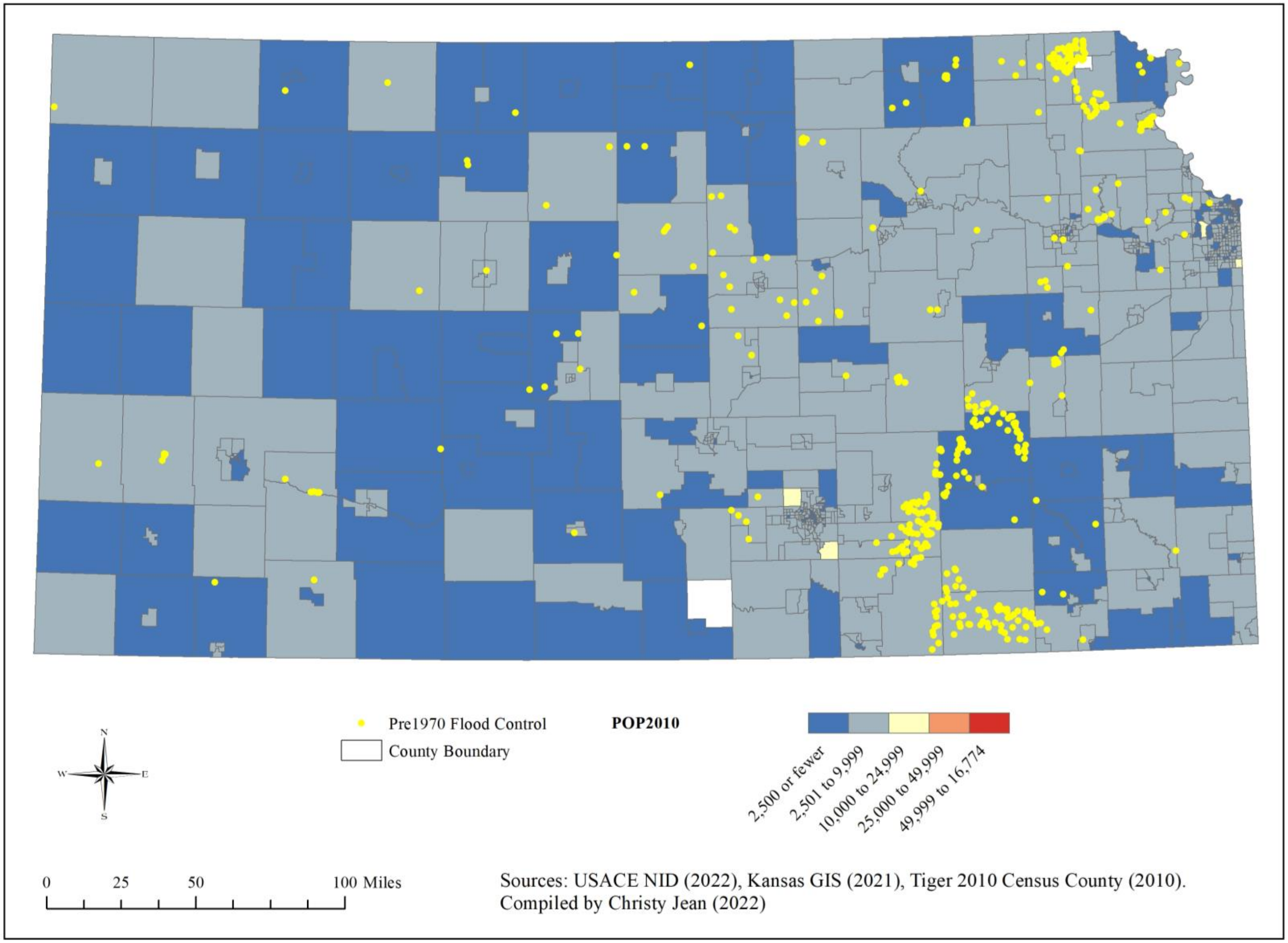
Table 3.4. Pre-1970 flood control intermediate-size dams within watershed basins.

Watershed Basin	Pre-1970 Flood Control Intermediate Size Dams					
	by Storage	Percentage	by Height	Percentage	by Storage and Height	Percentage
Cimarron	6	1%	3	1%	2	1%
Kansas – Lower Republican	71	13%	108	24%	44	18%
Lower Arkansas	21	4%	5	1%	3	1%
Marais Des Cygnes	39	7%	42	9%	24	10%
Missouri	14	3%	57	13%	10	4%
Neosho	41	7%	25	6%	16	6%
Smoky Hill - Saline	35	6%	16	4%	11	4%
Solomon	30	5%	23	5%	17	7%
Upper Arkansas	87	16%	14	3%	14	6%
Upper Republican	2	0%	2	0%	0	0%
Verdigris	126	23%	133	29%	94	38%
Walnut	80	14%	25	6%	12	5%
Total	**552**		**453**		**247**	



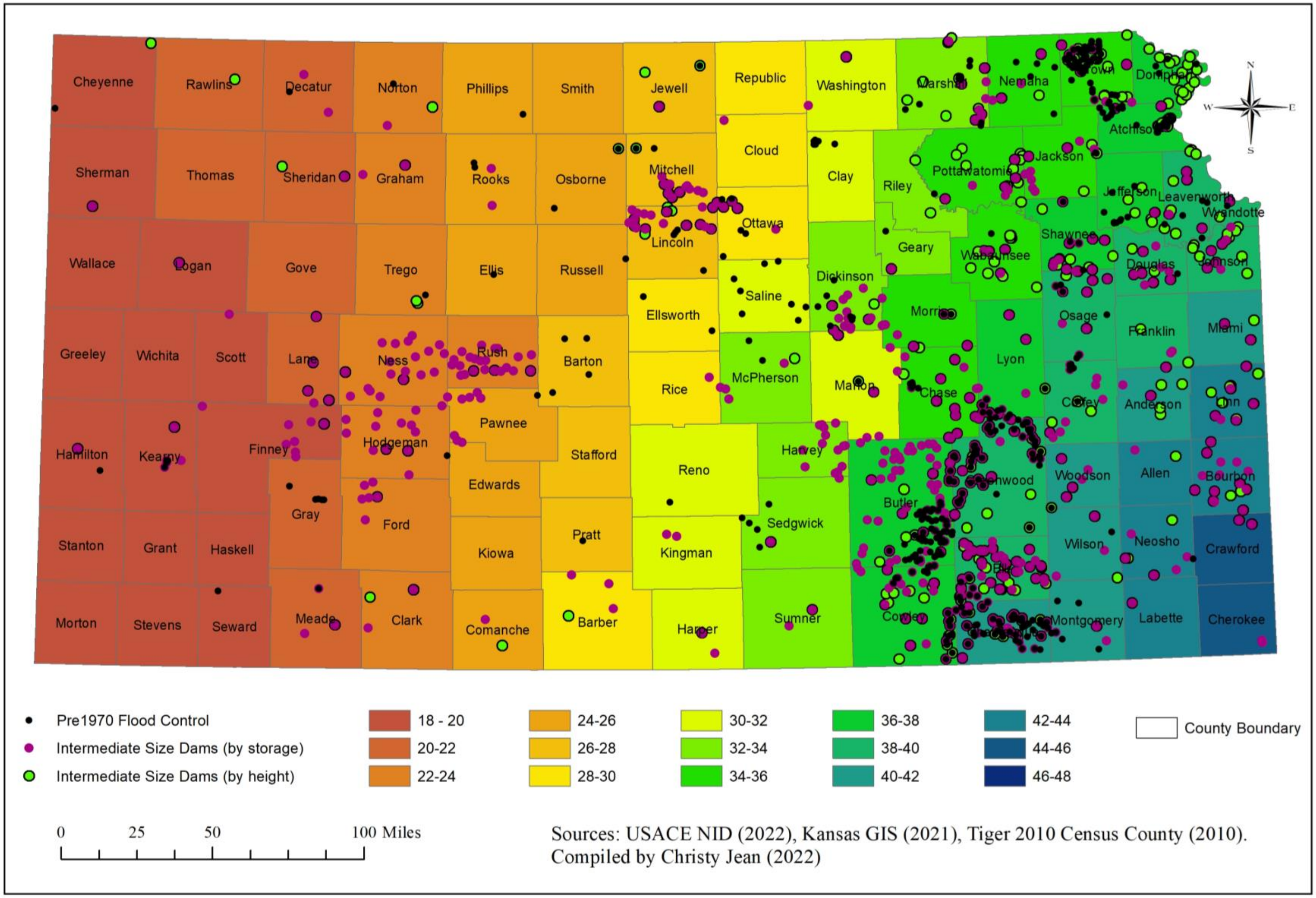
Sources: USDA, NRCS (2013), USGS, KDA, DWR (2017). USGS (1999), US Census (2010), USACE NID (2022)
Completed by: Christy Jean (2022)

Figure 3.9. Pre-1970 flood control dams classified by USACE intermediate-sized dams within watershed basins.



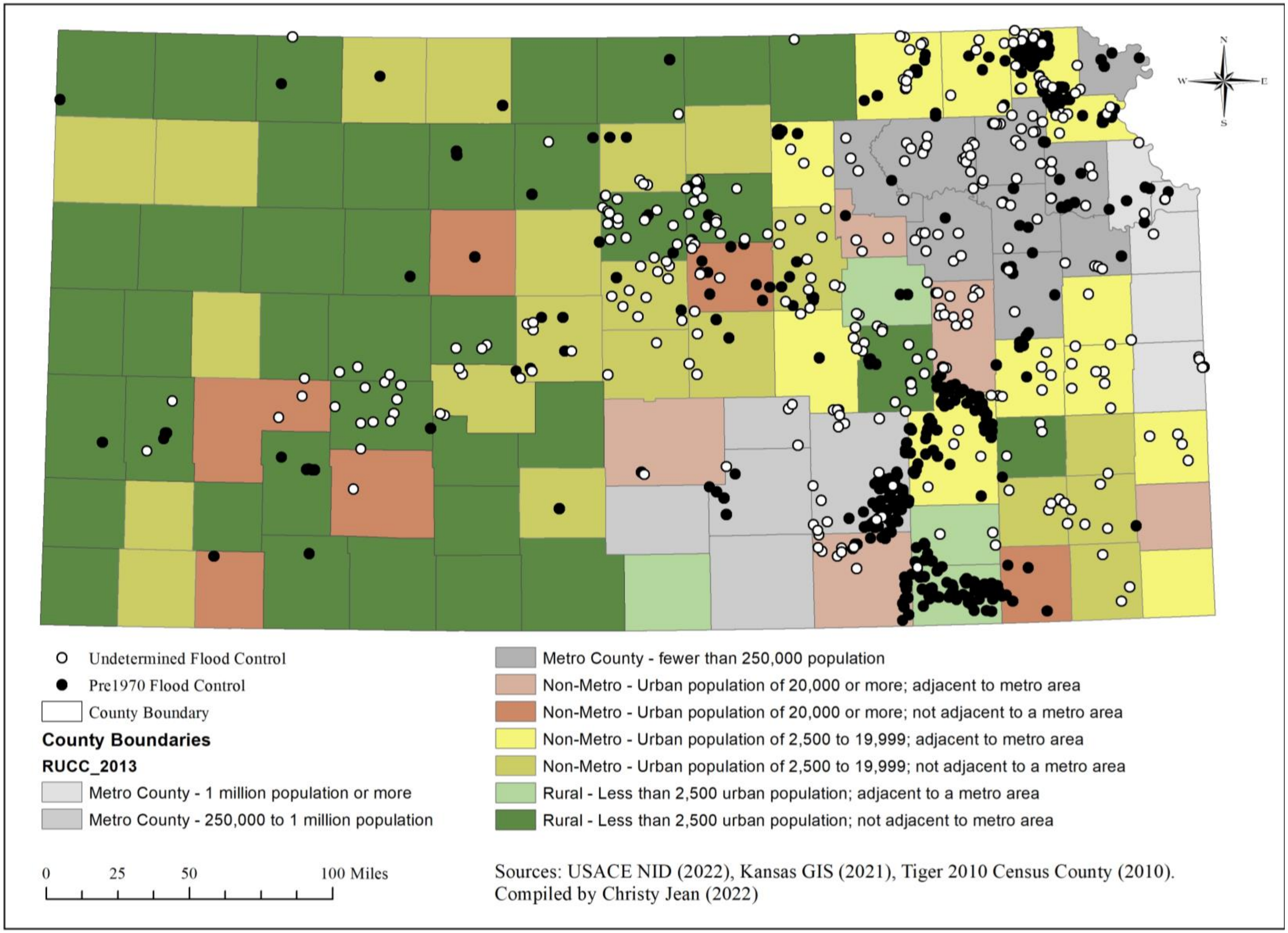
Sources: USACE NID (2022), Kansas GIS (2021), Tiger 2010 Census County (2010).
Compiled by Christy Jean (2022)

Figure 3.10. Pre-1970 Flood Control and Intermediate-sized dams by county tract.



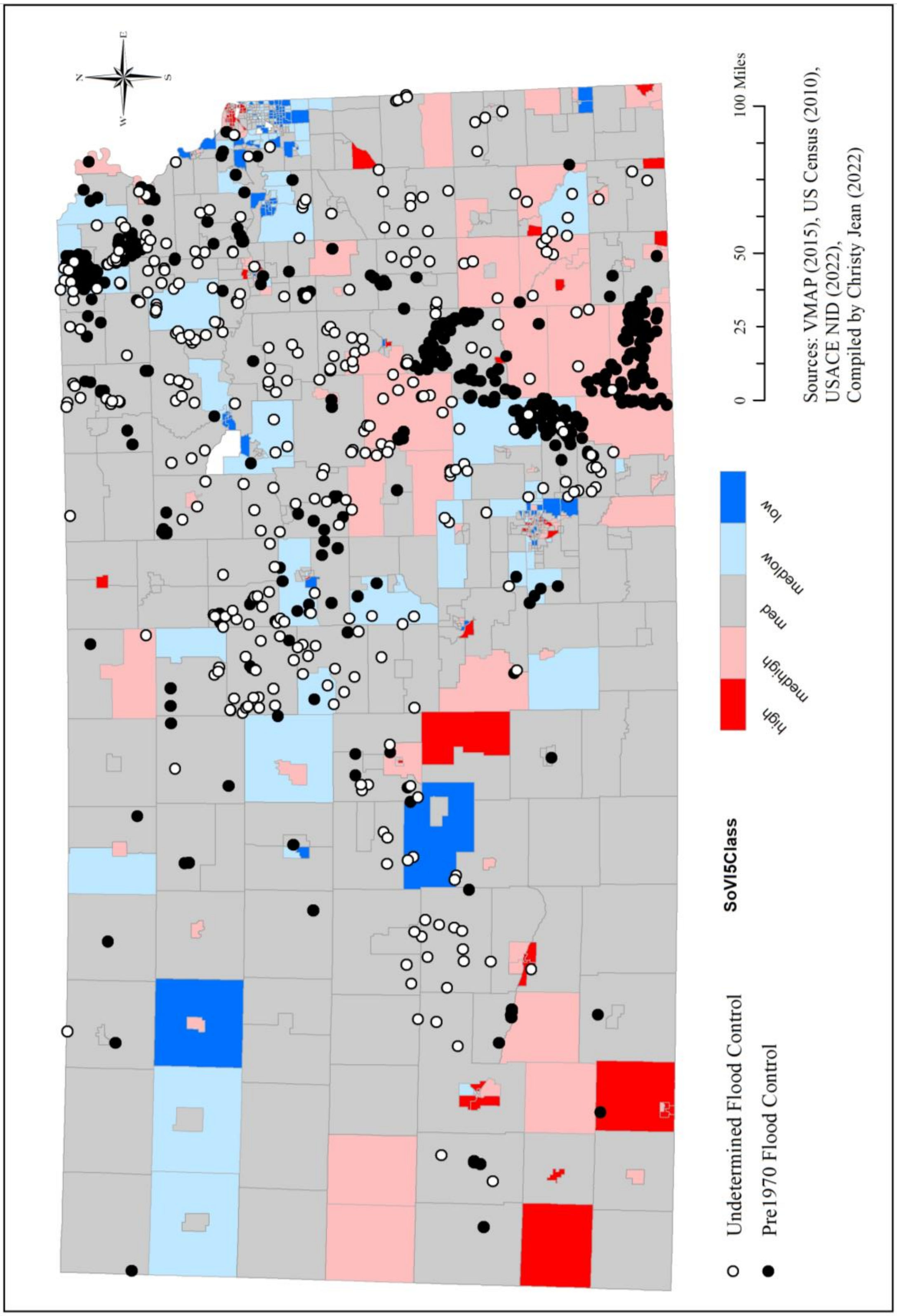
Sources: USACE NID (2022), Kansas GIS (2021), Tiger 2010 Census County (2010).
Compiled by Christy Jean (2022)

Figure 3.11. Pre-1970 Flood Control and Intermediate-sized dams by average annual precipitation.



Sources: USACE NID (2022), Kansas GIS (2021), Tiger 2010 Census County (2010).
Compiled by Christy Jean (2022)

Figure 3.12. Pre-1970 Flood Control and Intermediate-sized dams by rural-urban continuum codes.



Sources: VMAP (2015), US Census (2010), USACE NID (2022),
Compiled by Christy Jean (2022)

Figure 3.13. Pre-1970 Flood Control and Intermediate-sized dams by social vulnerability index.

Dams in eastern Kansas with the highest potential risk

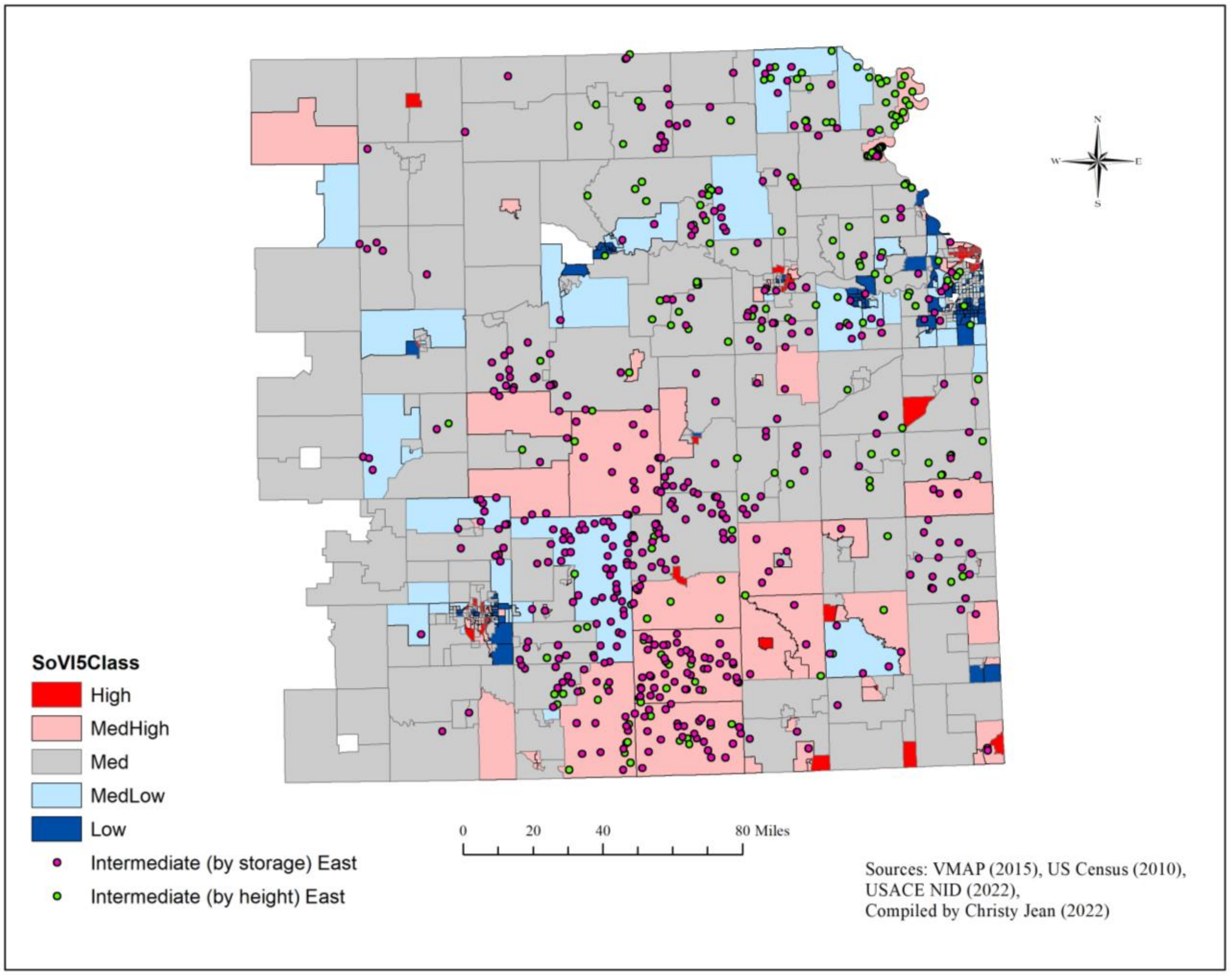
Kansas extends from roughly 102°W to 94.6°W. Using the 98th meridian as a line of demarcation between the eastern and western halves of the state allowed me to divide the state into two sections while maintaining the integrity of county boundaries. The furthest western counties used in this study include Republic, Cloud, Ottawa, Saline, McPherson, Harvey, Sedgwick, and Sumner. Overall, there were a total of fifty-one counties (Table 3.5) that were examined as part of RQ1 to determine which intermediate-sized dams (by either height or storage capacity) were at greatest risk to dam failure given:

a) characteristics of the dam (construction date prior to 1970)
b) proximity of the dam to residents of the area (2010 population data by tract)
c) characteristics of nearby communities that are most likely to be impacted by the dam (Social Vulnerability Index (SoVI) and Rural Urban Continuum Code (RUCC) classifications)
d) climate predictions (counties east of the 98th meridian as those likely to experience greater average annual precipitation in the near future)

Table 3.5. Eastern Kansas counties.

Allen	Coffey	Jackson	Montgomery	Shawnee
Anderson	Cowley	Jefferson	Morris	Sumner
Atchison	Crawford	Johnson	Nemaha	Wabaunsee
Bourbon	Dickinson	Labette	Neosho	Washington
Brown	Doniphan	Leavenworth	Osage	Wilson
Butler	Douglas	Linn	Ottawa	Woodson
Chase	Elk	Lyon	Pottawatomie	Wyandotte
Chautauqua	Franklin	Marion	Republic	
Cherokee	Geary	Marshall	Riley	
Clay	Greenwood	McPherson	Saline	
Cloud	Harvey	Miami	Sedgwick	

In terms of the social vulnerability of communities, should a hazard event occur, tracts considered to be high (red) or medium high (MedHigh) (pink) are at a higher risk of incurring more severe negative social impacts compared to other communities at the same level, which are depicted as medium low (MedLow) (light blue) or Low (dark blue) (Figure 3.14). Among the eastern counties, there are 232 intermediate-sized dams that are located in a tract with a SoVI rating of MedHigh. MedHigh was the highest SoVI ranking associated with intermediate-sized dams.



Sources: VMAP (2015), US Census (2010), USACE NID (2022), Compiled by Christy Jean (2022)

Figure 3.14. Dams in eastern Kansas with the highest risk potential.

There are a total of 59 intermediate-sized dams within eastern Kansas that are considered to be at higher risk to dam failure given their location, construction date, primary purpose of flood control, and a SoVI rating of MedHigh. Of those, 18 dams were considered to have a high hazard classification and an active Emergency Action Plan (Table 3.6). The factors column in Table 3.6 indicates the primary purpose and intermediate-size dam classification, where the H and/or S indicate whether that dam met the size classification based on height (H), storage (S), or both (HS), and FC indicates that it is a flood control dam constructed prior to 1970. Further markers described the tract number, 2010 Census population, and the area's RUCC code. Other markers, including hazard classification and Emergency Action Plan status, as reported on the United States Corps of Engineer's National Inventory of Dams database, were evaluated.

The next highest SoVI rating was medium (Med), which had a total of 297 intermediate- sized dams. There were a total of 52 intermediate-sized dams within eastern Kansas that are considered to be at higher risk of dam failure given their location, construction date, primary purpose of flood control, and a SoVI rating of medium. Of those, 15 dams were considered to have a high hazard classification and an active Emergency Action Plan (Table 3.7). The remaining dams on the eastern half of the state are considered to be at a lower risk of incurring negative social compacts as compared to those relative to them.

Table 3.6. Intermediate-Sized Dams with a SoVI Rating of MedHigh and with High Hazard.

County	RUCC Code	2010 POP	Tract No.	SoVI Rating	KS0 Dam ID	Factors	Classification	EAP
Chautauqua	Rural Adjacent	3669	9646	MedHigh	2201	HSFC	High Hazard	Yes
Chautauqua	Rural Adjacent	3669	9646	MedHigh	2451	HSFC	High Hazard	Yes
Chautauqua	Rural Adjacent	3669	9646	MedHigh	2452	HSFC	High Hazard	Yes
Atchison	NonMetro Adjacent	2907	818	MedHigh	2010	HSFC	High Hazard	Yes
Morris	NonMetro Adjacent	2516	9637	MedHigh	0001	HFC	High Hazard	Yes
Woodson	Rural NotAdjacent	1720	966	MedHigh	0011	HFC	High Hazard	Yes
Atchison	NonMetro Adjacent	6403	817	MedHigh	2427	HFC	High Hazard	Yes
Atchison	NonMetro Adjacent	6403	817	MedHigh	2428	HFC	High Hazard	Yes
Atchison	NonMetro Adjacent	6403	817	MedHigh	2429	HFC	High Hazard	Yes
Atchison	NonMetro Adjacent	6403	817	MedHigh	2430	HFC	High Hazard	Yes
Atchison	NonMetro Adjacent	6403	817	MedHigh	2431	HFC	High Hazard	Yes
Atchison	NonMetro Adjacent	2907	818	MedHigh	2436	HFC	High Hazard	Yes
Atchison	NonMetro Adjacent	2907	818	MedHigh	2437	HFC	High Hazard	Yes
Atchison	NonMetro Adjacent	2907	818	MedHigh	2438	HFC	High Hazard	Yes
Atchison	NonMetro Adjacent	2907	818	MedHigh	2446	HFC	High Hazard	Yes
Atchison	NonMetro Adjacent	2907	818	MedHigh	2448	HFC	High Hazard	Yes
Atchison	NonMetro Adjacent	2907	818	MedHigh	2449	HFC	High Hazard	Yes
Atchison	NonMetro Adjacent	2907	818	MedHigh	2450	HFC	High Hazard	Yes

Table 3.7. Intermediate-Sized Dams with SoVI Rating of Medium and with High Hazard.

County	RUCC Code	2010POP	Tract No.	SoVI Rating	KS0 Dam ID	Factors	Classification	EAP
Butler	Metro	3652	209.03	Med	2126	3	High Hazard	Yes
Morris	Rural NonAdjacent	3407	9636	Med	2512	3	High Hazard	Yes
Greenwood	Non-Metro NotAdjacent	2162	9656	Med	2279	3	High Hazard	Yes
Greenwood	Non-Metro NotAdjacent	2162	9656	Med	2280	3	High Hazard	Yes
Greenwood	Non-Metro NotAdjacent	2162	9656	Med	2282	3	High Hazard	Yes
Greenwood	Non-Metro NotAdjacent	2162	9656	Med	2297	3	High Hazard	Yes
Osage	Metro	2893	102	Med	2409	3	High Hazard	Yes
Marion	Non-Metro Adjacent	2794	4897	Med	0006	HFC	High Hazard	Yes
Morris	Rural NonAdjacent	3407	9636	Med	0001	HFC	High Hazard	Yes
Coffey	Metro	2947	9662	Med	0004	HFC	High Hazard	Yes
Montgomery	NonMetro_20K NotAdjacent	3953	9507	Med	2395	HFC	High Hazard	Yes
Cowley	Non-Metro_20K Adjacent	3066	4932	Med	2231	SFC	High Hazard	Yes
Shawnee	Metro	8020	37	Med	1959	SFC	High Hazard	Yes
Osage	Metro	2893	102	Med	2406	SFC	High Hazard	Yes
Leavenworth	Metro	3851	714	Med	1248	3	High Hazard	Yes

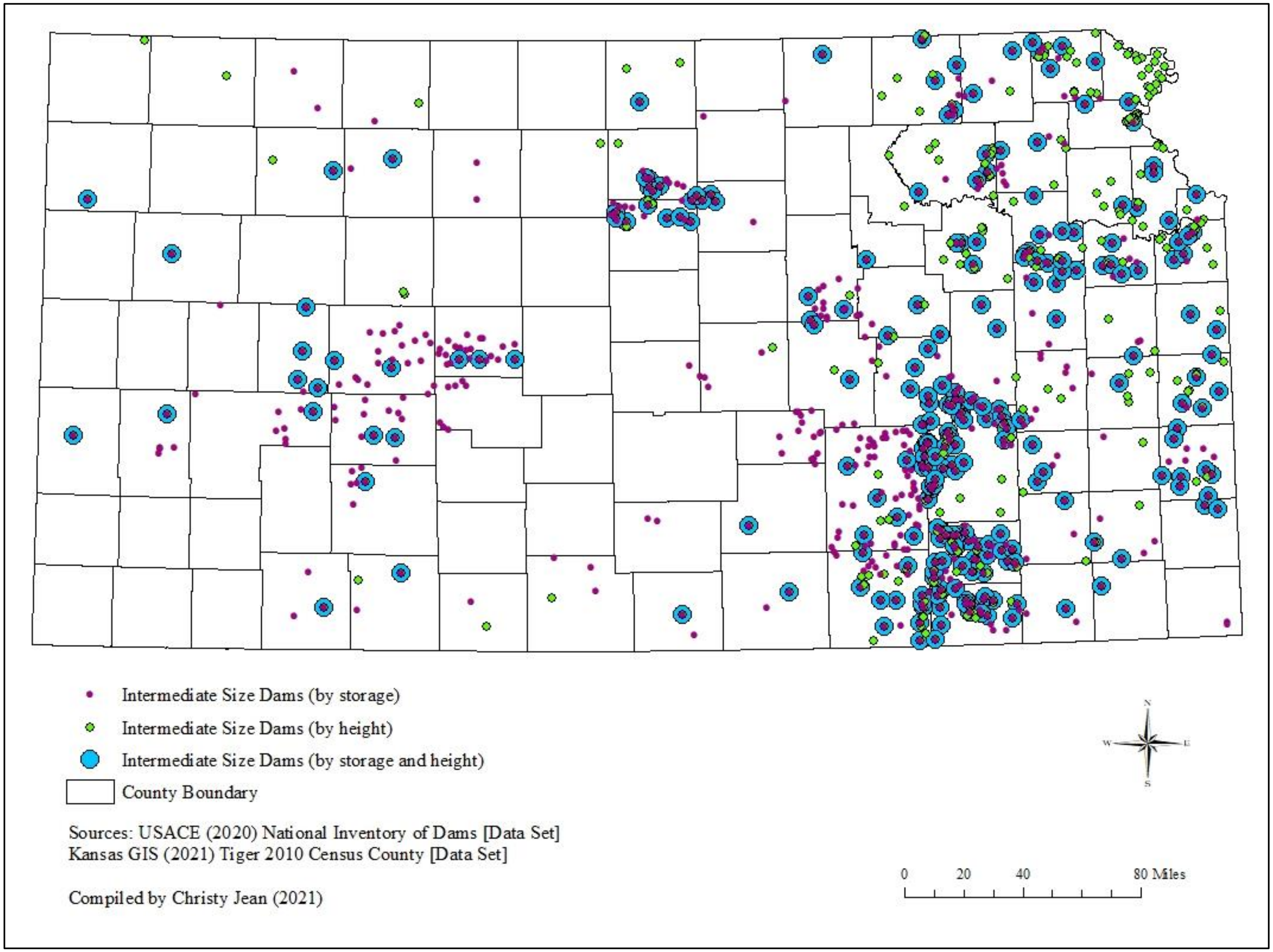
Dam study site selection

Narrowing down the large number of Kansas dams for this study required development of criteria related to the potential to cause significant damage to persons and property in the event of a dam failure. The criteria used to select dams for this study focused on size, hazard classification, age, primary purpose, nearby population, and location with respect to changing climate (rainfall) (Table 3.8). Differences in SoVI ratings and rural urban continuum codes were also considered, to ensure inclusion of different perspectives.

Table 3.8. Selection criteria for study dams.

Criterion	Inclusion characteristic	Specific metrics
Size	Intermediate	storage capacity 1,000 to <50,000 ac-ft or height 40 to <100 ft
Hazard class	High	EAP available
Age	>50 years old by 2020	construction before 1970
Primary purpose	Flood control	
Nearby population	Viable for sampling	>10 buildings within FEMA flood zone or within 200 m of river centerline
Location	likely to experience increased frequency and more intense 24- hour rainfall totals	Above average rainfall distribution within 90th percentile or greater

There are three size classifications for dams based on the dam's height (ft) and storage capacity (acre-feet). Size category is determined by either storage capacity or height of the structure, whichever results in the larger category (USACE 1979). The dam height is measured from the natural bed of the stream (or the lowest elevation of the outside limit barrier) to the maximum water storage elevation (or to the top of the dam) (USACE 1979). Dam storage capacity is derived from regional and hydrological models that relate the mean and variance of annual streamflow (EPA 2017). Sedimentation, or the accumulation of sediment in a reservoir, is dependent on the carrying capacity of sediment by incoming streams (Graf 2006). Vulnerability increases as the loss of storage capacity increases and disrupts the balance of available water and variable climatic conditions (EPA 2017). Reservoir sedimentation is responsible for diminishing dam storage capacity and benefits. **Intermediate dams were chosen for this study because of their storage capacity, which has the potential to cause significant upstream or downstream damage, and because they are often privately owned or are less likely to be regulated by a larger agency that has the resources to provide necessary upkeep and maintenance**. In addition, intermediate-sized dams have received less attention regarding hazard potentials and residents' perceptions than large dams. An intermediate dam has a storage capacity of 1,000 to less than 50,000 acre-feet or a height from 40 feet up to (but not including) 100 feet. Out of the 6,403 dams in Kansas, there were 453 dams between 40-100 feet in height, 552 with a storage capacity between 1,000 and 50,00 acre-feet, and a total of 247 that had overlapping size characteristics (Figure 3.15).



Sources: USACE (2020) National Inventory of Dams [Data Set]
Kansas GIS (2021) Tiger 2010 Census County [Data Set]

Compiled by Christy Jean (2021)

Figure 3.15. Intermediate dams by size classification.

Hazard classifications (Table 3.9) pertain to the potential loss of life or property damage in the area downstream of the dam in the event of a failure (USACE 1979). Although the definition provided by the US Army Corps of Engineers (USACE) specifically mentions downstream damage, upstream damage has occurred as a result of water not being released in order to prevent downstream flooding. Dams that have a high hazard potential are required to have an emergency action plan (EAP). As part of the criterion, dams selected for the study had an active emergency plan, indicative of status as a relatively hazardous dam. A total of 328 dams in Kansas have an active EAP, but it is possible that more dams may have one that has not been reported or recorded or may be in need of one. According to the NID, 4,966 dams are reported as "Not Required" to have an EPA and 109 that do not have one. Of the 453 intermediate size dams that had a storage height between 40-100 feet, 139 dams had an active emergency action plan.

Table 3.9. Hazard Potential Classification (USACE 1979).

Category	Loss of Life	Economic Loss
Low	None Expected	Minimal (undeveloped to occasional structures, agriculture)
Significant	Few	Appreciable (notable agriculture, industry, or structures)
High	More than a few	Excessive (extensive community, industry, or agriculture)

To be selected for study, dams had to have a construction date prior to 1970, making the dam over 50 years old by 2020, and with a primary purpose of flood control. This reduced the number of eligible dams to 18. The United States Department of Agriculture (USDA) stipulates that watershed structures are designed with a sediment storage life of no less than 50 years and no more than 100 years despite variances in design features and construction materials (NWPM 2009). This may be in part to operating within certain budget constraints. Overbuilding a dam to last more than 100 years is likely not very cost effective. Maintenance costs increase as dams age, due in part to physical deterioration, inadequate maintenance, and environmental changes over time. Many watershed districts in Kansas have proposed new dam construction in their areas because it is more cost-effective than repairing older dams.

Aerial images of the 18 dam sites were reviewed to gauge the general geography of the area. In order to have a viable population to sample from, more than 10 buildings within the FEMA flood zone area or within 200 meters of the river centerline were needed for this study. Dams that were not selected[4] included those that were located in a state park, a predominately agriculture area or in an area with little to no buildings constructed within the floodplain. After reviewing the number of dams that would be eligible for the study, it was clear that in order to get a better response rate, I would need to focus on dams that had larger populations for a viable sample size. As a result, I chose to keep the 7 dams that met both the storage capacity and height size classification requirements and that also met the nearby population requirements. Three additional dams, Marion Dam, Fall River Dam, and Toronto Dam, met the intermediate size of under 100 ft in height but had a storage capacity greater than 50,000 acre-feet. On maps (GIS) used for selection, the length of the river centerline extended 10 miles upstream and 10 miles downstream from the head of the dam. This extent was used because it covered special flood zones as indicated by FEMA, a nearby town where livelihood had the potential to be affected during a flood event, and/or included a larger group of potential respondents that may experience upstream or downstream influences in the event of a flood event or dam breach. At this point 10 dams were in a preliminary list of study sites.

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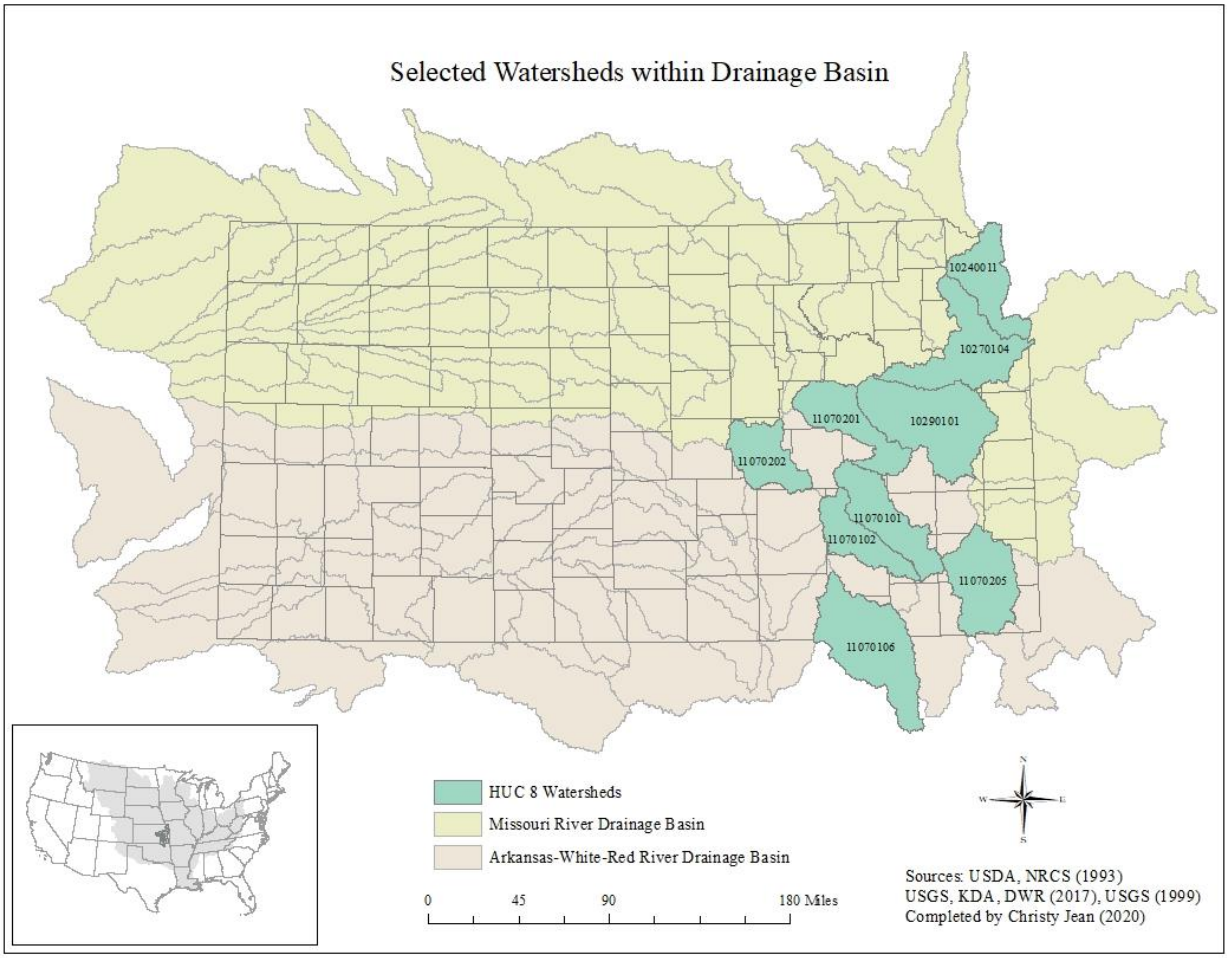
[4] [4]KS00023, KS02017, KS02150, KS02201, KSO2282, KS02309, KS02481, and KS09002.

Finally, the dam sites had to be located in areas likely to experience increased frequency and more intense 24-hour rainfall totals to be selected. These locations were based on a 2015 study that analyzed the frequency and magnitude of rainfall events with potential impacts on flooding in Kansas among 23 stations between 1890-2013 (Rahmani et al. 2015). All 10 dams met this criterion. Upon evaluation of the rainfall events that exceed the daily maximum rainfall and frequency events in the 90th, 95th, and 99th percentile, the findings of the trend analysis suggested that Kansas was likely to experience more frequent and more intense 24-hour rainfall totals in the near future. Using the findings from the Rahmani et al. (2015) study, I used the spatial analyst tool, kriging, in ArcGIS to illustrate the spatial distribution and changes in percentile, based on the data from the 23 precipitation stations in Kansas. In a performance comparison of different interpolation methods used to predict spatial distribution patterns of rainfall magnitudes, they found kriging to be among the most accurate methods for quantifying spatial autocorrelations among selected sample sites with minimum variance (Yang and Xing 2021). The locations of dam sites were overlayed onto the daily maximum rainfall and frequency event rainfalls in the 90th, 95th, and 99th percentiles to determine which study sites were likely to experience increased frequency and higher magnitude rainfall events.

Selected Study Sites

The study areas for this project include 10 dam locations across nine different watersheds in eastern Kansas and in both major river drainage basins, the Missouri River drainage basin and the Arkansas-White-Red River drainage basin (Figure 3.16). The ten dams shown in Table 3.10 were used as study sites for this project. Data provided in the table is sourced from the USACEE National Inventory Dam's database as of April 2022. Dam profiles, including information on the selected study sites project scope, structure, inspection and evaluation, response preparedness, and risk, can be found in Appendix A.



Sources: USDA, NRCS (1993)
USGS, KDA, DWR (2017), USGS (1999)
Completed by Christy Jean (2020)

Figure 3.16. Selected eastern Kansas watersheds.

Table 3.10. Study Dam Sites[5]

Age	Dam Name	River	Nearest City	Dam Type	Dam Height (feet)	Reservoir Storage (acre-feet)	Drainage Area (sq. miles)
56	Bear Lake (Little Kaw Creek Detention Dam)	Kaw Creek – Tr	Mahon	Rockfill	41	1,738	4.4
58	White Clay Brewery WS Dam 23 (FRD No 23)	Brewery Creek	Atchison	Earth	48.2	2,660	2.8
55	Sedan Multiple Purpose Dam (DD No 6-28 LD)	Deer Creek	Sedan	Earth	50.1	3,250	7
58	Switzler Creek Watershed Dam (DD No 7)	Hoover Branch	Burlingame	Earth	41	4,537	4.9
78	Council Grove City Lake Dam	Canning Creek	Council Grove	Earth	75	14,613	8
*	Cedar Creek Reservoir	Cedar Creek	Greely	Earth	70	24,000	63
61	Lake Parsons Dam	Labette Creek	Parsons	Earth	52	38,000	37.1
52	Marion Dam (Marion Lake)	Cottonwood River	Marion	Earth	67	189,200	200
72	Fall River Dam (Fall River Lake)	Fall River	Fall River	Earth	94	256,400	585
60	Toronto Dam (Toronto Lake)	Verdigris River	Coyville	Earth	90	318,900	730

A map was created for each dam site, to include the flood zone, a 200 m buffer from the flood zone, and buildings located within the buffer and inside the flood zone (Figure 3.17; see

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[5] [5] Cedar Creek Reservoir does not have a construction date listed on the NID. The steering committee for Cedar Creek Reservoir was started in 1968 which would make the dam at least 50 years old.

Appendix B for maps of all study locales) using FEMA flood zone maps available in GIS form or as scanned images. Flood hazard areas are identified on FEMA flood zone maps as an SFHA (Special Flood Hazard Area), which indicates that an area has a 1-percent annual chance of being inundated by a flood event in any given year. More commonly, this percentage is referred to as a base flood or 100-year flood. SFHA's are divided into five types of A zones (A, A1-20, AE, AO, and AH). Newer flood insurance maps (FIRMS or DFIRMS) use Zone X to show Zones B (area of moderate flood hazard which exits between the limits of the base and the 0.2 percent annual change, commonly referred to as a 500-year flood) and Zone C (area of minimal flood hazard outside of the SFHA and have a higher than the elevation of the 0.2 percent annual chance flood level). Ponding and local drainage problems may prevent X Zones from being mapped as A zones if they do not meet the criteria to be mapped as a SFHA. All flood zone terms are as defined by FEMA. In Figures 3.17, 6.6, and all of the maps in Appendix B, the following flood zones were mapped:

A: SFHA - no base flood elevation is provided

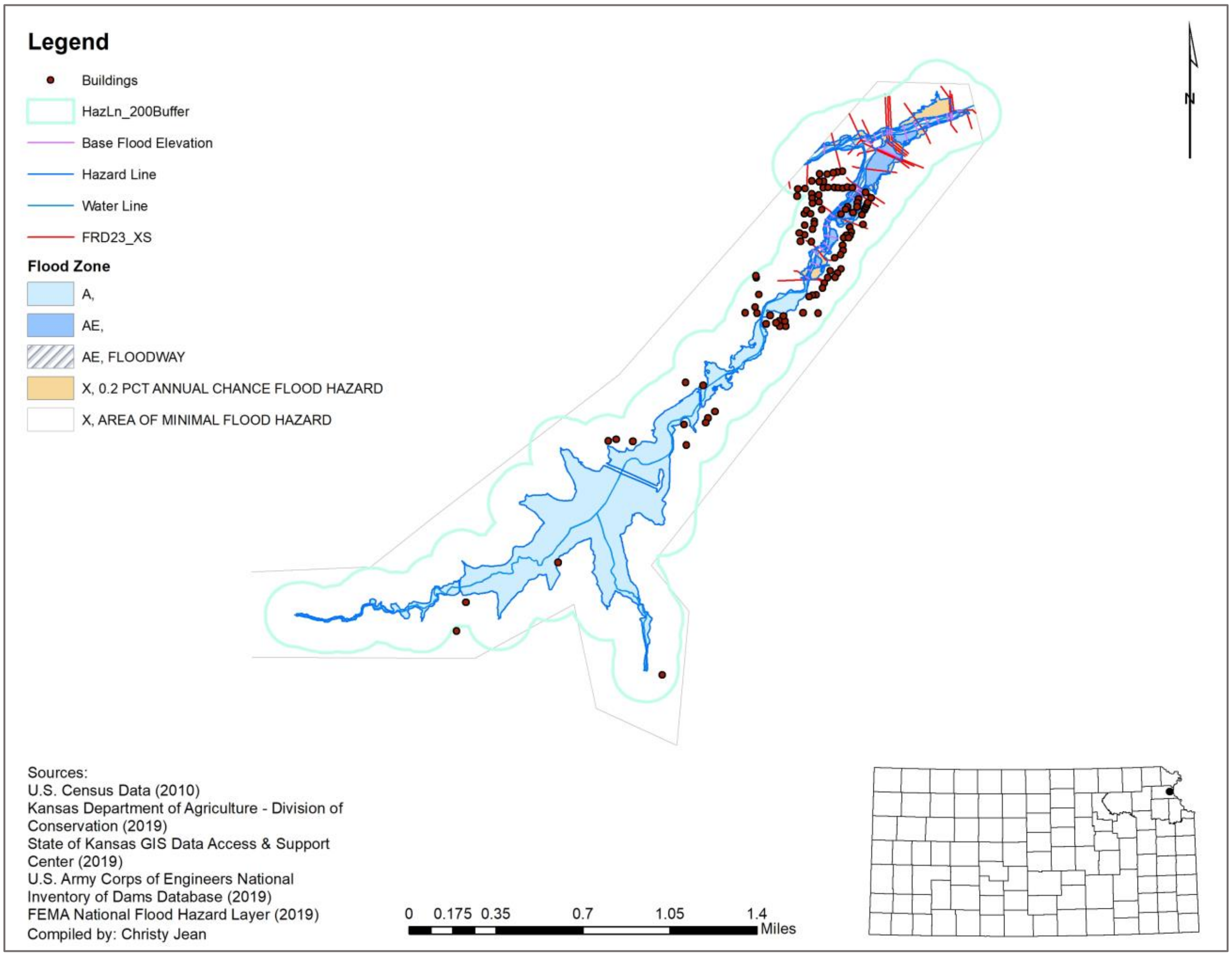
AE: SFHA - base flood elevation provided

AE, floodway – channel of a watercourse and that portion adjacent to the floodplain that must remain open to permit passage of the base flood without increasing the water surface elevation, by more than usually one foot.

X, 0.2 Percent Annual Chance – Moderate flood hazard, used to designate floodplains of little hazard, such as those with average depths of less than 1 foot.

X, Area of Minimal Flood Hazard – Minimal flood hazard

The buffer and buildings information were needed because the intent was to collect information from selected individuals living inside and outside of the flood zone to allow for comparison of flood risk perceptions (O'Neill et al. 2016). Three dam sites − Sedan, Fall River, and Toronto − did not have a FEMA flood zone map at all. In these cases, a 200 m buffer zone around the waterbody and one 200 m for the centerline of the river were used. I chose to stay within a 200 meter buffer for two reasons: 1) the dam sizes selected for this study are large enough to impact the livelihood of a nearby town or to influence upstream and downstream residents in the event of a flood event or dam breach and 2) it was necessary to have a manageable sample size that allowed me to select more than one dam, as part of my objective is to study flood risk perceptions near different Kansas dams.



Sources:
U.S. Census Data (2010)
Kansas Department of Agriculture - Division of Conservation (2019)
State of Kansas GIS Data Access & Support Center (2019)
U.S. Army Corps of Engineers National Inventory of Dams Database (2019)
FEMA National Flood Hazard Layer (2019)
Compiled by: Christy Jean

Figure 3.17. Example of flood maps created for each dam (White Clay Brewery WS Dam 23 - FRD No 23).

Characteristics of the population are an essential factor in determining how the location and responses of high-risk groups may be impacted by flood risk. The following section takes into consideration the rural and social vulnerability differences among the population that is most likely to be affected by the dams selected. This also contributes to understanding how flood risk perception differs spatially among the study sites.

Rural-Urban Continuum Codes have been updated each decennial since 1974, allowing researchers to observe how population density and metro influence changes occur in smaller residential groups within the county level. Figure 3.18 illustrates the location of the selected dam sites within their watershed boundary, and with respect to their levels of rurality. Due to the geographical nature of a watershed boundary, one or more counties with differing continuum codes may exist within a single watershed. Dams are often constructed with the intent to serve multiple purposes outside of flood control. Particularly in rural areas, dams are used for fire control, irrigation, livestock and fishponds, making land more manageable for agricultural purposes, protecting roads and towns, and water supply. In addition to their multiple services, dams can also provide positive social impacts such as opportunities for economic development (tourism, agriculture, expansion), aesthetic appeal, and increased social capital (sense of community and feeling of belonging, decreased migration) (Hosayni, Mirakzadeh, and Lioutas 2017). As downstream development increases, dam failure can now affect neighborhoods and industrial areas that were once open fields (FEMA 2013). However, the dependency on dams to provide multiple purposes also puts them at a disadvantage should the dam fail. Without a barrier to protect roads, the delivery of essential goods and services during an emergency becomes less effective as populations are smaller and further removed from major population areas.

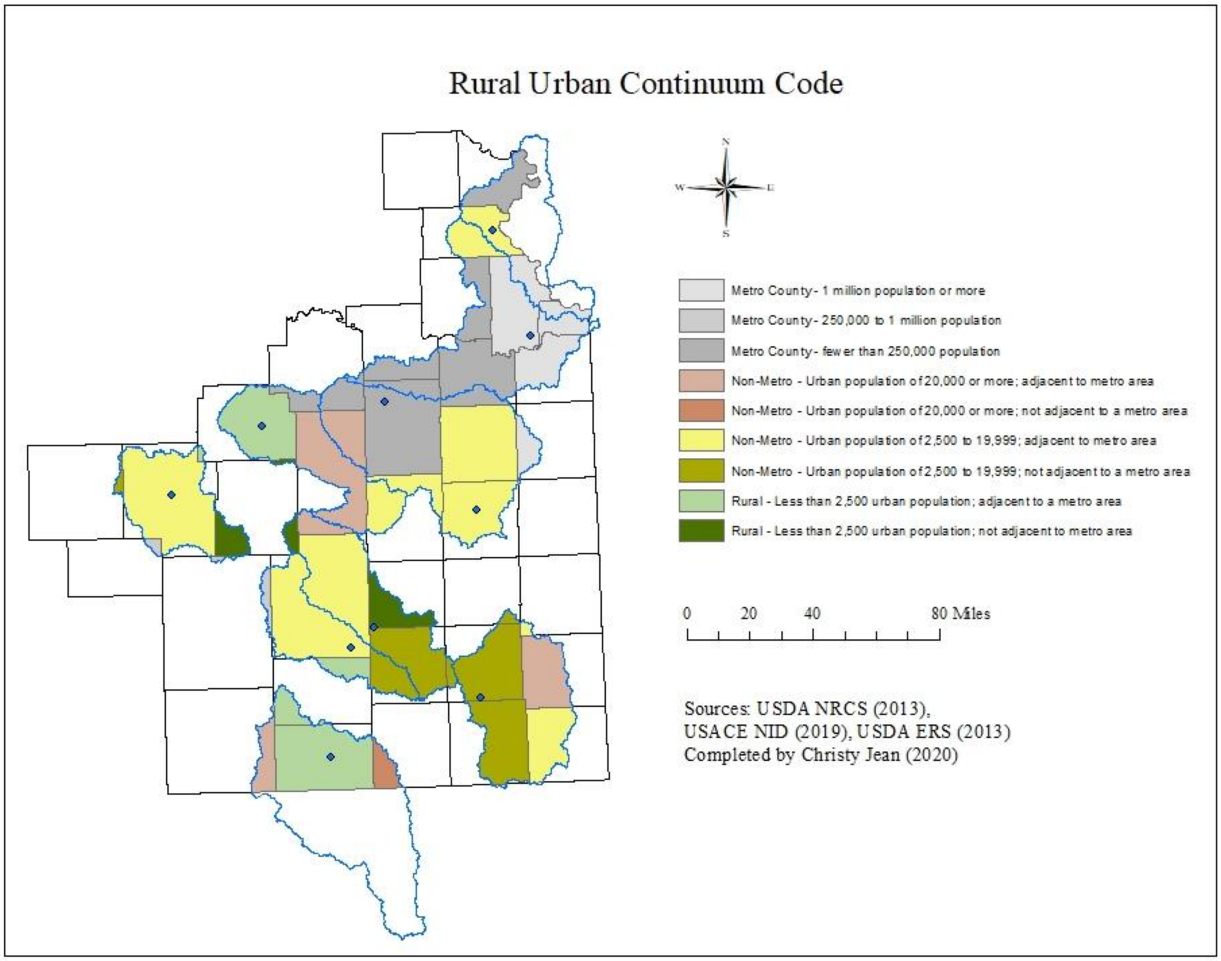


Figure 3.18. USDA ERA 2013 Rural-Urban Continuum Codes for selected 10 dam sites in watershed boundary.

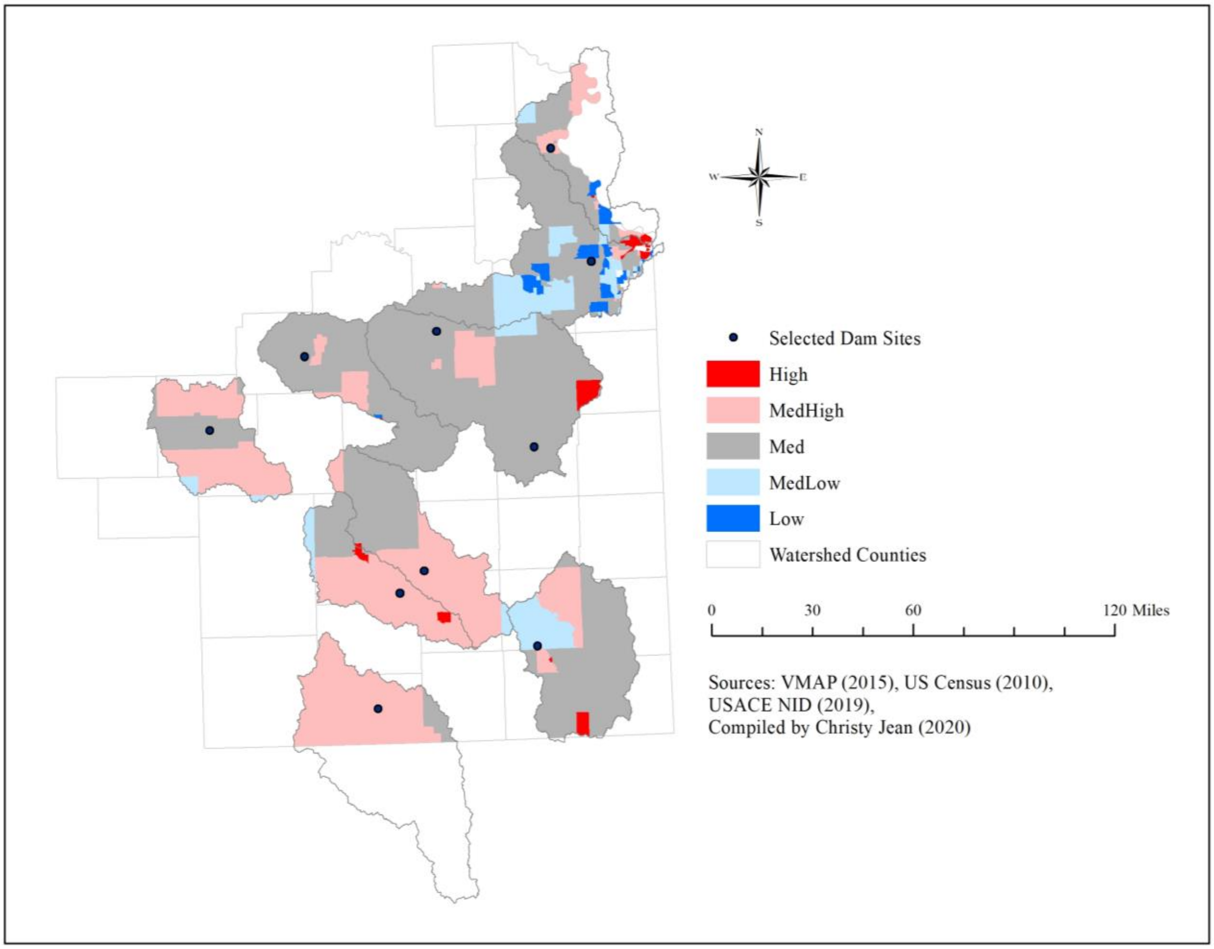
Social Vulnerability

Data used to determine a social vulnerability index are derived from the 2010 U.S. Census Five-Year American Community Survey, 2010-2014. The index uses 29 socio-economic variables (Table 3.11) from the United States Census Bureau to determine a community's ability to prepare for, respond to, and recover from hazards (Hazards and Vulnerability Research Institute). In Figure 3.19, the SoVI classes overlay the selected dam sites within the extent of the watershed boundaries. The combination of multiple SoVI classes within one watershed illustrates how communities in different counties can experience social vulnerability differently from the same source, in this case, the location of a particular dam.

Table 3.11. List of SoVI® 2010-14 Variables (n=29). Source: University of South Carolina Hazards and Vulnerability Research Institute (2021).

Socioeconomic Variables	**Variable Description**
QASIAN	Percent Asian
QBLACK	Percent Black
QHISP	Percent Hispanic
QNATAM	Percent Native American
QAGEDEP	Percent of Population under 5 years or 65 and over
QFAM	Percent of Children Living in 2-parent families
MEDAGE	Median Age
QSSBEN	Percent of Households Receiving Social Security
QPOVTY	Percent Poverty
QRICH200K	Percent of Household Earning over $200,000 annually
PERCAP	Per Capita Income
QESL	Percent Speaking English as a Second Language with Limited English Proficiency
QFEMALE	Percent Female
QFHH	Percent Female Headed Households
QNRRES	Nursing Home Residents Per Capita
HOSPTPC	Hospitals Per Capita (County Level Only)
QNOHLTH	Percent of Population Without Health Insurance (County Level Only)
QED12LES	Percent with Less than 12th Grade Education
QCVLUN	Percent Civilian Employment
PPUNIT	People per Unit
QRENTER	Percent Renters
MDHSEVAL	Median Housing Value
MDGRENT	Median Gross Rent
QMOHO	Percent Mobile Homes
QESTRCT	Percent Employment in Extractive Industries
QSERV	Percent Employment in Service Industry
QFEMLBR	Percent Female Participation in Labor Force
QNOAUTO	Percent of Housing Unites with No Car
QUNOCCHU	Percent of Unoccupied Housing Units
QMORTBRDN	Percent of all households spending more than 40% of their income on housing expenses (Tract Level Only)

The combination of multiple SoVI classes within one watershed illustrates how communities in different counties can experience social vulnerability differently from the same source, in this case, the location of a particular dam. It is important to recognize that SoVI considers population size in its ratings, which affects categorization of rural areas and small towns.



Sources: VMAP (2015), US Census (2010),
USACE NID (2019),
Compiled by Christy Jean (2020)

Figure 3.19. SoVI class of dam locations within associated watershed.

Summary

This chapter provided background information about Kansas's climatic and social conditions, and the historical significance of dams in the state. The current status of dams and identification of the riskiest dams in eastern Kansas address RQ1 and fed into selection of study sites for this research. The mid-continental climate variability in Kansas contributes to severe weather events, which are often exacerbated by the significant variations in the annual precipitation gradients across the state. As climate change is expected to increase the magnitude and frequency of extreme weather events, the social vulnerability of at-risk populations also increases. The concern of natural disasters and hazards has the potential to threaten significant portions of the state's rural population that will directly feel the impacts of climate change and aging dams in their area.

In the early part of the 20th century, the demand to control Kansas' rivers resulted in a state with the second-largest number of dams in the country. Over 6,400 dams in Kansas, with an average age of 51, fragment over 10,000 miles of streams and rivers. At the same time, population density is increasing, and climatic conditions are intensifying, while dams are reaching and exceeding their designed life expectancy.

Intermediate-sized dams have the potential to cause considerable damage in the event of a dam failure. The riskiest dams identified in the eastern portions of Kansas are those that have already exceeded the typical design life of most dams (50-100 years), include a nearby population with a medium to medium-high social vulnerability score, and are expected to experience greater average annual rates of precipitation in the near future. As part of RQ1, the riskiest dams are classified as **high-hazard dams** that meet the criteria mentioned earlier. This included 59 intermediate-sized dams with a medium-high social vulnerability score (18 with an active emergency action plan) and 52 intermediate-sized dams with a medium social vulnerability score (15 with an active emergency action plan). Among the dams selected for the study, four were chosen from the medium-high social vulnerability group (KS0003, KS00011, KS02010, KS02451), four from the medium social vulnerability group (KS00006, KS01248, KS02409, KS02512, and KS07006. The final dam selected was KS02514 which had a social vulnerability of medium-low.

Selected study areas focused on intermediate-sized dams that had an Emergency Action Plan in place based on their hazard classification, an age of 50 years or greater, a primary purpose of flood control, a nearby population viable for sampling, and in a location that is likely to experience increased frequency and more intense 24-hour rainfall totals. Ten study dam sites were selected to gain greater insight into how flood risk perception varies when only part of the population is at foreseeable risk and to compare how perceptions relate to physical risk situations.

Chapter 4 - Questionnaire and Interview Methods

Introduction

Traditionally, researchers examine risk and risk perception separately due to the two concepts' dominantly quantitative versus qualitative approaches. Both are necessary for understanding how a population will respond to hazards and disasters. An explanatory sequential mixed methods approach was used to gain an in-depth perspective of flood risk perception near Kansas dams through mailed questionnaires and semi-structured interviews. In this case, a sequential strategy was used, where interviews followed mailed questionnaires in order to help explore potential explanations of questionnaire results.

Mixed Methods: Design and Approach

The need to generalize a population while gaining an in-depth perspective on the perception of flood risk near Kansas dams required a mixed-methods approach, where quantitative and qualitative data could be integrated. Mixed methods integrate quantitative and qualitative research with a single approach, by merging, connecting, or embedding the data together (Creswell 2014). The intent of qualitative data collection is to locate and obtain extensive information from a small sample while the intent of the quantitative data is to include meaningful statistical tests. The use of mixed methods during research helps in establishing the validity and rigor of both qualitative and quantitative processes. The triangulation of findings from different methods while checking for consistency of results helps to establish validity.

A sequential mixed method approach was used to conduct questionnaires followed by semi-structured interviews in the study areas. Participants were divided into two major groups: A) residents not actively involved with watershed activities, and B) local experts, including watershed managers and members, as well as state and federal agencies associated with dam safety and water resource management. Literature suggests that risk perception puts these two groups at different advantages (Messner and Meyer 2006). This divide creates an additional component in understanding the perception of flood risk at the local level. Interviews were conducted with representatives of both groups; however, the surveys were only distributed to non-expert residents (group A). Since vulnerability can affect one's access to resources, access to political power and representation, and social capital (Cutter et al. 2003), both the questionnaires and interviews include a series of closed questions so at to understand respondent attributes (Hay 2010). The questionnaire included open-ended and closed-ended questions that covered the following topics: flood/dam awareness, risk perception, flood vulnerability, demographic, and socio-economic characteristics (Appendix C).

Questionnaires

The questionnaire used in this study was developed to provide information to improve understanding of how perceptions of risk relate to a physical risk situation, specifically with respect to potential risk related to medium-sized aging dams. The survey design also is meant to be replicable at a variety of scales, which may contribute to understanding of flood risk perceptions – a need in the natural hazards field (Kellens et al. 2011, Birkholz et al. 2014).

Questionnaire Content

The purpose of the questionnaire was to examine how residents near selected Kansas dams perceived flood risk, and to better understand how their perception varied by both physical and social vulnerabilities because geographic characteristics to hazards are significant determinants of flood risk perception (O'Neill 2016). A total of five themes, including flood/dam awareness, risk perception, flood vulnerability, demographic characteristics, and social vulnerability, were addressed through a series of 40 open-ended and closed-ended questions (Appendix C).

Flood and dam awareness were gauged by an individuals' responses to questions addressing their awareness of living in and at-risk areas, flood warning systems, and actions to take in the circumstances of an extreme event (Burningham et al. 2008). To assess risk perception, questions on expected damage (Sjoberg 2000, Ludy and Kondolf 2012, Bosschaart et al. 2013), perceived personal flood exposure/consequences (Bosschaart et al. 2013), and trust in flood safety and/or safety measures (Baan and Klijn 2004) were used. These topics were addressed to help improve understanding of how personal interpretations of flood risk might influence people's likelihood to undertake action (O'Neill 2016).

Linking personal experience and indirect knowledge are critical factors for understanding how physical and social vulnerabilities affect an individual's ability to recover after a hazardous event. Questions related to vulnerability considered previous experience, socio-economic status (Cutter 1996, Messner and Meyer 2006, Mitchell 1989), preparation level (Sjöberg 2000, Baan and Klijn 2004, Bosschaart et al. 2013), and experience with flooding (Sjöberg 2000, Atreya and Ferreira 2012, Baan and Klijn 2004, Kellens et al. 2011, Ludy and Kondolf 2012). Social vulnerabilities may be mediated by other factors, such as cognitive (personal interpretation or previous experience), socioeconomic (age, gender, marital status, incomes, housing tenure, and education), and geographical characteristics (distance or proximity to a hazard) of an area (O'Neill 2016). Socioeconomic data from the US Census and geographical characteristics based on ArcGIS analysis were used to select study sites. Study sites were selected based on hot spot analysis used to identify vulnerable populations by race, poverty level, rural/urban, and age based on census data. These initial characteristics were selected as a base for narrowing down the extensive numbers of dams across the state to be used for the study. Study sites were further narrowed down by those having greater average annual precipitation of more than 32 inches per year and being less than 10 miles distant from the nearest town center.

Table 4.1. Potential Factors Related to Risk Perception and Questionnaire Content.

Factors	Constructs	Questionnaire Content/Theme
Cognitive	Previous experience, damage experienced, emotional/affective responses, negative emotions, public trust, preparedness	Flood/Dam Awareness, Flood/Self Vulnerability, Risk Perception
Socioeconomic	Age, gender, marital status, income, housing, education	Demographic
Geographical	Distance or proximity to hazard, distance to river, elevation, flood risk ratings, expected personal or flood damages	Flood/Dam Awareness, Flood/Self Vulnerability, Risk Perception

The questionnaire content was designed to assess risk perception in the selected study sites by focusing on questions that addressed cognitive, socioeconomic, and geographical factors through themes on flood/dam awareness, risk perception, flood vulnerability, demographic, and social vulnerability (see research objectives in Chapter 1). Examples of cognitively based questions by theme include:

Q3. Has your property ever flooded before? If so, please explain (for examples: approximate date, affected property, depth of water) (Flood/Dam Awareness – RO1, RO2)

Q6. How prepared would you feel in the event of a major flood? (Flood/Self Vulnerability – RO1, RO2, RO3)

Q10. I think my community would be affected by flooding (Risk Perception – RO1, RO2, RO3)

The following are examples of geographically based questions by theme:

Q1. Do you live in a floodplain? (Flood/Dam Awareness – RO1, RO2, RO3)

Q26. My property would be affected if there is a dam failure. (Flood/Self Vulnerability – RO1, RO2)

Q23. How would you rate the risk of dam failure in your area? (Risk Perception – RO1, RO2, RO3)

Additional questions asked for the participant's thinking regarding the potential of future flooding risk associated with development or other physical changes near the dam (see Appendix D).

The questionnaire was designed and structured using the Tailored Design Method, also known as TDM or 'the Dillman method,' conceived by Don A. Dillman in 1978 (Dillman, Smyth, and Christian 2009). The TDM approach was designed to have useful and easy-to-answer questions, accessibility to the researcher's contact information, and explanations of the purpose of the research to encourage participants' responses. Some of these characteristics, particularly explanation of research purposes and provision of contact information, have become standard under human subjects' research rules and institutional review board (IRB) expectations. The layout and construction of open-ended and closed-ended Likert style questions, physical dimensions of the questionnaire, recommended coverage and sampling sizes, and organization of data collection were influenced by the TDM. Specific question wording may be found in Appendix C and description of specific results in the next chapter. Layout also may be seen in the questionnaire copy in the appendix. Procedures were approved by the Kansas State University IRB (9315).

Sampling

For the purposes of understanding how Kansas residents assess their vulnerability to at-risk dams, purposive and criterion sampling were used for participant selection. Purposive sampling is used where a group, individual, or event is being selected to understand a particular phenomenon, unlike random sampling which is often used to generalize a large sample of the target population (Onwuegbuzie and Leech 2007). Criterion sampling involves selecting a population who all share a trait in common relevant to the topic. In this case, criteria were applied to select a population of study dams, and to select a sample of residents for questionnaire distribution. Criteria for this study were based on populations who live near a selected intermediate sized dam, with an existing emergency action plan, in a region that experiences greater average annual precipitation than the rest of the state, and who experience social vulnerabilities (Table 2.2).

Unlike clearly defined county boundaries and property lines, the locations of dams are organized in a more organic nature, with the tributaries of a river setting a distinct set of geographical parameters. Stream and dam locations also affect creation of communities in which the majority of the population may be concerned with water resource use and where there may be a general concern about the effects of flood risk in the area. Several ecological factors, including soil degradation, flood prevention, agricultural land practices, and water control, influence the way people interact with dams.

The target groups for flood risk perception studies often are based on local populations, where residents can provide first-hand knowledge of flood activity and provide insight of their local area. This includes selecting participants whose most helpful characteristics for the purpose of this study stem from their proximity to a dam. Here, the first strategy was to use ‘typical case’ sampling which illustrates what is considered ‘average’ (Hay 2010). Typical case sampling was selected to narrow the range of variation by selecting participants that shared specific geographical characteristics (proximity to a dam, similar experiences with average annual precipitation/heavy rainfall) under the assumption that individuals that lived near a dam and in these regions would behave similarly. The second strategy, criterion sampling (Hay 2010), was used to identify participants who lived within 10 miles either upstream or downstream of a dam with an emergency action plan already in place, and therefore would have knowledge and experience associated with flooding and dams.

The Tailored Design Method (Dillman, Smyth, and Christian 2009) was used to determine a representative sample size of populations near small dams in Kansas, using the formula:

$$N_s = \frac{(N_p)(p)(1-p)}{(N_p)(B/C)^2 + (p)(1-p)}$$

where Ns is the sample size needed, given the size of the population; Np is the number of “units” in the population (people, in this case: 157,460); p is the proportion of the population expected to respond “yes” or “no” to an equation, B is the margin of error, and C is the corresponding Z score associated with the desired confidence level (Dillman, Smyth, Christian 2009).

To achieve a 95% confidence level with a (+/-) 5 margin of error for this survey, the sample size should be 383. Due to subject matter and likely varying interest in dam conditions, questionnaires were mailed to 1,100 addressees in an attempt to achieve a 40% response rate.

Questionnaire Distribution

Ten dam study sites (Table 4.2) were selected based on their construction date and nearness to vulnerable populations using demographic data (American Community Survey 2017), applying the Social Vulnerability Index (SoVI) and recent research examining increasing precipitation trends in Kansas (Rahmani et al. 2016). SoVI scores may contain a range of numbers if the dam or waterway included more than one SoVI shapefile. I worked closely with Lorton Data to use their sampling service. They were unable to provide addresses based on the dam's location but could provide some information on addresses in nearby towns within the county of the dam. I used a combination of Google Earth and ArcGIS to identify where the selected addresses were in relation to the dam. After several addresses had been verified as either 10 miles upstream or 10 miles downstream of the dam, I put the addresses into Excel. Using a random generator through Excel, I was able to select a series of random addresses within the appropriate study area for questionnaire distribution. To maintain control of which address received a questionnaire, each randomly selected address was assigned a number, 1 to 1100.

Table 4.2. Dam Sites.

Dam Study Site	Year Completed	Nearest City	SoVI Score (Range)	SoVI 5 Class	Expected Precip Trend	Precip. Departure from Normal (2021)
Fall River	1948	Fall River	1.4	MedHigh	Increasing	0.8
Marion	1968	Marion	0.71-0.79	Med	Increasing	-1.6
Toronto	1960	Coyville	1.25-1.89	MedHigh	Increasing	6.1
Little Kaw	1964	Mahon	-0.02-0.68	Med	Increasing	1.5
WCB – FRD No. 23	1962	Atchison	2.13	MedHigh	Increasing	-4.3
Switzler Creek	1962	Burlingame	-0.07	Med	Increasing	4.4
Sedan MPD	1965	Sedan	1.4	MedHigh	Increasing	-7.4
Council Grove	1942	Council Grove	0.47	Med	Increasing	-2.
Lake Parson	1959	Parson	-1.96-1.36	MedLow	Increasing	6.4
Cedar Creek	1968*	Greely	.53-.92	Med	Increasing	6.7

In order to determine survey mailings, I geocoded addresses on satellite base maps using ArcGIS to determine estimated population size for the selected dam, which in turn would be used to identify each dam's sample size given a 95% confidence level with 5% margin of error. Only 999 of the mailed questionnaires reached their destinations (101 were undeliverable); with a return of 102 usable completed questionnaires the response rate was 10.2%. **Given the overall low number of responses, analysis of returned questionnaires must treat respondents as the population of study rather than statistically presuming them to be representative of all potential respondents.**

Return rates varied among study sites (Table 4.3). Significant flooding during the week of July 4th, 2019, was noted on several of the returned questionnaires, which may account for higher response rates from the Marion Lake area, in addition to having a larger sample size.

Table 4.3. Questionnaire Distribution.

Dam	Estimated Population Size	Mailed Out	Undeliverable	N Adjusted	Completed
Fall River Lake	100	80	6	74	8
Marion Lake	2000	320	52	268	35
Toronto Lake	100	80	11	69	7
Little Kaw Creek	94	76	8	68	3
FRD No 23	89	73	0	73	10
Switzler Creek	150	108	11	97	7
Sedan MPD	50	45	8	37	2
Council Grove	86	71	0	71	5
Lake Parsons	550	225	5	220	16
Cedar Creek	25	20	0	20	9
Total	**3246**	**1100**	**101**	**999**	**102**

An Excel spreadsheet with the reference numbers assigned during the random selection process contained the recipient's mailing address. Each questionnaire was mailed in a large envelope that contained a color questionnaire (Appendix D), an introductory letter describing the study (Appendix E), and a return envelope with postage. The reference number for each address was handwritten in two separate locations: the bottom left corner of the large envelopes and on the interior of the return envelope in an indiscernible location. The questionnaire packets were mailed out during the summer of 2019. The reference numbers on the outside of the envelope allowed me to track which questionnaire packets were completed. The reference numbers written on the inside of the envelope were used to track which respondents completed the questionnaire and could be removed from the distribution list. Follow-up correspondence was sent to reference numbers that had not been removed from the list. Postcard reminders (Appendix F) were sent to 600 recipients two weeks after the initial packets were mailed out. A total of 300 nonrespondents received a second packet, including a questionnaire and stamped return envelope after one month. Nonrespondents were selected participants that did not respond to the first questionnaire or postcard reminder. A final reminder postcard was sent out two weeks after the second packet was delivered.

Questionnaire Processing and Analysis Methods

As questionnaires from the initial mailing were returned, the mailing address was removed from the spreadsheet, and the reference number was recorded in a separate Excel spreadsheet. By immediately removing the addresses, I was able to send postcard reminders and, eventually, the second packet without sending a reminder or duplicate mailing to someone who had already completed the questionnaire. Removing the addresses also provided anonymity for respondents who had completed the questionnaire before processing their responses.

Questionnaire responses were coded and processed in Microsoft Excel as they were received and did not correspond to the questionnaire reference number. The respondents were assigned identification numbers as they were processed so I could anonymously cite them for open-ended responses. The spreadsheet was divided into three tabs, 1) direct data entry – all responses were recorded here, 2) closed-ended questions, and 3) open-ended questions. The rows were used to record the responses from each respondent. The columns were labeled as Q1- Q40 to correspond to the numbered questions in the questionnaire. Using the respondents reference number, I recorded whether the respondent was upstream (Code: 1) or downstream of the dam

(Code: 2), if they were in an identified FEMA flood zone (Code: 1-11), and to which dam they were associated with (Coded 1-10). It was important that I was aware of their general location in relation to the dam to determine how their actual flood risk related to their perception of flood risk should a major flood event or dam failure occur.

Quantitative data were analyzed in Minitab 18.1 statistical software (2021). Univariate analysis was used to obtain descriptive statistics as a way to describe variables through central tendency (e.g., mean, mode, median) and dispersion (e.g., range, standard deviation). Chi-Square methods were used to test association among nominal variables, while Pearson and Spearman methods were used to identify correlations among interval and ordinal variables, respectively. Association is important in determining if two variables are statistically significant, while correlation identifies the relationship and strength between two variables. Correlation values potentially range from -1 (negative correlation) to 1 (positive correlation), where 0 implies no relationship. Statistically significant correlation coefficient values are where the p-value is less than or equal to the significance level . Cronbach's alpha was used to test the reliability of the mailed questionnaire and of the main categories focusing on flood/dam awareness, flood risk vulnerability/self-awareness, and risk perception. Cronbach's alpha is a measure of internal consistency with a scale ranging from 0 to 1 to determine how closely related a set of items are as a group. When measured items are not correlated or show no covariance, alpha = 0, and only approach closer to 1 when the measured items have shared covariance. Commonly accepted among most social science and medical fields, the universal standard for reliability is when alpha is above .7 (Cho and Kim 2015).

Qualitative (open-ended) responses from the questionnaire were imported into NVivo 11 for coding analysis. NVivo is a software program specifically used to analyze unstructured text, including surveys and interviews. The coding software allows for simple text analysis, such as text search or word frequency, and more in-depth analysis, such as matrix coding queries to identify patterns and themes, and crosstabs to compare open-ended and close-ended questions to each other.

Interviews: selection and questions

Interviews serve as a useful component in understanding perception. Selected participants, interview instruments, and transcription analysis work together to create a holistic view of shared ideas and common themes among individuals. Interviews have been tools utilized to fill gaps in knowledge from observation or the use of census data, while investigating complex behaviors and motivations, essentially bringing people into the research process (Dunn 2010). Research using mixed methods often is done in order to 'triangulate' information gained from different types of collection – to check for consistency – and to supplement data constrained by means of data collection. For this research, interviews served to supplement and aid understanding of questionnaire responses, and to provide a check for consistency between the questionnaire respondents and the more expert interviewees. Interviews with local leaders and experts are instrumental in providing knowledgeable insight while also maintaining a position to receive feedback from local residents and implement change where needed.

The most willing participants were those who already had an interest in dam or flood management. Interviews with decision makers, local experts, and water-resource managers, engineers, or others who were directly involved with the selected dam sites were contacted between the fall of 2019 and the spring of 2020. During my interview process, the reaction to the COVID-19 pandemic made it more difficult to directly contact interviewees. Many potential interviewees were not going to their offices or were not available to take my calls. This extended my interview process over a period of almost 12 months, trying to reach anyone who would be able to provide an expert opinion on the dams I had selected for my site. Based on those I was able to contact, I was able to conduct 17 interviews with appropriate information sources. Personal interview data are thus based on conversations with 17 individuals who were identified through public records (such as those working for government agencies), contacts suggested by other participants familiar with the study area(s), and downstream residents who reached out to speak with me in person instead of or in addition to completing the written questionnaire (Table 4.2). To protect the privacy of the interviewees, positions marked with a number indicate the same occupation at varying dam sites and may include more than one job title. Some interviewees were able to offer feedback on multiple sites due to their position and involvement in multiple study areas.

Table 4.4. Interviewee Positions.

Watershed District Manager (4)
Kansas Department of Water Resources representative
County Extension Agent (3)
Kansas State University Supplemental Nutrition Assistance Program (SNAP) Education Officer (1)
City Manager (2)
States Association of Kansas Watershed District director
Natural Resources Conservation Services representative
Dam Caretakers (2)
Downstream Residents (3)

Given the purposes of the research and the multiple study sites over a relatively broad spatial area, it was understood that representative samples would be extremely difficult to obtain and, indeed, would not necessarily provide the type of information I was seeking. Although I attempted to include a wide range of individuals, limiting factors such as willing participants and the size of the study area can confine the research (Rudestam 2014). Due to travel and work restrictions during the COVID-19 pandemic, many government workers were not coming to work or were not available to answer my calls. Multiple attempts were made for the majority of participants in order to contact them for interviews. Dams are rarely thought of until something goes wrong, creating an "out of sight, out of mind" mentality. All interviews were conducted by phone and recorded after receiving verbal consent from the participant.

The construction of perception through narratives and concepts (Rudestam 2014) provides a platform to understand perceptions of flood risk, through semi-structured interviews. Semi-structured interviews "balance the desire on the part of the researchers to investigate specific topics, while still allowing some flexibility for the participants to discuss issues that they saw as relevant" (Reddy 2011). To maintain flexibility participants are not limited to standardized questions; question sets are structured enough that the researcher can guide the conversation to cover their research topic (Dunn 2010). Each interview was structured around guiding topics (Appendix G) but allowed for the interviewers to follow their own course with the use of more detailed, probing questions. Topics included flood and dam awareness, risk perception, flood vulnerability and risk perception. I asked probing/follow-up questions in an attempt to "explore the boundaries of the participants' knowledge while gaining insight to their thought process'' (Hersha, Wilson, and Baird 2014). One of the advantages of conducting interviews as a way to understand flood risk perception near at-risk dams is the ability of the researcher to address present-day concerns. Location can add to the benefits of interviewees, as when site visits enable greater familiarization with study locations, and when face-to-face interviews provide better opportunities for development of rapport and fuller communication.

Unfortunately, these benefits were not obtained at a time of pandemic and restricted travel, although on-site interviews had initially been planned.

The interviews were semi-structured and designed to last 30-45 minutes, so participants were allowed the freedom to speak as little or as much as they like on a particular question. Prior to the interview, it was explained that the interviews were part of a larger study looking at 10 aging dam sites in eastern Kansas to better understand flood risk perceptions and improve risk communication. When scheduling the interview, I provided a written informed consent to those participants willing to accept the form via email ahead of time (Appendix H). Before starting the interview, I stated that the research had been approved by the Institutional Review Board for Kansas State University[6] I reiterated the first paragraph of the informed consent, ensuring they understood the interview was completely voluntary and at their own discretion, that the interview would be recorded for the purposes of analysis only, and that their personal identification and information would remain completely confidential. Each interviewee agreed to being recorded.

Interview Processing and Analysis Methods

Audio recording, note-taking, and transcribing data from interviews allows for further analysis with the use of coding. Identifying themes can be achieved through the use of latent content analysis, where underlying meanings are explored (Dunn 2010). Other forms of coding include identifying key themes through number counts, contextual references in phrases, and finding similarities within the data. Coding can be managed through qualitative data analysis programs such as NVivo and Atlas.ti. The coding process is meant to sort and retrieve the data (Dunn 2010), which can be accomplished by establishing nodes, or themes where data intersect.

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Nodes are entered into the software to gauge frequency of repeated responses from a target audience (Hersha, Wilson, and Baird 2014). Open-ended responses from the questionnaire and transcribed interviews were uploaded into NVivo to identify meaningful themes. After inserting the data into NVivo, a node matrix was automatically created based on significant noun phrases to identify common themes. Auto coded themes were grouped based on similar stem words (ex: house, houses, and housing).

Phone interviews were recorded using an Olympus VN-541PC digital voice recorder. Audio files of the interviews were uploaded and stored on a secure USB storage device. Although NVivo has the capability to import audio files for automatic transcription, the software has some difficulty transcribing changes in speech patterns (mumbling, talking low, talking too fast, accents) and includes unnecessary interjections. After the files were exported, each audio file was manually transcribed into a prepared word document. The word documents were prepared ahead of time, with the guiding questions I asked during the interview. Transcriptions varied from 1 to 3 hours depending on how long the participant talked. Complete transcriptions were then uploaded into NVivo for coding and analysis.

Summary

An explanatory sequential mixed-methods approach was used in this research to gain greater insight into how flood risk perception varies near Kansas dams among populations at actual risk to a significant flood event or dam failure and populations that are not. This approach consists of two phases, sequentially executed before being interpreted for further results. The first phase allowed for the collection and analysis of quantitative data, in the form of mailed questionnaires. The second phase included collecting and analyzing qualitative data, which involved semi-structured interviews of local stakeholders and water resource experts. An explanatory sequential method is useful in following up quantitative results with qualitative data to explain findings from one phase with data collected in the second phase.

Questionnaires for this study used both open-ended and close-ended Likert-scale questions to provide quantitative and qualitative data covering five themes related to flood risk perception. The Tailored Design Method was used to complete the mailing process for the questionnaires, which occurred over the summer of 2019, beginning in June, and officially ending by August. Eleven hundred questionnaires were distributed among ten dam study sites in Kansas that were selected based on their construction date, nearness to a vulnerable population, and increasing precipitation trends.

Initial contact efforts for interviews were between the fall of 2019 and the spring of 2020. The impact of Covid-19 on local, state, and federal offices directly affected access to the experts needed for the study. Seventeen phone interviews were conducted with local stakeholders and water resource experts, with at least one representative from each dam site. The explanatory sequential mixed method approach provided a general idea of flood risk perception near dams triangulated with rich qualitative data to explain further how risk perception varies among dam sites. In Chapter 5, results based on the methods described in this chapter will be reported.

Chapter 5 - Perceptions

Introduction

A sequential mixed methods approach was used to gather data through the use of mailed questionnaires and follow-up expert interviews on the perceived risk of flooding near selected Kansas dams. Descriptive statistics and correlation analysis of the closed-ended responses from the mailed questionnaire are presented first. Open-ended responses were coded with NVivo software (version 11) and are summarized to provide depth to the close-ended material. Finally, the results of the interviews from key informants provide qualitative data that enhance and broaden information regarding the perceptions and differences between experts and laypeople in order to offer a more comprehensive understanding of how flood risk perception varies between those at actual risk and those less likely to experience flooding in at risk situations. T he study area for the mailed questionnaires and interviews was developed through the initial use of GIS and secondary data to determine where Kansas dams were at an increased risk to dam failure (see Chapter 3).

Mailed Questionnaire

The mailed questionnaire gathered responses from participants on flood/dam awareness, flood vulnerability (self-awareness), risk perception, and socio-demographic data. To achieve a 95% confidence level with a (+/-) 5% margin of error for an estimated total population of 157,460, the sample size should be 383. A total of 1,100 questionnaires and follow-up communications were mailed out in an attempt to achieve a 40 percent response rate. Of the 1,100 questionnaires mailed, 101 were undeliverable making my adjusted sample size 999. Undeliverable questionnaires included mailings that were unopened and returned, delivered to unoccupied addresses, or marked as return to sender. Of the 999 deliverable questionnaires, a total of 102 were completed and returned, providing a 10.2 percent survey response rate. With 102 usable returns from a mailing to 999 potential respondents, the margin of error for my survey is calculated as 9.7 percent for the entire population. Although the response rate was lower than anticipated and the margin of error exceeds a desirable level, the data provide a first look at perceptions related to dam conditions and risk. Due to the low rate of return, **it is best to consider the findings here as representative of sample members rather than the overall population** (157,460) as a whole. Still, sample members are of concern, based on selection criteria, and their views of medium-size dams are relevant to my research topic and guiding questions. With the data limitations the study has been faced with, **the 102 respondents make up the population to which questionnaire responses are applicable**. Sampling and responses related to overall population are described below, but findings are pertinent to the respondent group rather than being generalizable.

The questionnaires were distributed based on the estimated population size near each dam (Table 5.1). In an attempt to reach a greater response rate from the smaller populations, I mailed questionnaires to 70-80 percent of the estimated population. Stratified random sampling was used: for larger dams, such as Marion Lake Dam, I used a sample size of approximately 15 percent of the population, with the expectation that I would receive at least a 10 percent response rate from those areas where the estimated population size exceeded 200 (Table 5.1).

Table 5.1. Mailing Distribution.

Dam ID	Dam Name	Est. Pop Size	Mailed Out	Percentage
KS0003	Fall River Lake	100	80	80%
KS00006	Marion Lake	2000	320	16%
KS00011	Toronto Lake	100	80	80%
KS01248	Little Kaw Creek	94	76	80%
KS02010	FRD NO 23	89	73	82%
KS02409	Switzler Creek	150	108	72%
KS02451	Sedan MPD	50	45	90%
KS02512	Council Grove	86	71	82%
KS02514	Lake Parsons	550	225	40%
KS07006	Cedar Creek	25	20	80%
	Total	**3246**	**1100**	

Return rates varied among sites (Table 5.2). Significant flooding during the week of July 4, 2019, was noted in several questionnaires which may account for higher response rates from the Marion Lake study area (Marion County), in addition to having a larger sample size.

Table 5.2. Total completed/useable questionnaires.

Dam ID	Dam Name	Undeliverable	N Adjusted	Completed	Complete (%)
KS0003	Fall River Lake	6	74	8	4%
KS00006	Marion Lake	52	268	35	5%
KS00011	Toronto Lake	11	69	7	7%
KS01248	Little Kaw Creek	8	68	3	7%
KS02010	FRD NO 23	0	73	10	7%
KS02409	Switzler Creek	11	97	7	10%
KS02451	Sedan MPD	8	37	2	11%
KS02512	Council Grove	0	71	5	14%
KS02514	Lake Parsons	5	220	16	13%
KS07006	Cedar Creek	0	20	9	45%
	Total	**101**	999	**102**	

The majority of the respondents were married (66%), white (99%), men (64%), and either employed full time (44%) or retired (42%). They owned their homes (91%), which were described as single-family homes, 1 story (63%), or 2 story (35%). The high representation of whites is a direct reflection of the demographics in the area as reported by the 2010 Census (Figure 5.1). Men are overrepresented in the respondent group (Figure 5.2).

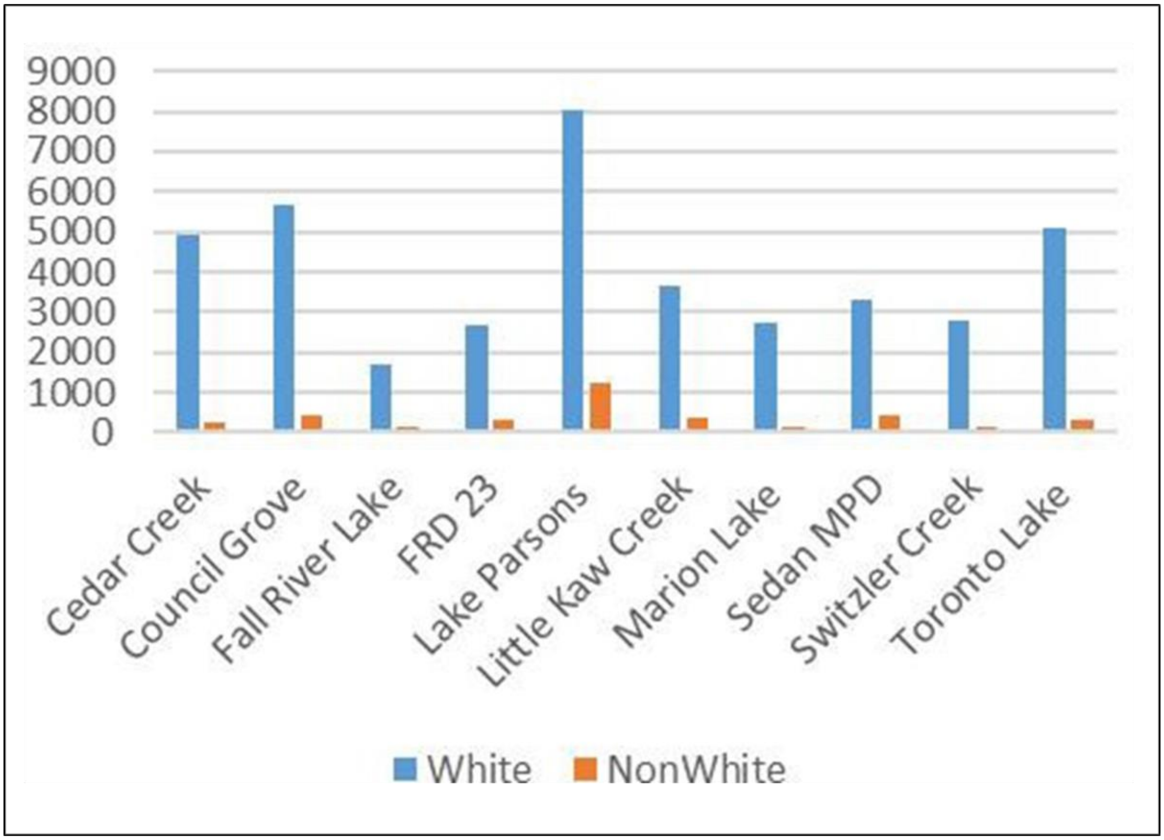

Figure 5.1. Race by dam location (census tracts) (US Census 2010).

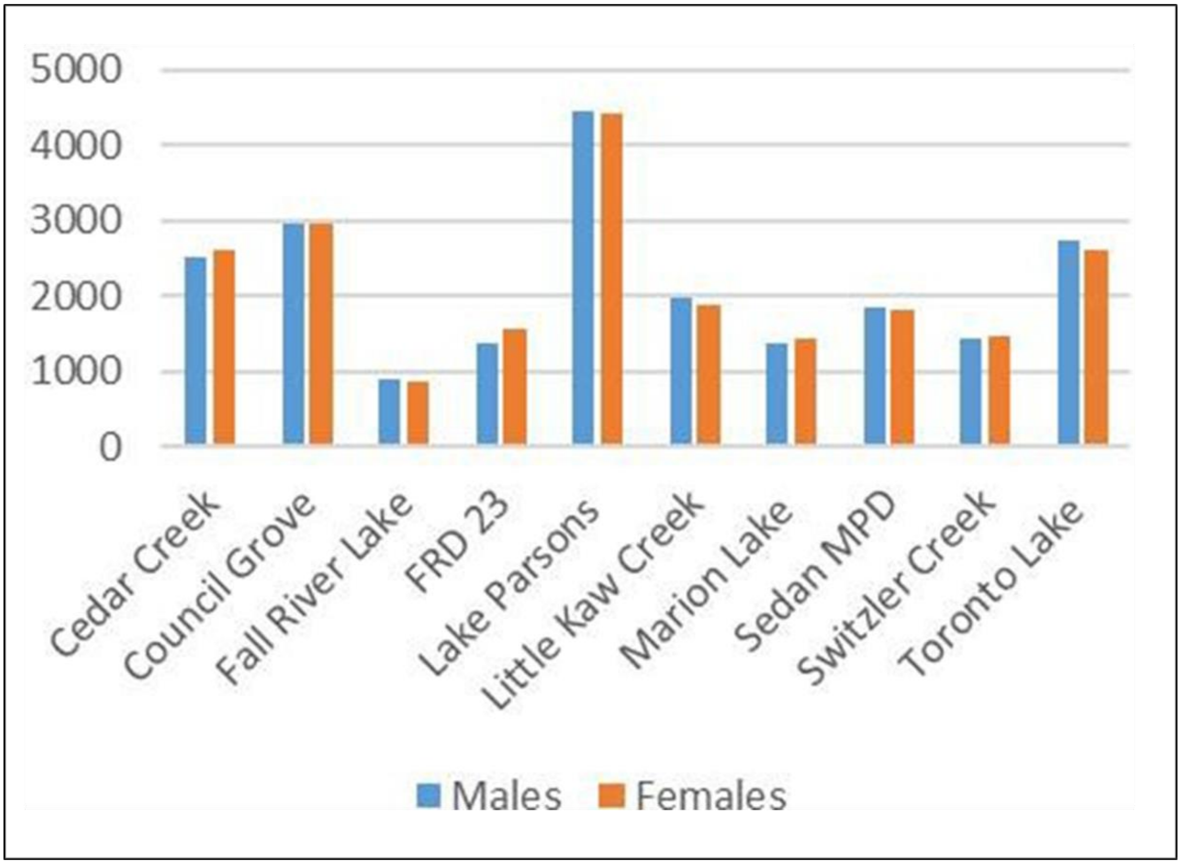

Figure 5.2. Gender by dam location (census tracts) (US Census 2010).

The highest number of respondents were between the ages of 55-64 (27%), followed closely by age groups 65-74 (23%) and 75+ (24%). Most respondents reported living in their residence between 21 and 30 years (21%). Question 40 asked “What is your annual household income?” and were given five possible responses: $80,000 or above (29%), $60,000 to $79,999 (18%), $40,000 to $59,999 (23%), $20,000 to $39,999 (19%), and under $20,000 (12%). The median response for annual household income was $40,000 to $59,999. EEO-1 Job Categories and Titles (EEOC 2006) were used to categorize responses to the open-ended question “What kind of work do you do?”. The EEO-1 classification guide is used to convert Census job codes and titles into the ten EEO-1 survey job categories. Each job category defines the job and provides examples of the types of jobs in the category. Written responses were categorized into one of the ten survey job categories to be grouped and analyzed in a closed-ended format. Of the 92 completed responses to question 39, the top 3 occupations given were professionals (30%), craft workers (21%), and administrative support workers (15%). Respondents categorized as professionals held occupations such as pilot, banker, teacher, doctor, lawyer, farmer, and veterinarian. Craft workers included mechanics, machinists, contractors, and repair personnel. Administrative support workers were respondents who held various positions with the city, social workers, and office managers. Seventy-seven of 102 respondents were located downstream of the dam, which corresponds to the more significant number of downstream residents who received a questionnaire: 80% of the mailed questionnaires were delivered to addresses downstream of the selected dam sites.

Closed-Ended Responses

Close-ended questions were divided into three categories: flood/dam awareness, flood vulnerability/self-awareness, and risk perception of dam failure. A Likert Scale rating system was used for the majority of questions in the mailed survey as a way to gauge a collective sense of attitudes and opinions from the participants. In most cases, the respondents were given either a multiple-choice option of 3 responses or a Likert rating with 5 potential responses.

Non-Likert multiple-choice questions were intentionally written and coded differently based on the style of the question. They were rated on a 3-pt scale, with the options yes, no, or don’t know, and were coded 1, 2, and 3, respectively. Some research suggests that offering a “don’t know” option encourages people to admit when they lack the necessary information or experience to provide an answer or defend an opinion (Krosnick and Presser 2010). Questions 1-5 and 8 are categorized as flood/dam awareness questions but were not included as a 5-pt. Likert scale question so that the respondents were given the opportunity to select “Don’t know” if they felt they did not have the information needed to answer the question.

These questions were designed to be answered quickly without intimidating the participant. For example, Question 1’s “Do you live in a floodplain?” is followed by the selection options of Yes, No, and Don’t know. By providing the “don’t know” option, the respondent is able to answer the question without feeling the need to acquire additional information or to justify their answer. A summary of the multiple-choice questions is located in Table 5.3.

Table 5.3. Three-point multiple choice questions.

Question No.	Question	Questionnaire Content/Theme
1	Do you live in a floodplain?	Flood/Dam Awareness
2	Is your property below the water level of the nearby river?	Flood/Dam Awareness
3	Has your property ever flooded before?	Flood/Dam Awareness
4	Do you purchase flood insurance for your home?	Flood/Dam Awareness
5	Has flooding ever affected you indirectly?	Flood/Dam Awareness
8	Has anyone ever told you that your property is at risk of flooding?	Flood/Dam Awareness

The responses for the Likert scale questions focused on level of agreement, preparedness, concern, confidence, and risk. They were rated on a 5-point scale with 1 as the lowest level of response (e.g., strongly disagree) and 5 as the highest (e.g., strongly agree). Neutral responses on the 5-point Likert scale were rated and coded as 3. Specific terms associated with each rating level, such as those signifying levels of agreement, are indicated with a presentation of the responses below (Table 5.4) and may be seen on the questionnaire form (Appendix D). Additional tables are included for question 7 (Table 5.5) and question 18 (Table 5.6), which went beyond the 5-pt Likert rating scale. Question 7: “What are you most likely to experience if there is a major flood event in your area?” had a series of 6 possible responses for the participants to indicate where they were most likely to experience flooding on their property and in their home. Question 18 was a rank order multiple choice question where participants were given a list of ten purposes of a dam and asked to rank the top three purposes they thought were relevant for the dam in their area. The respondents were instructed to rank them in order of 1,2,3, with number one being the primary purpose they thought the dam was constructed.

Table 5.4. Close-ended responses: Responses to 5-point Likert scale items.

	Response item	Responses (low to high)				
		1 n (%)	2 n (%)	3 n (%)	4 n (%)	5 n (%)
Flood/Dam awareness	How confident are you that you could explain the purpose of a dam?	2 (2%) Very unconfident	9 (9%) Somewhat unconfident	9 (9%) Neither	33 (33%) Somewhat confident	46 (46%) Very confident
	Primary - Rank the top 3 purposes of the dam in your area	(See Table 5.5)				
	I think the dam is well maintained by the responsible party.	7 (7%) Very unconfident	5 (5%) Somewhat unconfident	25 (26%) Neither	39 (40%) Somewhat confident	22 (22%) Very confident
	I think the dam will protect against flooding.	3 (3%) Completely Disagree	8 (8%) Disagree	26 (26%) Neither	44 (44%) Agree	18 (18%) Completely agree
	I think the dam will provide sufficient flood control beyond its designed life expectancy.	4 (4%) Completely Disagree	12 (12%) Disagree	44 (44%) Neither	29 (29%) Agree	10 (10%) Completely agree
	I am not worried about the designed life expectancy of the dam.	6 (6%) Completely Disagree	20 (20%) Disagree	30 (31%) Neither	26 (27%) Agree	16 (16%) Completely agree
Flood vulnerability/Self awareness	How prepared would you feel in the event of a major flood?	10 (10%) Very prepared	13 (13%) Somewhat prepared	28 (28%) Neither	36 (36%) Somewhat prepared	14 (14%) Very prepared
	What are you most likely to experience if there is a major flood event in your area?	(See Table 5.6)				
	Have you ever felt concerned that your property was at risk during a flood event?	11 (11%) Very concerned	32 (31%) Somewhat concerned	59 (58%) Not concerned at all	0 (0 %) Somewhat concerned	0 (0 %) Very concerned
	I think my community would be affected by flooding.	2 (2%) Completely Disagree	5 (5%) Disagree	15 (15%) Neither	34 (34%) Agree	45 (%) Completely agree
	I think my community could be affected by flooding in the coming year.	3 (3%) Completely Disagree	14 (14%) Disagree	46 (46%) Neither	21 (21%) Agree	16 (16%) Completely agree
	My property could be affected by flooding from the river	24 (24%) Completely Disagree	27 (27%) Disagree	12 (12%) Neither	19 (19%) Agree	18 (18%) Completely agree
	If there is a flooding event, it would affect my livelihood	17 (17%) Completely Disagree	30 (30%) Disagree	18 (18%) Neither	24 (24%) Agree	11 (11%) Completely agree
	If there is a flooding event, daily life would be disturbed for a long time.	12 (12%) Completely Disagree	21 (21%) Disagree	26 (26%) Neither	27 (27%) Agree	14 (14%) Completely agree
	If there is a flooding event, it would be a life-threatening situation for my and my family.	25 (25%) Completely Disagree	39 (39%) Disagree	24 (24%) Neither	5 (5%) Agree	6 (6%) Completely agree
Risk perception of dam failure	How would you rate the risk of dam failure in your area?	33 (34%) Low Risk	24 (25%) Somewhat low risk	28 (29%) Medium risk	6 (6%) Somewhat high risk	6 (6%) High risk
	In the event of a dam failure, would you be concerned about flood risk your area?	9 (9%) Very unconcerned	13 (13%) Somewhat unconcerned	5 (5%) Neither	28 (28%) Somewhat concerned	44 (44%) Very concerned
	Are you more at risk to dam failure/flood damage than others in your area?	36 (36%) Low Risk	29 (29%) Somewhat low risk	12 (12%) Somewhat at risk	11 (11%) Moderately at risk	11 (11%) Much more at risk
	My property would be affected if there is a dam failure.	20 (20%) Strongly Disagree	19 (19%) Disagree	15 (15%) Neither	22 (22%) Agree	25 (25%) Strongly agree
	Do you feel confident in your ability to protect 1) yourself and family, 2) property in the event of a dam failure?	6 (6%) Very unconfident	11 (11%) Somewhat unconfident	12 (12%) Neither	38 (38%) Somewhat confident	33 (33%) Very confident

Table 5.5. Close-ended responses: Responses to question 18.

		Response Item		
		Rank the top 3 purposes of the dam in your area		
Responses (low to high)		**Primary**	**Secondary**	**Teritiary**
1 n (%)	86 (33%) Flood Control	78 (80%)	5 (6%)	3 (4%)
2 n (%)	1 (0%) Fire Protetion	0 (0%)	0 (60	1 (1%)
3 n (%)	6 (2%) Stock or Small Fish pond	1 (1%)	4 (65	1 (1%)
4 n (%)	23 (9%) Fish and Wildlife Pond	1 (1%)	18 (21%)	4 (5%)
5 n (%)	6 (2%) Debris Control	0 (0%)	5 (6%)	1 (1%)
6 n (%)	4 (2%) Hydroelectric	1 (1%)	2 (2%)	1 (1%)
7 n (%)	7 (3%) Irrigation	0 (0%)	3 (3%)	4 (5%)
7 n (%)	63 (24%) Recreation	4 (4%)	31 (36%)	28 (35%)
9 n (%)	55 (21%) Water Supply	10 (10%)	17 (20%)	28 (435
10 n (%)	12 (5%) Don't Know/Other	3 (3%)	1 (1%)	8 (10%)

Table 5.6. Close-ended responses: Responses to question 7.

Response Item	Responses (low to high)					
	1 n (%)	2 n (%)	3 n (%)	4 n (%)	5 n (%)	6 n (%)
What are you most likely to experience if there is a major flood event in your area?	62 (65%)	5 (5%)	3 (3%)	1 (1%)	3 (3%)	21 (22%)
	Water in the yard, but not the house	Standing water in the house	Standing water above 5 inches in the house	Standing water above waist level in the house	First floor in many houses would be flooded	I'm not sure

By coding the responses, I was able to calculate a numerical summary of central tendency and dispersion from the data collected (Table 5.7). A complete summary of descriptive statistics for the close-ended survey questions is located in Appendix J. Measuring central tendency using mean, median, and mode provided a center of distribution that was most typical/representative of the data collected. In order to determine the variability among data values, I used standard deviation to calculate how far each data value was from the mean. Responses and histograms for closed-ended questionnaire questions are listed in Appendix K. Cronbach's alpha was calculated to determine the internal consistency of 17 Likert-Scale closed ended questions. The internal consistency refers to how closely related a set of items (variables based on questions from the questionnaire) are to each group of concerns (flood/dam awareness, flood vulnerability/self-awareness, and dam failure).

Table 5.7. Close-ended responses: Summary statistics of multiple-choice questions.

Variable	N	Percent	Mean	StDev	Min	Med	Max	Mode	N for Mode	Skew	Kurt
Floodplain	100	98	1.83	1.01	1	2	9	2	45	3.76	25.1
Prior flooding	100	98	1.78	0.61	1	2	3	2	58	0.16	-0.49
Standing water level	101	99	2.61	1.91	1	2	9	2	81	2.99	7.48
Insurance	101	99	1.93	0.26	1	2	2	2	94	-3.44	10.1
Warning	100	98	1.85	0.56	1	2	3	2	67	-0.05	0.06
Indirect flooding	101	99	1.33	0.51	1	1	3	1	70	1.2	0.37
Open-Ended: Yes/No	100	99	1.10	0.30	1	1	2	1	90	2.71	5.44
Open-Ended: Location to dam	65	66	1.80	0.54	1	2	3	2	44	-0.15	0.04
Coded: Responsible	82	80	6.94	2.71	1	8	11	8	28	-0.69	-0.44

In descriptive statistics, skewness and kurtosis can be used to summarize the asymmetry of data distribution and whether the data is heavy- or light-tailed relative to a normal distribution, respectively. Skewness is a measurement used to indicate whether a distribution of data is distorted by analyzing the direction of outliers. A normal distribution has zero skew. A skewness with a value less than -1.0 means the distribution is left-skewed. Both location and flood zone variables have a left-skew distribution. One of the primary purposes of the questionnaire was to determine whether respondents were aware of their location and vulnerability in relation to a nearby at-risk dam. Additional data was used to compare the actual location of the respondent (based on addresses) to the respondents' ability to identify their location. The **actual location** (geographic situation) of the respondent considered the three variables: 1) whether the respondent lived upstream or downstream of the selected dam site, 2) their location based on current flood zone maps, and 3) the dam they were most closely associated with (Appendix C). Based on the skewness measurement, the actual location of most respondents has a left-skewed distribution (values less than -1.0). For the upstream/downstream variable, a left-skewed distribution indicates that most respondents lived downstream of the dam (Table 5.8, Appendix K). As to where the respondents were located based on FEMA flood-zone maps, the skewness measurement of -1.38 (Table 5.8, Appendix K) indicates that most respondents lived in the 50-100m buffer zone, as depicted in Appendix B.

Table 5.8. Summary statistics, actual location data.

Variable	N	Percent	Mean	StDev	Min	Med	Max	Mode	N for Mode	Skew	Kurt
Location	102	100	1.75	0.43	1	2	2	2	77	-1.2	-0.56
Flood zone	102	100	7.78	3.30	1	9	11	9	37	-1.38	0.37
Dam	102	100	4.56	3.42	1	4	10	1	35	0.35	-1.48

Given a normal distribution, kurtosis (the measure of whether a distribution is a heavy-tailed or light-tailed relative to the normal distribution) has a normal distribution of 3. Anything less than 3 is light-tailed and is considered to be platykurtic. A platykurtic distribution means the excess kurtosis value is negative, which also means it has fewer extreme events (positive or negative) than a normal distribution. The kurtosis of the three variables in Table 5.8 are each below three, which means that they have fewer extreme outliers than the normal distribution.

For the first topic, flood/dam awareness, each of the questions was designed to measure how the respondents were able to self-assess their own level of awareness when it comes to the purpose, maintenance, and expected design life of the selected dam site closest to them. Flood/dam awareness questions were made up of five 5-point Likert scale questions (Table 5.9), with a Cronbach's alpha of .93. The second topic, flood vulnerability/self-awareness, targeted the respondent's previous flooding experience and how they gaged their level of concern regarding future flood events. This included questions about how their property, community, and livelihood would be affected by a future flood event. Flood vulnerability/self-awareness questions were comprised of seven 5-point Likert scale questions and had a Cronbach's alpha value of .77.

Questions on the third topic, risk perception of dam failure, were aimed at understanding how respondents gaged their level of flood risk in the event of a dam failure, whether the location of the dam put them more at risk than others, and how it would affect their ability to protect their property and their ability to protect their family. Risk perception of dam failure had five 5-point Likert scale questions and had a Cronbach's alpha value of .65. All three topics contribute to understanding flood risk perception near Kansas dams. The reliability of the questionnaire scored at 0.80, indicating that there is .37 chance of random error in the scores.

Based on the general rule of thumb for Cronbach’s alpha, where an alpha greater than 0.9 is excellent; an alpha greater than .08 is good; and an alpha greater than 0.7 is considered acceptable (George and Mallery 2003), this suggests the survey instrument is reliable, in that it is likely to produce the same or similar results if the same individual were to retake the test under similar conditions. Cronbach alpha coefficients of 0.93, 0.77, and 0.65 were reported for flood/dam awareness, flood vulnerability/self-awareness, and risk perception of dam failure, respectively. In this case, the Cronbach’s alpha value indicated a chance of random error based on the questions associated with risk perception of dam failure.

Table 5.9. Close-ended responses: Summary statistics for 5-point Likert Scale questions.

	Variable	N	Percent	Mean	StDev	Min	Med	Max	Mode	N for Mode	Skew	Kurt
Flood/Dam Awareness	Explain Dam Purpose	99	97	4.13	1.05	1	4	5	5	46	-1.2	0.7
	Primary Purpose	98	96	2.48	3.05	1	1	10	1	78	1.67	0.95
	Secondary Purpose	86	84	6.49	2.46	1	8	10	8	31	-0.71	-0.74
	Tertiary Purpose	79	78	7.84	2.11	1	8	10	8, 9	28	-1.97	3.48
	Well-Maintained	98	96	3.65	1.10	1	4	5	4	39	-0.82	0.31
	Protect against flooding	99	97	3.67	0.97	1	4	5	4	44	-0.66	0.3
	Operate beyond designed life expectancy	99	97	3.29	0.95	1	3	5	3	44	-0.19	0.05
	Not Worried about life expectancy	98	96	3.27	1.15	1	3	5	3	30	-0.12	-0.78
	Coded: Responsible	82	80	6.94	2.71	1	8	11	8	28	-0.69	-0.44
Flood vulnerability/Self awareness	Preparedness	101	99	3.31	1.16	1	3	5	4	36	-0.47	-0.52
	Property likely to experience	95	93	2.38	2.11	1	1	6	1	62	1.03	-0.82
	Concern about property	102	100	2.47	0.69	1	3	3	3	59	-0.93	-0.34
	Community affected	101	99	4.14	0.98	1	4	5	5	45	-1.13	0.92
	Comm. affected w/i coming year	100	98	3.33	1.01	1	3	5	3	46	0.08	-0.35
	River flood affect property	100	98	2.80	1.46	1	2	5	2	27	0.24	-1.37
	Affect livelihood	100	98	2.82	1.28	1	3	5	2	30	0.17	-1.13
	Daily life disturbed	100	98	3.10	1.24	1	3	5	4	27	-0.13	-0.95
	Life-threatening	99	97	2.27	1.09	1	2	5	2	39	0.85	0.4
Risk perception of dam failure	Concern of flood risk after dam failure	99	97	3.86	1.36	1	4	5	5	44	-0.97	-0.41
	More at risk than others	99	97	2.31	1.36	1	2	5	1	36	0.78	-0.65
	Property affected by dam failure	101	99	3.13	1.48	1	3	5	5	25	-0.13	-1.41
	Able to protect family/property	100	98	3.81	1.19	1	4	5	4	38	-0.92	-0.04
	Rate risk of dam failure	97	95	2.26	1.18	1	2	5	1	33	0.66	-0.27

Flood/Dam awareness

I asked respondents to gage their own level of dam knowledge and awareness through a series of close ended questions, with one question on the primary purpose of a dam, divided into 3 parts. When asked “How confident are you that you could explain the purpose of a dam?”, the overwhelming response was that people understood and could communicate the purpose of a dam (mean = 4.13; mode = 5). To gain an understanding of how well people knew the purposes of the dam in their area, Question 18 was a 3-part question that asked respondents to rank the top three services they felt the selected dam site was intended for. Most people identified flood control as the primary purpose of the dam, only 20 (20.4%) of the 98 respondents listed something else as the primary purpose. Of all three purposes combined, 12 respondents did not know or felt the dam had a purpose other than the 9 options provided. The options listed in the questionnaire for Question 18 are also the same options that the U.S. Army Corps of Engineers uses to identify the purpose of dams in the National Inventory Database.

When respondents were given the statement “I think the dam is well maintained by the responsible party,” the mean value of 3.65 suggests that most respondents were near neutral and neither strongly agreed nor disagreed. In the open-ended questions, respondents reported their opinions about who or what entity should be responsible for dam maintenance. Common responses were coded 1-11. The majority of respondents felt the U.S. Army Corps of Engineers were responsible for dam maintenance. Responses marked as other included “God,” “The DAM LEVEL is CONTROLLED by HUMANS!!,” “The dam in my area is not for flood control,” and the “Builder of the dam. Engineer who designed it.”

Table 5.10. Question 28 Common Responses.

Response Item		
Who should be held responsible in the event a dam is no longer able to provide flood control?		
Code		n(%)
1	Land/Property Owners	4 (5%)
2	Watershed District/Dept.	2 (2%)
3	City	9 (11%)
4	County	3 (4%)
5	State	4 (5%)
6	Federal Government	6 (7%)
7	Government	4 (5%)
8	U.S. Army Corps of Engineers	28 (34%)
9	More than 1 answer	12 (15%)
10	Unsure	4 (5%)
11	Other	6 (7%)

Nearly two out of three respondents (62 percent) felt the dam could protect against future flooding. In a separate statement that asked respondents if they were worried about the design life of the dam, slightly more than one-third of (39 percent) said they were not worried, whereas 26 percent disagreed with the statement. The largest consensus of respondents (44 percent) neither agreed nor disagreed when asked if they thought the dam would be effective beyond its designated design life.

Flood Vulnerability/Self-awareness

In terms of preparedness, half of respondents felt very prepared (14 percent) or somewhat prepared (36 percent) in the event of a major flood. Only 23 percent felt somewhat unprepared or very unprepared. The majority of respondents (65 percent) reported that they were likely to experience water in the yard but not in the house during a flood event. Of the 95 respondents who answered this question, only 21 (22 percent) were not sure what type of flooding they were likely to experience. Fifty-nine percent of respondents were not concerned at all when asked, “Have you ever felt concerned that your property was at risk during a flood event?”. Flooding from the nearby river was not a major concern for most respondents. The mean value of 2.8 (and mode of 2) suggests that most respondents disagreed that their property could be affected by flooding from the river.

With respect to community, 79 out of 101 (78 percent) respondents agreed or completely agreed that their community would be affected by flooding (Question 10), but 14 percent disagreed, and 3 percent completely disagreed that the community would be affected by flooding within the coming year (Question 11). With most unsure – 46 percent neither agreeing nor disagreeing that flooding would have an effect during the next year – a fairly large proportion (37 percent) suspected that there could be flooding effects on their community within the year. In spite of these indications, people feel relatively safe in their communities with little concern about flood disruption. The majority of respondents disagreed that their livelihood would be affected (47 percent), their daily life disturbed (42 percent), or that they were likely to be in a life-threatening situation (65 percent).

Dam failure risk perception

Overall, respondents felt a medium to somewhat low risk when asked to rate the risk of dam failure in their area. However, when asked “In the event of a dam failure, would you be concerned about flood risk in your area?” there was an overwhelming concern: out of 99 respondents, 44 (44 percent) were *very concerned* and 28 (28 percent) were *somewhat concerned*. As a follow up, respondents were asked whether they felt they are more at risk from dam failure/flood damage than others in their area. Twenty-nine (29 percent) respondents felt *slightly at risk* and 36 (36 percent) felt they were *not at risk*. Personal risk perceptions vary from those for property effects: most respondents *agreed or somewhat agreed* (25 and 22 percent, respectively) that their property **would** be affected in the event of a dam failure. More than three-quarters of respondents felt confident in their ability to protect their family or property.

Statistical analysis of quantitative data was analyzed in Minitab Statistical Software. Spearman's rank correlation analysis was used to determine associations between close-ended ordinal variables. Some open-ended questions were converted to ordinal ranks so they could be incorporated into the analysis. This included open-ended questions on who should be held responsible in the event of a dam failure, length of time at residence in years, town, county, age, and occupation. The associations most important for this study are related to risk perception. One of the main research questions is "how do local populations' perceptions of risk and vulnerability to at-risk dams vary?" Table 5.11 displays the Spearman's rank correlation values for associations between the ordinal level of risk perception (more at risk than others) and other ordinal categories with 95% confidence or better. The higher the value, suggests the stronger the relationship between the variables. In Table 5.11 the independent variables are listed when risk perception as the dependent variable. Only variables with a Spearman's rho p-value of 0.95 or higher were included in the table. Positive correlations indicate that these variables are moving in the same direction, where an increase in the independent variable also means that there is an increase in risk perception. Negative correlations signify that as one variable increases, the other variables, such as dams being seen as efficient or well maintained, tend to decrease.

Table 5.11. Spearman correlation between level of risk perception and other close-ended variables.

Variable	Spearman's Rho
Property affected	0.702
Daily Life	0.531
Life-threatening	0.527
Concern of dam failure	0.513
Livelihood	0.493
Community affected in coming year	0.237
Community affected	0.222
Dams well maintained	-0.26
Dam efficacy	-0.31

To determine how perceptions deviated from reality, I first examined whether residents who perceived living in a flood plain (Q1) actually lived in identified FEMA flood zone areas (Figure 5.3). The study found that most participants were more likely to identify whether they lived in a flood zone correctly. Participants who lived in a flood zone and answered yes to Q1 represented 77% of the total responses. A total of 22% of respondents who lived in a flood zone said they did not live in a floodplain or they didn't know. Interestingly, a significant percentage of respondents who answered no to Q1 lived in an area where a digitized FEMA flood map was unavailable.

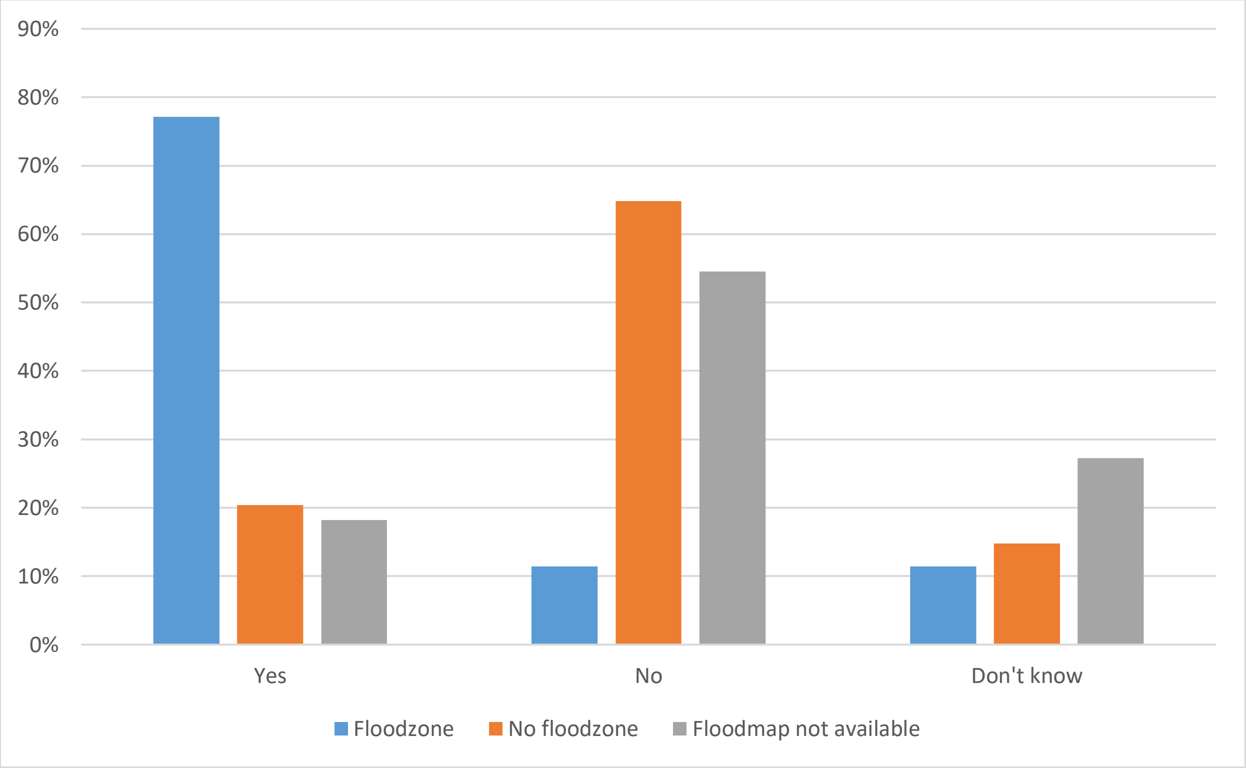

Figure 5.3. Perceptions based on Q1 given actual location

Findings from the study also revealed that respondents who lived in a flood zone felt their property would be affected if there were a dam failure (Figure 5.4) but still only considered themselves slightly at risk compared to others in the area (Figure 5.5). This suggests that while most participants could accurately identify their location in a flood zone, there is still a false sense of security among many flood zone-dwelling respondents who only find themselves or their property slightly at risk. This is consistent with flood risk literature (Terpstra et al. 2009, Burningham et al. 2008) which attributes a false sense of security based on the temporal removal of flood events.

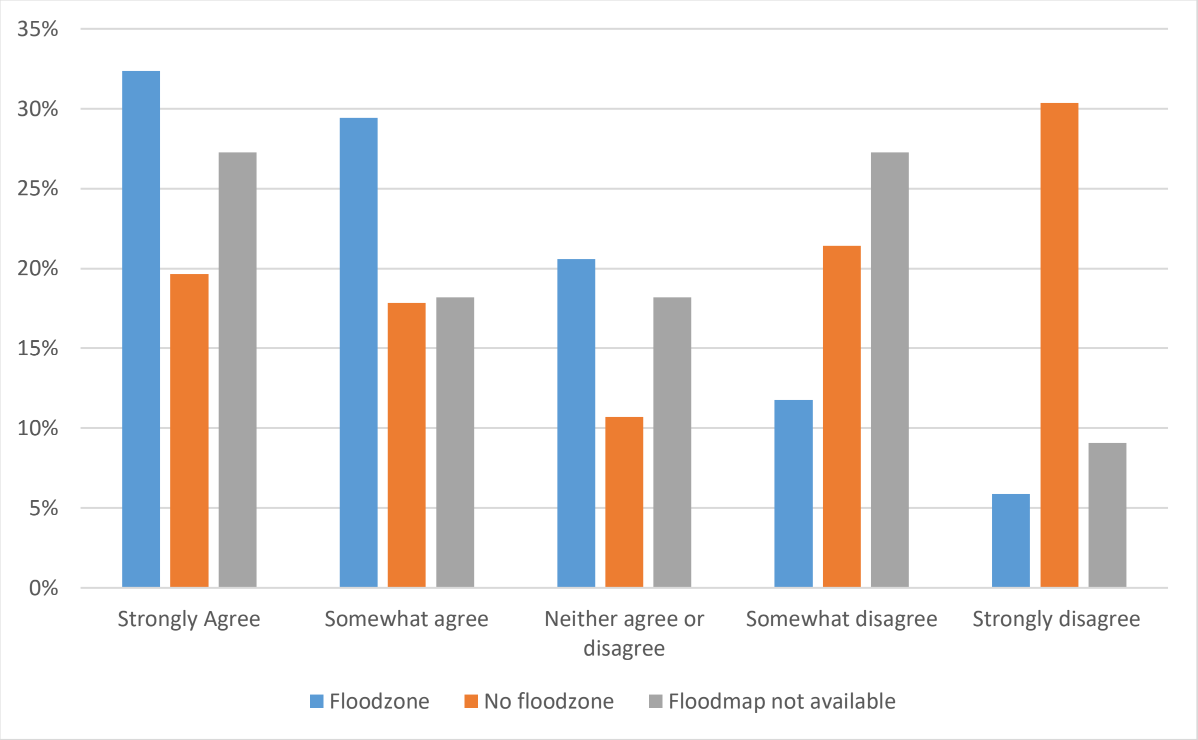

Figure 5.4. Perceptions based on Q26, given actual location.

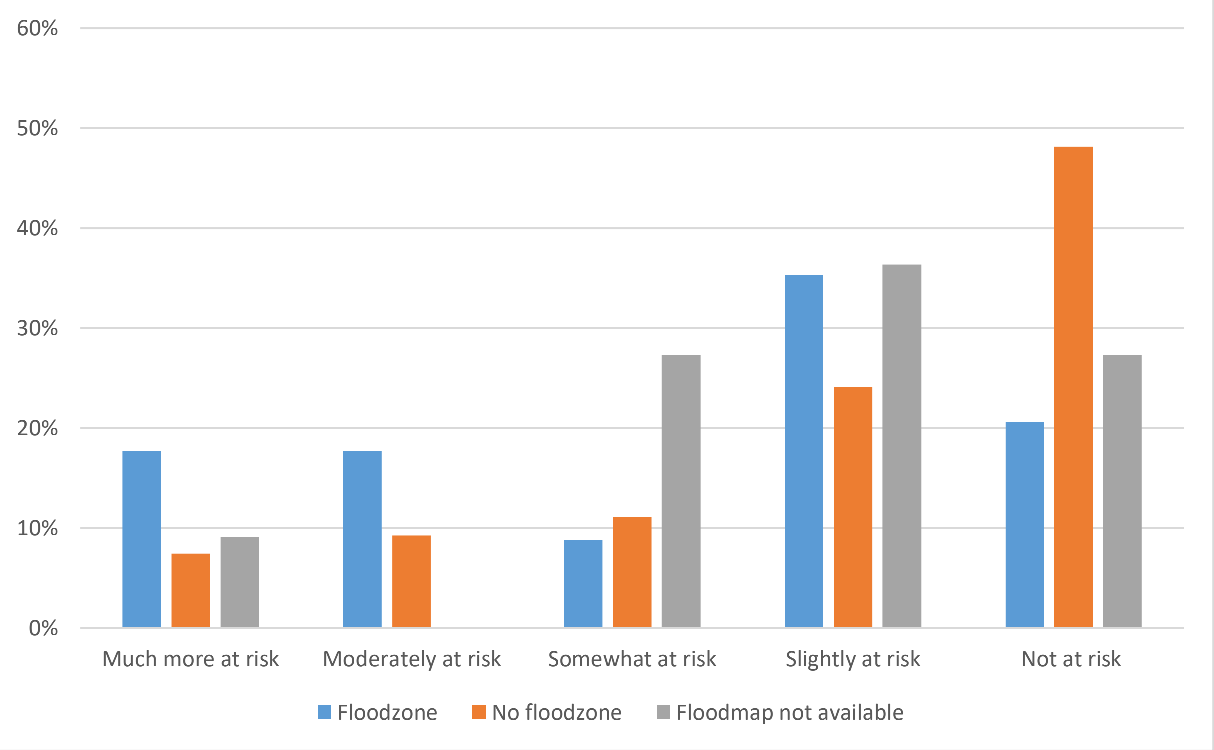

Figure 5.5. Perceptions based on Q25, given actual location.

Open-Ended Responses

Flood/Dam awareness

The first three questions of the questionnaire asked respondents to use a yes, no, or don't know format to verify whether they lived in a floodplain, lived on property below the water level in the nearby river, and whether their property had flooded before. Of 100 respondents who answered the question, 40 said they did live in a floodplain, 45 answered no to the question, and 15 respondents selected don't know. When asked whether the respondent's property level was below the water level of the nearby river, 88 percent of respondents said no. The remaining respondents confirmed they were below the water level (3 percent) or did not know (9 percent). For question 3, "Has your property ever flooded before?" a blank space was provided for further explanation with the following guidelines in parentheses: approximate date, affected property, depth of water. Thirty-two respondents who had indicated experiencing prior flooding provided additional information to describe the extent of the flooding. Significant flood events in 1951, 1993, and 2007 were mentioned:

> *1951 survey indicates ground around outside of home is 11" below 100 yr In the 50s before the dam was built*
>
> *In 1951 - 6" flooding my business G + R impl - my garage*
>
> *Yard in or about 1950 before a small dam at Lake Warnock. Keeps streams and waterways from flooding. Mo. River dams all failed/ Need fixed soon!*
>
> *Before the dam was built in the 1950s, the best farm ground flooded - the dam took that property. Its [sic] been in family over 100 yrs. House is on higher ground, but roadway would not be navigable. Only one way out and could be closed for days or more*
>
> *1951 flood, summer 14 years old went to attic, rescued by boat*
>
> *July 1993 The lower portion of our property was under water when a drainage ditch/creek flooded. No property damage.*
>
> *Spring 2007 it rained 20+ inches in 3 days flooded my pasture*

Many respondents credited the addition of a dike around the town for reduced flooding in their area:

> *1973-74 before dike around our town. Water level 2' to 3'*
>
> *Back in the 60s + 70s it did, but not since they built the dike around town Not since 1970 when land was redeveloped*
>
> *Recent flooding in the summer of 2019 was mentioned most frequently, by both upstream and downstream residents.*
>
> *This last July 2019 we had over 7" of rain and the town of Durham KS flooded - my house had 16" inside the main floor*
>
> *July 4 2019 2' deep garage, 1996 2' deep*
>
> *July 4th 2019, 1/2 our yard was under water. Not sure of depth but it was within 6 lineal feet of the 100 yr flood plain as described surveyors*

Some respondents indicated that frequent flooding occurs on the property but is typically in agriculture land.

> *Numerous times*
>
> *I don't know dates however I do know that it has been flooded at least two times in the last 2 years*

Respondents from the area of Marion Dam, constructed in 1968 (KS00006; Code 1), referenced significant flooding during the 1951 flood and flooding that occurred on July 4, 2019. Downstream residents attributed the lack of flooding in recent years to the construction of the dam and to a dike that was built around the town in the 1980s. Upstream residents in Durham, Kansas, reported flooding in their homes, businesses, and farm ground during the 4th of July flood. One respondent reported 16 inches of floodwater on the main floor of their home. Marion Dam was constructed by the USACE for the purposes of flood control, water supply, water quality, and recreation. The dam was designed to protect the city of Marion from the 'Standard

Project Flood,' a magnitude similar to a 0.2% annual chance flood. The reservoir controls discharge from 200 miles of drainage area from the North Cottonwood River. Revisions of the Flood Insurance Study (Study Number 20115CV000B) conducted by FEMA for the 12 cities[7] and one unincorporated area in Marion County. Results of the study focus on study area, engineering methods, flood management applications, insurance applications, and revisions. During the 2019 flood that occurred on the North Cottonwood River, several residents from Marion County expressed their concern over a lack of communication particularly during the flood water releases. Marion County residents commented on the heavy rain that caused upstream and downstream flooding. Concerns over dam failure in Marion County seem to be limited as a recent "50 year check up" has put some residents at ease and the nearby dike also helps provide an added sense of security.

> *They opened the dam without telling people and got flooded July 4 2019.*
>
> – Marion County Resident 1

> *Last year's floods were a true test to most of Kansas dams. Marion's dam was under some repairs. (50 year check up) and still held up, so much that towns above the dam were flooded.*
>
> – Marion County Resident 2

> *We are VERY concerned about the Corps of Engineers Management regarding water control- dams below us are not letting out water properly to control possible flooding upstream.*
>
> – Marion County Resident 3

Most respondents were able to provide a location (either upstream or downstream) with some measurement of distance. Distance from dam was provided in an open-ended format, so respondents could describe their location from the dam in their own words. This also provided

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[7] Burns, Durham, Florence, Goessel, Hillsboro, Lehigh, Lincolnville, Los Springs, Marion, Peabody, Ramona, Tampa, and Marion County (Unincorporated Areas)

an example of how familiar respondents were with their actual versus perceived distance from the dam. Nearly all of the respondents knew that the dam in their area provided flood control and at least 37 percent of respondents felt that the U.S. Army Corps of Engineers (USACE) should be held responsible[8] in the event a dam was no longer able to provide flood control.

Other responses to **Question 28: Who should be held responsible in the event a dam is no longer able to provide flood control?** cited various government entities at the local, city, state, and federal levels; multiple parties, or were unsure who should be held responsible. A few outliers responded with written in answers such as “God,” “The dam in my area is not for flood control,” or were confused by the question. The respondents were also asked their opinions on the efficacy of the dams to provide flood control beyond its designed life expectancy. In general, respondents seemed to be unsure on whether or not the dam would provide sufficient flood control beyond the 50 to 100-year design life but were not worried, in general, about the designed life expectancy. The majority of respondents did not think the dam would protect against flooding, nor did they feel the dam was being maintained by the responsible party.

Of all 10 sites, the majority of respondents (35 percent) felt like they were at low risk of dam failure, while only 7 percent reported a high risk. Out of 102 respondents on this item, only 12 (12 percent) saw themselves as being at medium risk. Given the larger number of male respondents, more males reported feeling low risk or somewhat at low risk to dam failure. Using percentages to determine differences among female and male responses in regards to risk, female

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[8] See Discussion Chapter for the difference between respondents’ understanding and actual responsibility regarding dams.

respondents reported feeling higher levels of risk (high risk, somewhat high risk and medium risk) while males reported low and somewhat low risk, more often (Figure 5.6).

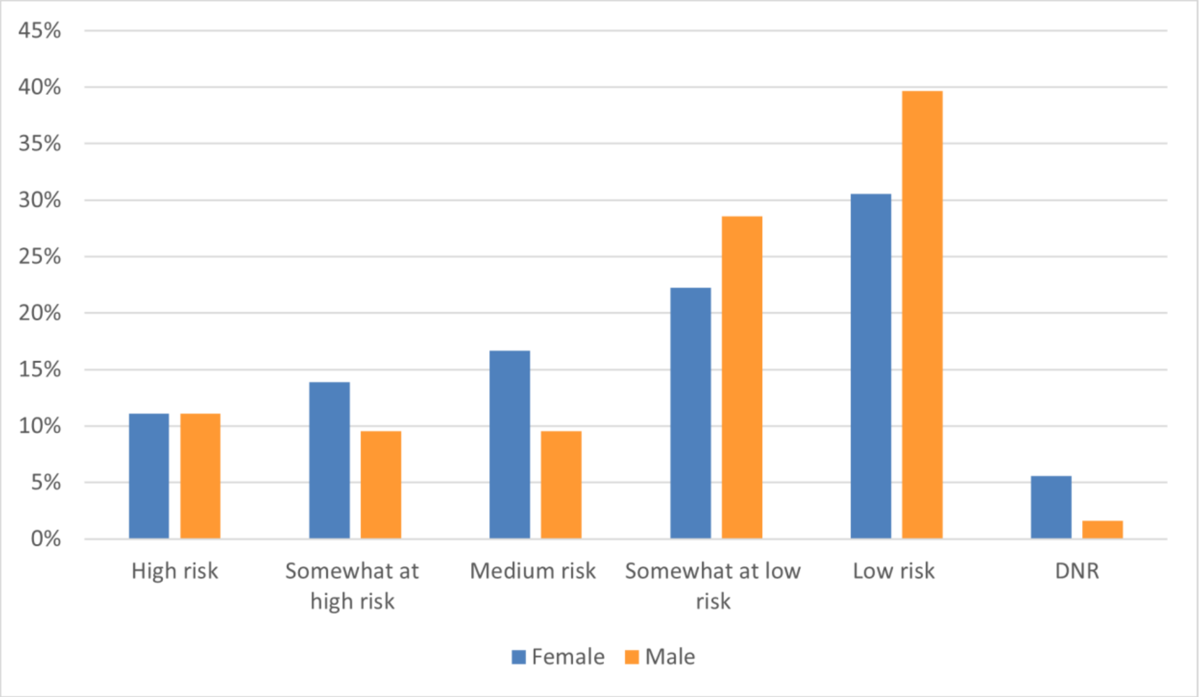


Figure 5.6. At-risk responses between men and women.

In other study dam sites, respondents were frustrated with what they felt to be last minute decisions (citing computer control and the U.S. Army Corps of Engineers) to open up the dam flood gates, which was seen as causing unprecedented flood damage. There was also praise from a Neosho County resident who took pride in the fact that her husband, who was the caretaker of the nearby dam, was also the same one to contacting residents downstream if there were any issues with the dam. While one respondent called for “comprehensive long term dam maintenance and preservation plans” (Marion County), others were unsure who maintained the dams or the dam purpose(s).

Risk perception regarding dam failure

Overall response on flood risk perception (In the event of a dam failure, would you be concerned about flood risk your area?; N=102) indicated that the majority of respondents did not feel that their property had ever been at risk during a flood event and were very unconcerned about whether the event of a dam failure in their area would cause flood risk.

Of the respondents who completed the questionnaire, most respondents (45%) completely disagreed that their community would be affected by flooding but were more neutral (49%) when asked if their community would be affected by flooding in the coming year. A general sense of preparedness was somewhat lacking among respondents who also did not feel confident in their ability to protect themselves and family, or their property in the event of a dam failure. Only 21% of respondents felt they were very or somewhat prepared in the event of a major flood. Given the responses to risk perception regarding dam failure, perceived risk varied by dam site (Figure 5.7). The average standard deviation among all study sites was below 1, indicating a low standard deviation. A low standard deviation with data clustered around the mean indicates data that is more reliable, with little variability in the dataset (Table 5.11). Lower rates of perceived risk were evident near Council Grove City Dam (medium SoVI) , Little Kaw Creek DD (medium SoVI), and the Sedan Multipurpose Dam (med-high SoVI). The highest rate of perceived risk was associated with Marion Lake, who recently experienced a significant rain event.

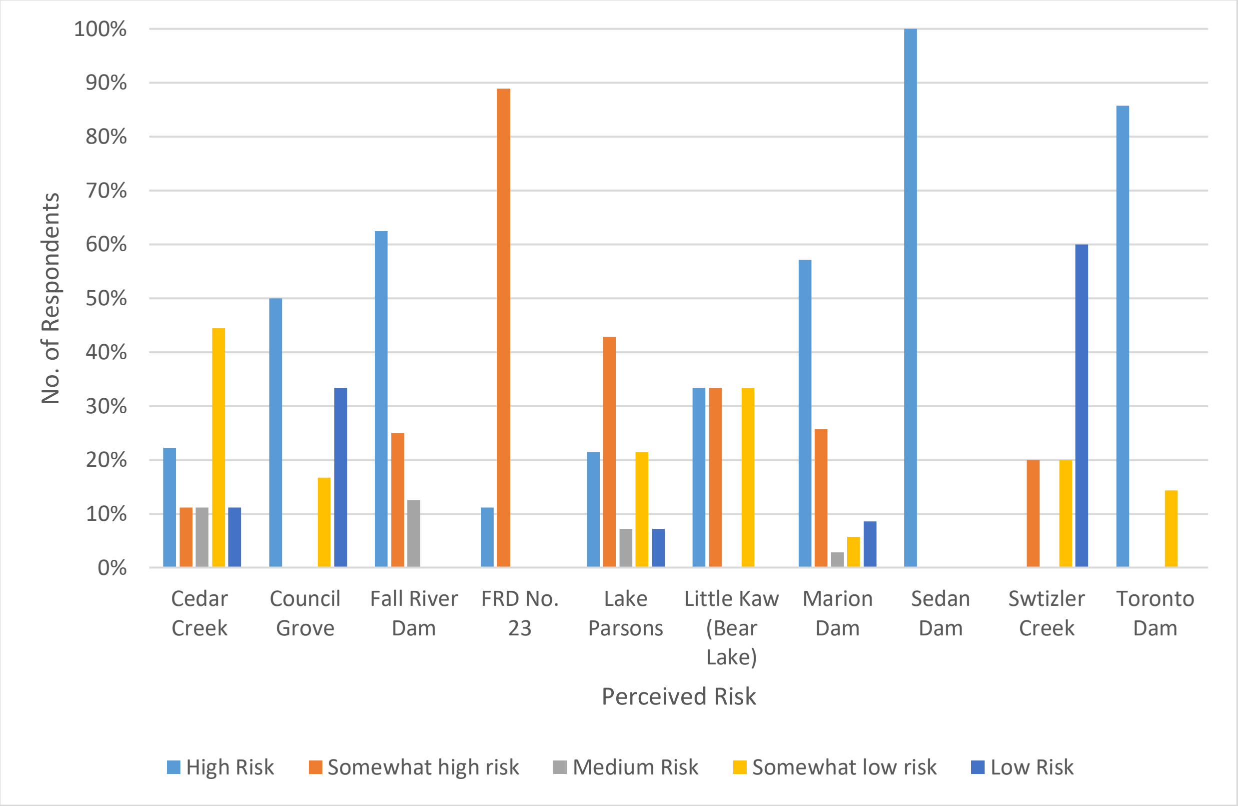


Figure 5.7. Perceived risk by dam location.

Table 5.12. Perceived Risk by Dam

NID ID No.	Dam	City	N	Per. Risk	Mean	SD
KS07006	Cedar Creek Reservoir	Garnett	9	3	2.67	0.50
KS02512	Council Grove City Dam	Council Grove	5	0	3.00	0.00
KS00003	Fall River Lake	Fall River	8	4	2.50	0.53
KS02010	FRD NO 23	Atchison	10	3	2.70	0.48
KS02514	Lake Parsons Dam	Parsons	16	6	2.44	0.81
KS01248	Little Kaw Creek DD	Bonner Springs	3	0	3.00	0.00
KS00006	Marion Lake	Marion, Durham, Florence	35	20	2.29	0.71
KS02451	Sedan MP Dam DD 6-28	Sedan	2	0	2.00	0.00
KS02409	Switzler Creek Watershed Dam 7	Burlingame	7	2	2.71	0.49
KS00011	Toronto Lake	Fredonia, Toronto	7	5	1.86	0.90

Interviews

Purposive sampling of water resource and dam experts were selected from the ten counties where questionnaires had been distributed, in addition to federal, state, and local government agencies considered to be knowledgeable of dam and water practices in Kansas. My original points of contact for selected interview officials were from the State Association of Kansas Watersheds, United States Department of Agriculture – Natural Resources Conservation Service, and Kansas Department of Agriculture - Division of Water Resources, who I had worked with during my thesis on Kansas watershed districts. Additional points of contact for selected interview locations were the counties' extension service offices and local watershed districts. Representatives from the federal, state, and local agencies helped in the identification and contact information of appropriate interviewees. Initial contact for the interviews was either in the form a cover letter (which contained a brief introduction of the research, my credentials, the reason for the study, and the reason the interviewee was selected for the study) through the selected party's email address, or a direct phone call so as to build rapport and to motivate participation (Bird 2009). Following IRB guidelines, interviewees were given the same information as questionnaire respondents and assured that their participation was completely voluntarily, there were no anticipated risks from the study, and they were allowed to stop the interview or refuse to answer questions at any time.

Administrating interviews by phone allowed for longer verbal responses as compared to the questionnaire, allowed for questions to be clarified, and for the probing of vague answers (Bird 2009). Semi structured interviews with guiding topics (Appendix G) covered in the questionnaire such as flood/dam awareness, risk perception, flood vulnerability, and risk communication. The question format was relatively simple and was the same or similar to questions on the questionnaire, which included:

> **Do you think that the [dam] is well maintained?**
>
> **Do you think the dam will continue to protect against flooding? Do you think the dam has reached its life expectancy?**
>
> **Are you concerned about the design life expectancy of the dam?**
>
> **Who, if anyone, should be held responsible in the event that a dam is no longer able to provide flood control?**

The remaining questions were structured to be addressed specifically by experts in the field. Those questions focused on expert perception of residents' responses, public awareness, and available resources to the public regarding flood inundation, dam breach and general risk communication. Interviews varied in length but were designed to last between twenty and forty minutes. All interviews were recorded with the permission of the participant and were later transcribed and coded through NVivo.

Interview Selection

Interviews conducted with dam managers, local stakeholders, and government agencies associated with water resources provided a different perspective on the flood risk perception associated with aging dams. The selection of interviewees served in roles that provided them with a substantial understanding of the local area and the community. To understand the perception of risk and vulnerability to the selected at-risk dams in the study, I wanted to examine how water resource experts perceived the risk and vulnerability of the people in the community. Of the eighteen interviewees, a total of 21 interviews were conducted (Table 5.13). Due to the nature of dam management by federal and state agencies, representatives from the USDA-NRCS and KDA-DWR were able to provide interviews for more than one location, when applicable. Representatives from KDA-DWR, USDA-NRCS, and SAKW were also able to speak more generally about dams in the region. SAKW did not speak about any of the dams from the selected study site but was able to provide valuable insight on flood risk perception near aging dams.

Table 5.13. Interviewees by study site.

Dam Study Site	Interviews (N)	
General Knowledge	3	KDA-DWR, USDA-NRCS, SAKW
Fall River	2	USDA-NRCS, Watershed District Manager
Marion	2	City Manager, Resident
Toronto	1	USDA-NRCS
Little Kaw	1	Dam Caretaker, Resident
WCB - FRD No. 23	2	USDA-NRCS, Watershed District Manager
Switzler Creek	2	Watershed District Manger, County Extension Agent
Sedan MPD	2	Watershed District Manger, County Extension Agent
Council Grove	2	County Extension Agent, Resident
Lake Parsons	2	KDA-DWR, Dam Caretaker
Cedar Creek	2	KSU Extension SNAP Ed, City Manger

Interview Responses

Of the 21 separate interviews, covering 10 study sides, all interviewees thought the dam was well maintained and believed the dam would protect against flooding in the future. One interviewee stated the dam would provide flood control as long as it was in existence, and despite knowing the age of the dam, did not think the dam had reached its life expectancy. Only five interviewees could tell me when the dam was built, and those who didn’t know suggested resources to find that information. The dam managers were typically the most knowledgeable of the dam history. When asked whether residents underestimate or overestimate the risks associated with flooding, half of the interviewees stated residents underestimate the risk associated with flooding. The remaining interviewee responses stuck within themes of “residents know the area,” “overestimate,” and “I couldn’t say.” Interview responses on the responsible party of a dam failure were typically the most long-winded. A representative from the City of Garnett explained that this question was situationally dependent on the contractual obligations of the dam and whether the city is still responsible if they “give the dam away.”

Summary

For several reasons, local populations' perceptions of risk and vulnerability to at-risk dams vary. Findings from the mailed questionnaire represent sample members rather than the overall population and include a series of close-ended and open-ended responses that focused on topics including flood/dam awareness, flood vulnerability (self-awareness), and risk perception of dam failure. However, responses were consistent with the literature, in that findings revealed that respondents who lived in a flood zone felt their property only considered themselves to be slightly at risk. Even though most participants could accurately identify their location in a flood zone, there appears to be a false sense of security among those at risk.

Recollections from previous flood experiences were attributed to events that occurred prior to dam construction or during significant wet years. Based on both close-ended and open-ended responses on flood/dam awareness, it is evident there needs to be more attention among respondents between how well they perceive a dam's ability to protect against flooding and their awareness of proper maintenance needed to prevent dam failure. This can be attributed to a false sense of security (Terpstra et al. 2009) and how risk perception lowers the greater the temporal distance from the flood (Burningham et al. 2008).

Dam failure risk perception revealed that most respondents did not perceive a likely risk of dam failure in their area but would be concerned in the event of a dam failure. The strongest correlation between the level of risk perception and other factors was among respondents who felt their property would be affected. Variations in the assessment of flood risk varied by dam site but were most evident by respondents from Marion Lake, who had just experienced a significant rain event (Messner and Meyer 2006, Brilly and Polic 2005). As evident from the differences in response rate, it is clear that recent flood events have the most impact on how a community thinks of their nearby dam (Burningham et al. 2008, Viglione et al. 2014).

Interviews with water-management experts revealed that dam managers were the most knowledgeable regarding the history and background of the dams associated with their area. However, most interviews revealed shortcomings in the available information accessible to the public. Many experts relied on residents' knowledge of the area when probed on questions about dam failure or future flooding. It is without question that limited resources and funding will continue to put a strain on watershed districts, private dam owners, and communities that are unable to maintain the condition of dams in the area. However, dams with proper maintenance are likely to exceed their design life expectancy.

Chapter 6 - Discussion

In Nov 2019, The Weather Channel released an article entitled "Aging Dams in U.S. Expose Thousands to Risk." In May 2020, National Geographic published 'The problem America has neglected for too long: Deteriorating Dams" (Wei-Haas 2020). The threat of aging and deteriorating dams is of the essence as the majority of us will watch them reach their life expectancy. The perception of flood risk in the area should start as an indicator of what communities need to address. This chapter will provide a discussion of the results of my study, which was guided by the following research questions (1) Which intermediate-sized dams in eastern Kansas are most at risk of dam failure, (2) How do local populations' perceptions of risk and vulnerability to at-risk dams vary, and (3) How can risk communication be improved among vulnerable populations. This chapter will also include limitations of the study, what I would have done differently, in hindsight, and address an emergent question to come out of this study: can we actually change flood risk perception?.

Findings relevant to Research Question 1: What intermediate-size dams in Kansas are most at risk of dam failure?

The first research question was addressed through analysis of information regarding dam conditions in Kansas, through secondary data and GIS analysis (chapter 3). The intermediate size dams in eastern Kansas that are most at risk of dam failure are based on the research criteria presented in chapter 3: KS02201, KS02451, KS02452, KS02010, KS0001, KS0011, KS02427, KS02428, KS02429, KS02430, KS02431, KS02436, KS02437, KS02438, KS02446, KS02448, KS02449, and KS02450. Like the dams selected for this study, these dams are mostly earthen, intermediate-sized dams, intended to reduce the flood risk of downstream populations. The dams are often privately owned and are less likely to be regulated by a larger agency that has the resources to provide necessary upkeep and maintenance. Since medium-sized dams are less likely to receive as much attention regarding hazard potential as larger dams, this increases their at-risk status. Specific dams were listed in chapter 3 and Appendix A; other related points of interest are summarized in the following paragraphs. As discussed earlier, rural populations with increased social vulnerability living in areas with projected precipitation increases contribute to the identification of at-risk dams.

The terms flood control and flood risk reduction are used interchangeably in this section. Over time, the shift from the term flood control has been replaced by the term flood risk reduction by water resource experts to emphasize the more realistic nature of reducing flood risk as opposed to controlling flood risk. In Kansas, there are 6,457 dams registered in the USACE National Inventory of Dams database. As of 2020, the average age of Kansas dams with a year completion date is 50 years old. Among the total number of registered dams in Kansas (6,457), 38 percent (2,467) of the dams have a completion date prior to 1970, making them 50 years old by 2020 (Figure 6.1). Dams listed with a primary purpose of flood risk reduction account for 27 percent of the total number of dams, with a slightly higher percentage of nearly 28 percent having no primary purpose listed at all (Figure 6.2). Dams often serve multiple purposes but were not considered here if flood risk reduction was not the primary purpose.

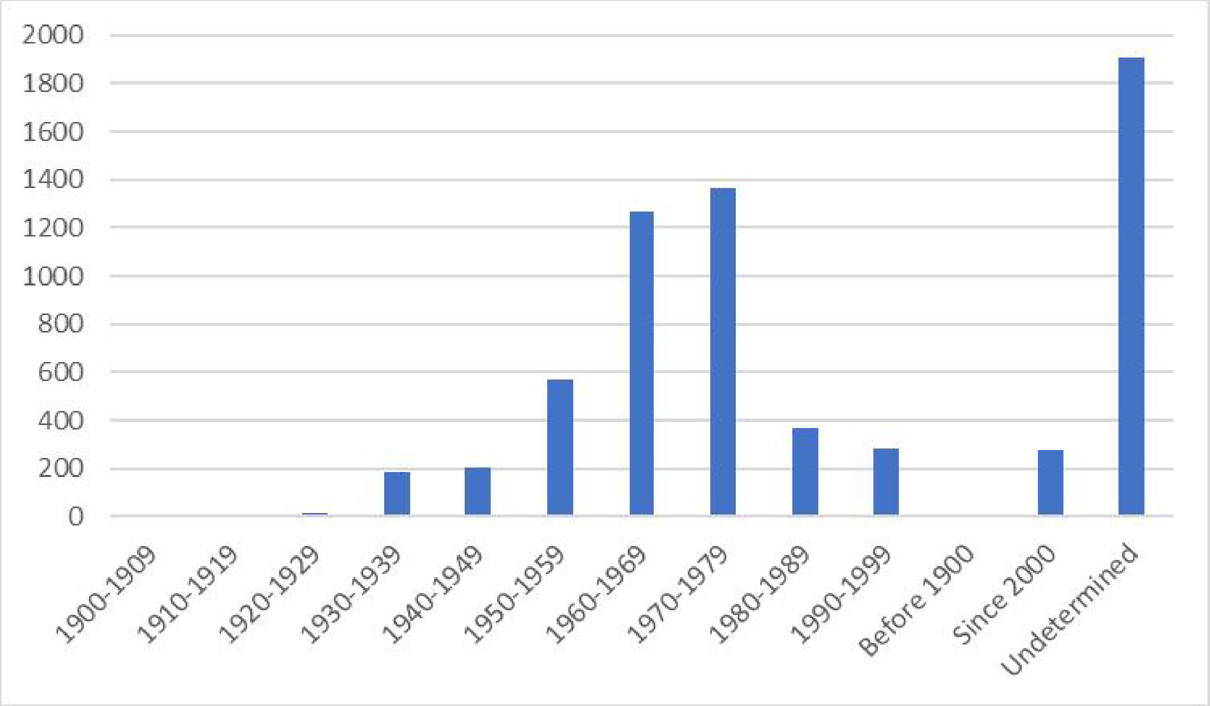


Figure 6.1. Total number of registered dams in Kansas by year completed date.

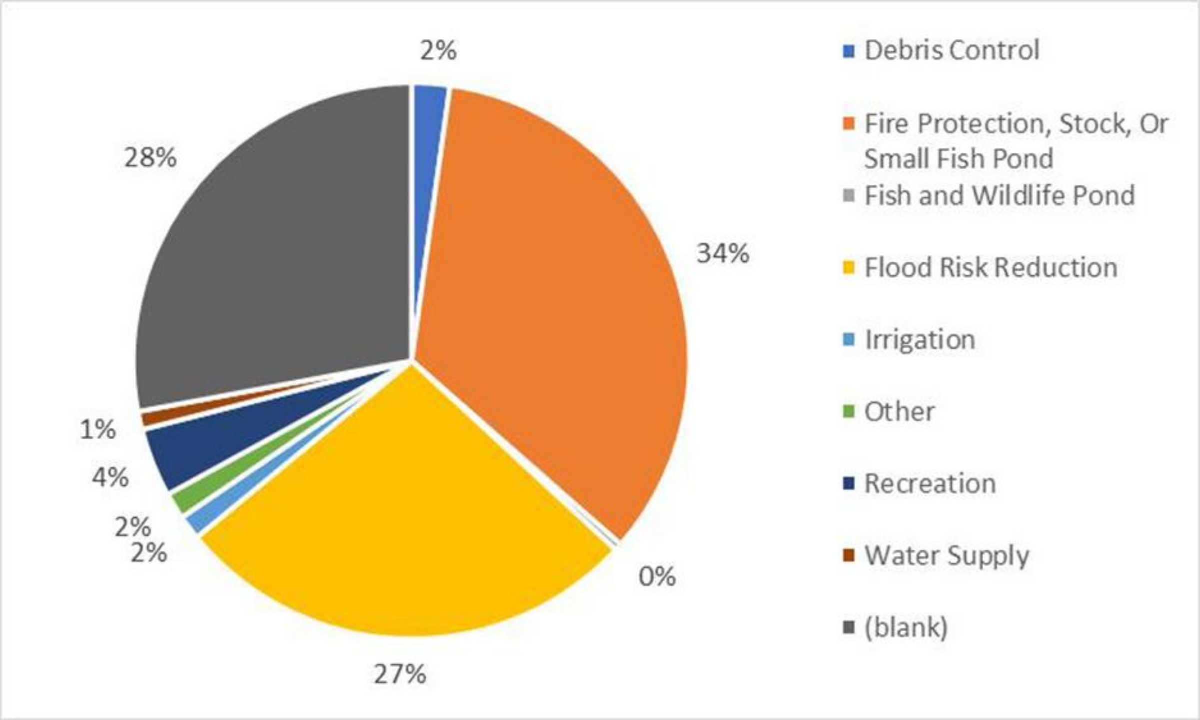
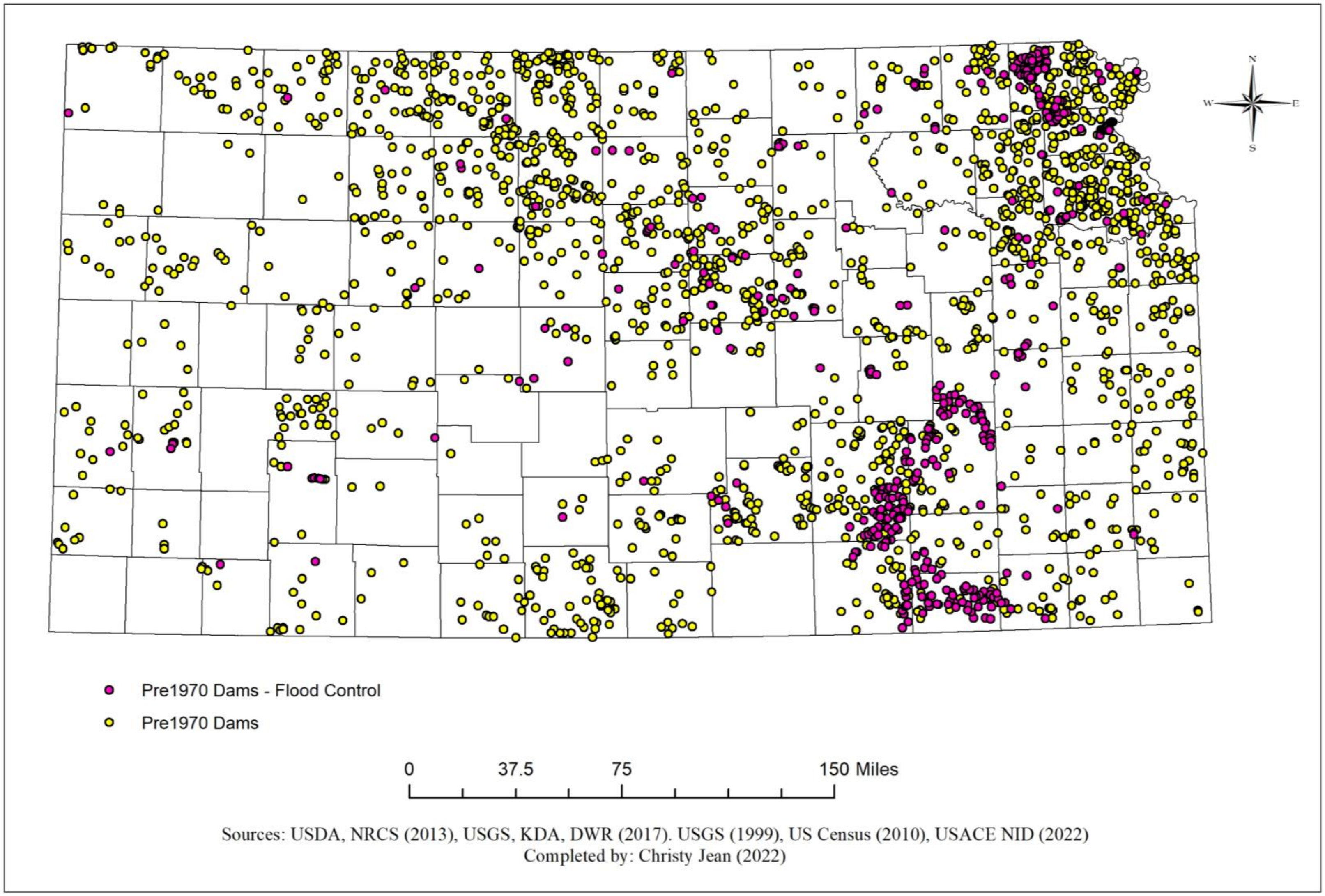


Figure 6.2. Primary purpose of Kansas Dams

After mapping the locations of the pre-1970 flood control dams, four noticeable clusters (Figure 6.3) were observable in the eastern half of the state: three major clusters in the southeastern part of the state and one smaller cluster in the northeastern part. In northeastern Kansas, special dams of interest are located on the following waterways with their associated tributaries: Walnut Creek in Brown County, the Little Delaware River in Brown and Atchison counties, and White Clay Creek and Brewery Creek in Atchison County. Clusters in southeastern Kansas include Chautauqua County with 45 pre-1970 flood control dams that are located in a northwestern to southeastern diagonal across the county, several Butler County dams along Hickory Creek, Rock Creek, and the north and south branches of the Little Walnut River, and dams along the East Branch Fall River and its tributaries in Greenwood County.



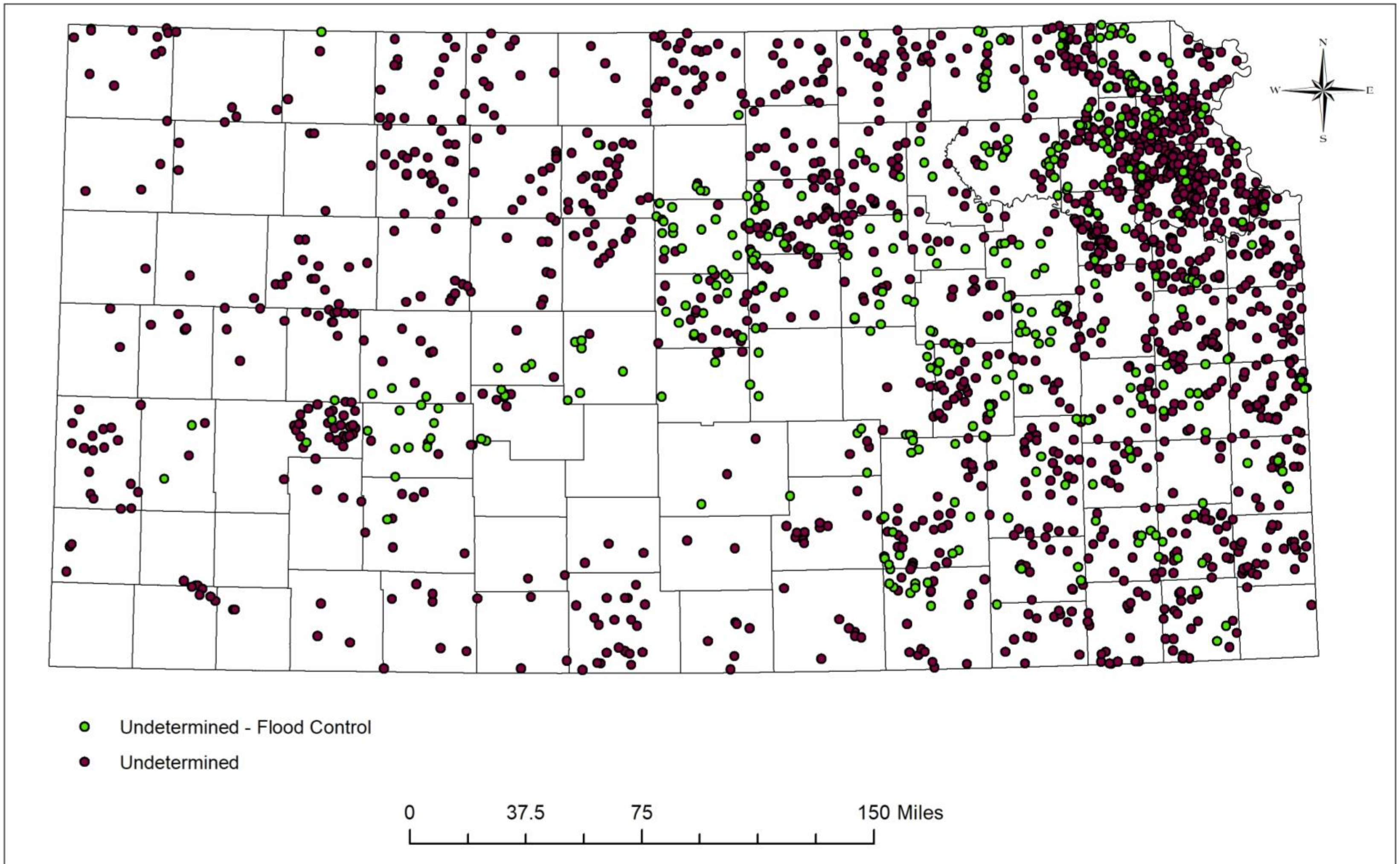
Sources: USDA, NRCS (2013), USGS, KDA, DWR (2017). USGS (1999), US Census (2010), USACE NID (2022)
Completed by: Christy Jean (2022)

Figure 6.3. At-risk dams: pre-1970 flood control dams.

Approximately 30 percent of the total number of dams in Kansas are categorized as “undetermined” in Figure 6.1, which includes all dams that did not have a registered completion date within the NID, due to missing, incomplete, or unavailable data on the dams. The majority of the dams (71 percent) without completion dates have a primary purpose of fire protection, stock, or small fishponds. However, at least 18 percent are used for flood risk reduction purposes.

Although these dams were not considered to be high risk because they did not meet the criteria of having a listed completion date before 1970, making them over fifty years old by 2020, they are notated here as an indicator that a large number of dams in Kansas are missing data which would provide essential for upstream and downstream communities that rely on their services. Of the intermediate-sized, undetermined, flood control dams, a total of 7 are considered high hazard and currently have an active emergency action plan. Two of the dams from this case study, Council Grove City Lake (Bear Lake) and Cedar Creek Reservoir, fell into this category, although their completions dates were able to be verified through local sources.

In Figure 6.4, the distribution of undetermined flood control dams is more spread out, as compared to the pre-1970 flood control dams. This spatial variability makes it more difficult in determining where immediate attention may be needed. Nonetheless, these dams are an indicator of where updated data and local information are crucial in painting a complete picture of dam safety and risk communication in Kansas.



Sources: USDA, NRCS (2013), USGS, KDA, DWR (2017). USGS (1999), US Census (2010), USACE NID (2022)
Completed by: Christy Jean (2022)

Figure 6.4. Flood control dams with undetermined year completion dates.

The most accessible dam information to the public is through the United States Corps of Engineers' National Inventory of Dams Database (NID). Some concerns over the accuracy and completeness of the NID contribute to the communication breakdown among decision-makers and the local population (National Academy of Sciences 2012). There also seems to be some discrepancy in the classification of high hazard dams between the USACE and the information available at the state level. For this study, the dams I selected were considered high hazard based on the data within the NID but may not illustrate the actual number of high hazard dams based on the classification of dam hazards as laid out by the Kansas Department of Agriculture. In the USACE Safety of Dams Policies and Procedures, a dam is only considered a high hazard if there is a direct loss of life but does not consider lifeline losses, property losses, or environmental losses (USACE 2014). According to the Kansas Department of Agriculture, in Kansas, a Class C (high hazard) classification for the dam is assigned if there is a potential loss of life or damage to more than one home, industrial or commercial facility, a public utility that services a large number of customers, traffic on high volume roads, recreation facilities that serve large numbers of the population, or a high-volume railroad line. A Class C hazard will also be considered if two or more Class B (significant hazard) classifications are present. Class B hazards include the potential for endangering few lives or causing damage to an isolated home, a public utility that serves a small volume of customers, traffic on a moderate road, smaller recreation facilities such as campgrounds, or low-volume railroad tracks.

Findings relevant to Research Question 2: How do local populations' perceptions of risk and vulnerability to at-risk dams vary?

According to the psychometric paradigm, an individual's perception of risk varies based on a combination of perceived risk characteristics and behaviors. The population of interest to this research is the people who reside near the study dams. However, due to the lower number of responses, the analysis of this study is not representative of all potential respondents but instead reflects the population returning questionnaires. Questionnaire respondents likely include a portion of the intended study population with greater interest in the topic of flood hazards as compared to nonrespondents. Overall, the results suggested that respondents were confident in their self-assessment of dam knowledge but may have a false sense of security based on their level of experience with flooding after the dam was constructed. Respondents were not concerned with personal flooding risk but thought there might be a concern for the community and were unsure of whether dams would provide flood control beyond their 50 to 100-year design lives. However, respondents overall were not worried about designed life expectancy.

Additionally, respondents did not consider dam failure or flood damage to be much of a risk. Cultural theory was used to understand how risk is perceived through personal experience, cultural biases, and social relations. This section addresses research question 2 and its sub question: 2a. Do perceptions align with factors related to failure risk?

Self-identified perceptions and attitudes related to flood awareness and concern of flood risk

The primary topics discussed in flood awareness and dam awareness focused on understanding whether a respondent could identify their location in relation to the nearby flood zone or dam, to share previous flooding experience, to self-assess their confidence level of explaining the purpose of a dam, and then rank the top three purposes of the dam in their area. Respondents were also asked about their level of agreement on dam maintenance, reliability, and who they felt was responsible in the event a dam was no longer able to provide flood control.

Dams and levee structures are often viewed as underappreciated and undervalued, despite the multiple resources they provide for many communities (National Academy of Sciences 2012). Dams are rarely thought of until they fail. While respondents were fairly confident in their assessment of dam knowledge, it appears that many respondents may have a false sense of security based on their level of experience with flooding after the dam was constructed. For some respondents, the last significant flooding they can recall happened during the Flood of 1951. This timing is related to the dam construction increase throughout Kansas during the latter half of the 20th century, making it less likely that residents have experienced flooding after installation of flood control structures. Many residents have experienced a relatively safe environment regarding flood control due to the large number of dams constructed during that period. After more than 50 years of flood control, aging dams provide a false sense of security even as they meet their design life span.

From Question 28, **Who should be held responsible in the event a dam is no longer able to provide flood control?**, 34% of respondents thought the USACE should be held accountable, 15% had more than one answer, and 11% said it was the city's responsibility. Of the dams selected for this study, the dams were designed by USDA NRCS (3), Larkin & Assoc. (1), A&E (1), CESWT (3), Unknown (1), and Wilson & Co (1). Of those, six are considered to be owned by the local government, three are federal, and one is privately owned. The federal dams are the only three dams that were funded, designed, and constructed by USDA NRCS. According to USACE (2014), the primary dam safety responsibility is with the agency or sponsor responsible for performing operation and maintenance, despite being designed or constructed by USACE (Table 6.1).

Table 6.1. USACE involvement and responsibility for dam/dam safety (Source: USACE 2014).

USACE Involvement	Responsibility for Dam Safety
Owns, operates, and maintains	USACE
Designed or constructed but operation and maintenance rests with others	Agency or Sponsor responsible for performing operation and maintenance
Designed, constructed, operated, maintained, and owned by others where flood control storage is provided under the 1944 Flood Control Act	USACE maintains data and participates in inspection only
Designed, constructed, operated, maintained, and owned by others and later modified by USACE	USACE assumes limited responsibility
Dams inspected and evaluated by USACE under the National Program for the Inspection of Non-Federal Dams, PL 92-367	USACE has no responsibility

Most respondents were unsure whether the dam would continue to provide flood control measures beyond the 50 to 100-year design life but were not worried about the designed life expectancy. The lack of information concerning the design life expectancy, the dam's condition, and the dam's reliability to continue to provide flood control affect how well dam and levee structures forecast future performance (National Academy of Sciences 2012). Without a complete understanding of the extent of risk, communities near aging dams are being put at a disadvantage concerning potential hazards and risks associated with dams that provide service beyond their intended design.

To gain a greater understanding of how respondents described their vulnerability in relation to potential flood hazards and their level of self-awareness, the following topics were covered: preparedness, concern about potential flooding events within their community and over time, and the effect flooding would have on their property, family, and livelihood. Overall, respondents to **Question 6**, **How prepared would you feel in the event of a major flood?**, felt very prepared to deal with a major flood, as most respondents did not think they would experience any flooding beyond the front yard and were confident in their ability to protect their family and their property in the event of a dam failure. When considering that nearly half of the respondents answered Question 1, **Do you live in a floodplain?** (Figure 6.5), that they either live in a floodplain or were unaware if they were in a floodplain (40 = yes, 15 = don't know), respondents did not seem to be very concerned about a dam failure or potential flood event.

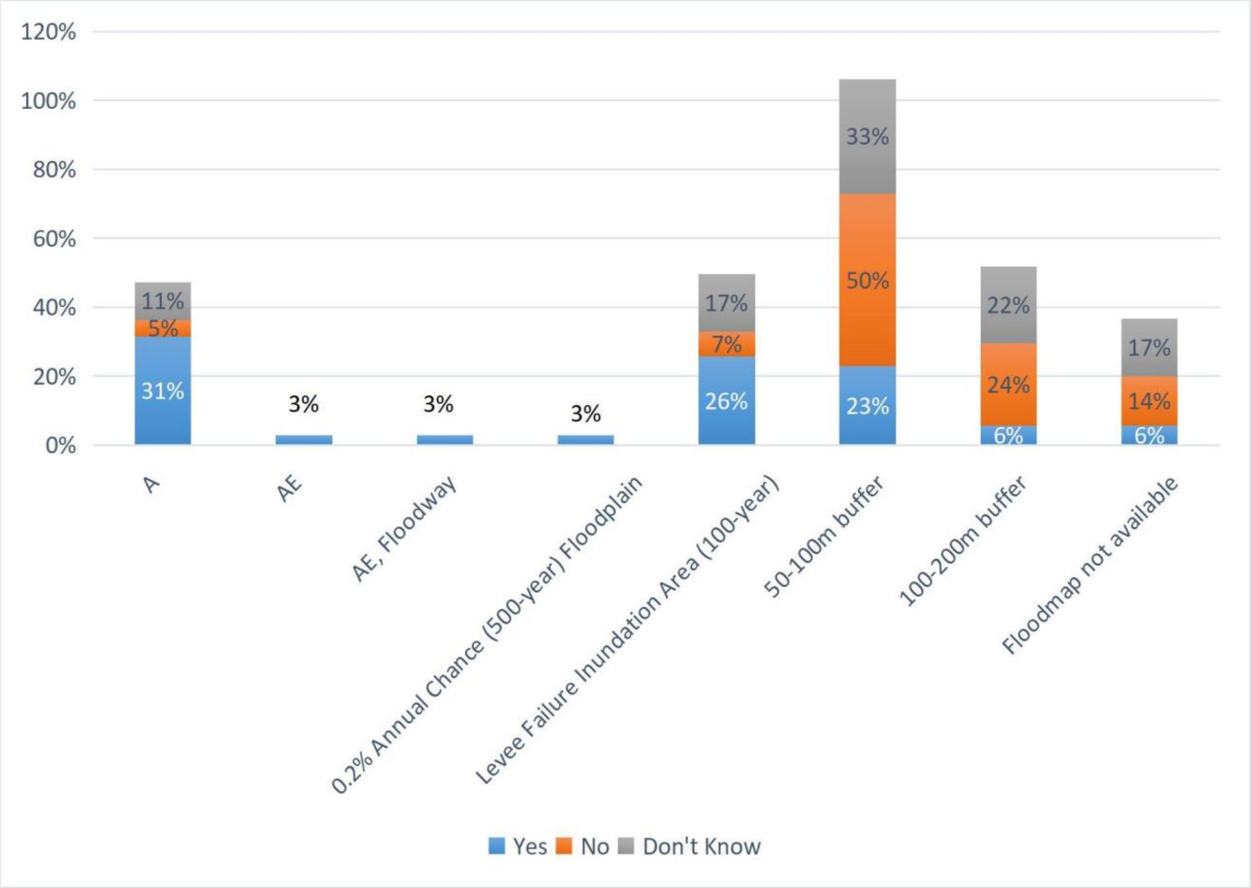


Figure 6.5. Responses to the questions, "Do you live in a floodplain?"

Alignment of perceptions with factors related to failure risk

Questions on risk perception asked respondents to address their concern about future flood events, the agreement with statements on flooding affecting their community spatial and temporally, their livelihood, daily life, and family. Additional questions asked respondents about their level of worry or concern about the nearby dam's designed life expectancy, flooding, and dam failure. In general, respondents weren’t concerned about flooding immediately but thought there might be a concern for flooding later on. Based on the questionnaire, respondents did not consider dam failure or flood damage to be much of a risk. However, when viewed by the dams individually, respondents near the Marion Dam were much more concerned about the risk of flooding in their area (Figure 6.6).

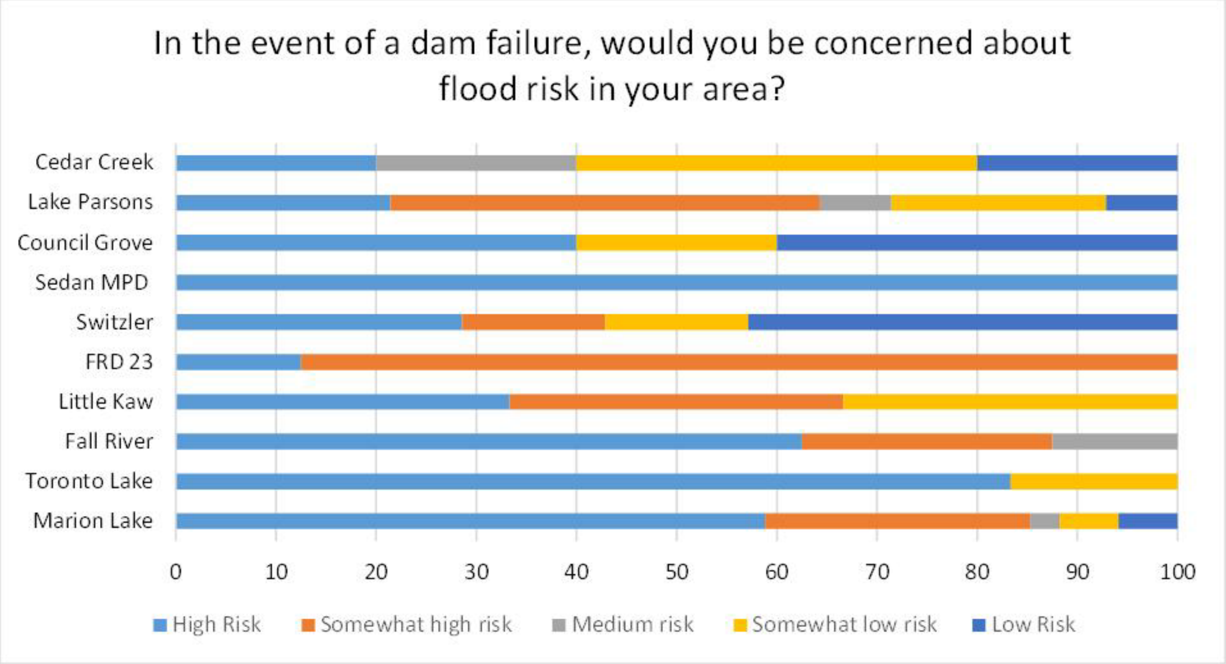


Figure 6.6. Concern about flood risk near the dam

During the July flooding in 2019, many Marion County residents felt the USACE improperly managed the release of the flood gates, causing significant flooding upstream in the city of Durham by keeping the gates closed too long and then releasing them too late, causing more flooding downstream in the city of Marion. Unlike the city of Marion, there are currently no digitized flood maps available in Durham through the Kansas Floodplain Viewer (Figure 6.7).

Figure 6.7. Marion Dam (Reservoir) DFIRM illustrates differences in flood information available to the cities of Durham (upstream) and Marion (downstream). Source: KDA Kansas Floodplain Viewer (2021).

Local community members who live near dams are likely to go unheard as maintenance costs, routine inspections, and competing priorities from other community need to push dams to the side as more seemingly immediate issues are addressed (National Academy of Sciences 2012). Marion Lake (Dam) is a prime example of a community suffering financial loss and limits to flood protection measures because of the lack of attention on dam and levee infrastructure as a whole.

Ways of Life

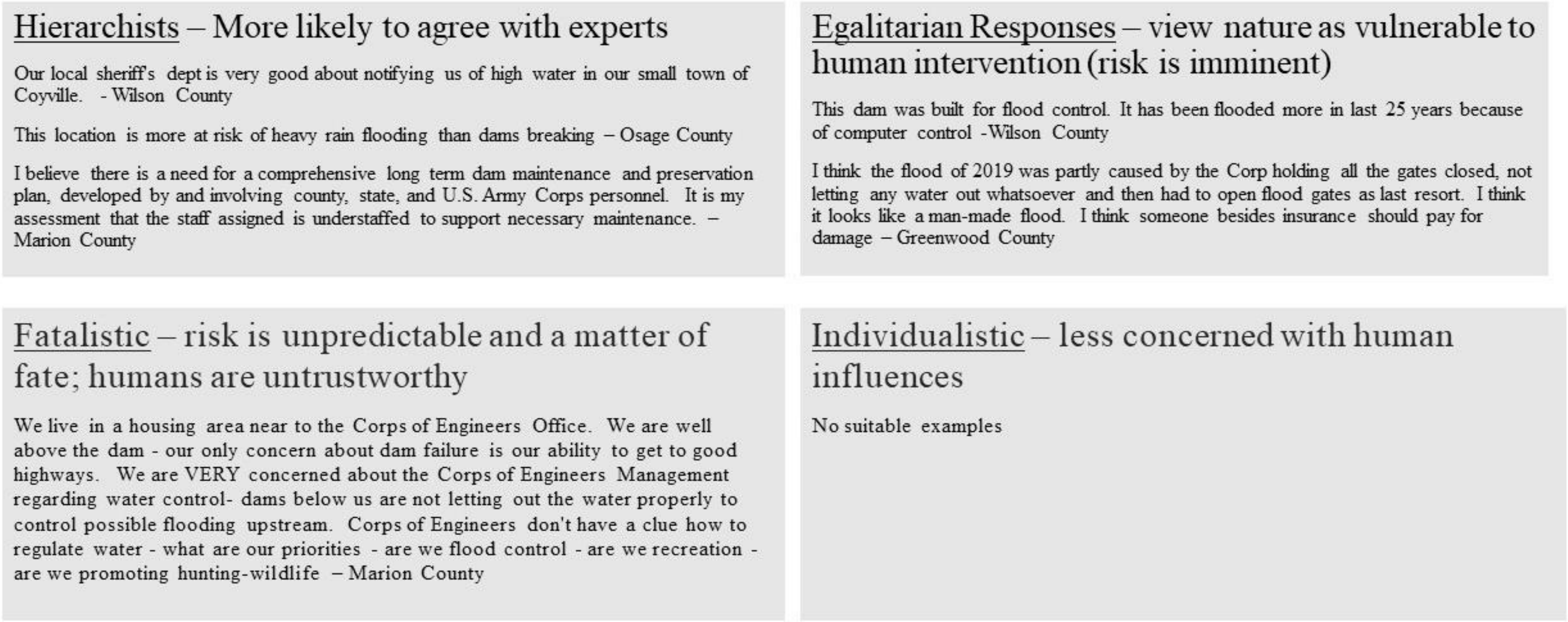
Based on questionnaire responses to items related to cultural theory, three groups emerged based on an individual's attitude and actions as a way to understand flood risk perception. The combinations of social relations and cultural bias were used to define a "way of life" to explain why individuals and groups perceive risk differently. Overall, local perceptions of risk and vulnerability to at-risk dams were identified among hierarchist, egalitarian, and fatalistic responses. There were no suitable examples of individualistic ways of life that were less concerned with human influences. Based on open-ended responses and interviews, these examples show how respondents fit into the separate ways of life identified in cultural theory (Thompson et al. 1990). Overall, experts and most of the responses to the questionnaire leaned more towards the hierarchists category, specifically as it related to the Corps of Engineers being more involved. Below are examples of how an individual's attitude was associated with a particular way of life. Responses obtained through the questionnaire are provided in Figure 6.8 to illustrate how direct quotes were categorized.

1. Hierarchists – local sheriff providing risk communication information, mistrust in climate more than dam, desire for more expert involvement

2. Fatalistic – distrust of USACE

3. Egalitarian – belief that technology is making communities more susceptible to flooding

4. Individualistic – no suitable examples



Hierarchists – More likely to agree with experts

Our local sheriff's dept is very good about notifying us of high water in our small town of Coyville. - Wilson County

This location is more at risk of heavy rain flooding than dams breaking – Osage County

I believe there is a need for a comprehensive long term dam maintenance and preservation plan, developed by and involving county, state, and U.S. Army Corps personnel. It is my assessment that the staff assigned is understaffed to support necessary maintenance. – Marion County

Egalitarian Responses – view nature as vulnerable to human intervention (risk is imminent)

This dam was built for flood control. It has been flooded more in last 25 years because of computer control -Wilson County

I think the flood of 2019 was partly caused by the Corp holding all the gates closed, not letting any water out whatsoever and then had to open flood gates as last resort. I think it looks like a man-made flood. I think someone besides insurance should pay for damage – Greenwood County

Fatalistic – risk is unpredictable and a matter of fate; humans are untrustworthy

We live in a housing area near to the Corps of Engineers Office. We are well above the dam - our only concern about dam failure is our ability to get to good highways. We are VERY concerned about the Corps of Engineers Management regarding water control- dams below us are not letting out the water properly to control possible flooding upstream. Corps of Engineers don't have a clue how to regulate water - what are our priorities - are we flood control - are we recreation - are we promoting hunting-wildlife – Marion County

Individualistic – less concerned with human influences

No suitable examples

Figure 6.8. Ways of Life Examples from Open-Ended Questionnaires.

Findings relevant to Research Question 3: How can risk communication be improved for vulnerable populations?

Through the interviews, I found that agencies were unfamiliar with local dam information within their county. Many agents were unable to provide accurate or any information regarding age, condition, or status of the dam in question. Other shortcomings in risk communication are the lack of digitally available flood maps for many rural areas.

The final question of the interview was based on risk communication. At the end of the interviews, I asked **'In what ways do you think that [your department] has been successful in providing information on high-risk situations regarding dams and flood control?** The term "your department" was substituted with the appropriate organization or unit to be relevant to the person that was being interviewed (i.e., City of Garnett, Division of Water Resources, etc.). All the respondents used some form of social media, most often mentioning *Facebook*, but also including *Instagram* and *Twitter*. Other forms of dissemination included quarterly and annual newsletters (paper and digital), local government websites, word of mouth, informational booths during community events, and personal phone calls. There was also mention of working with other agencies, such as Emergency Management and local watershed districts.

Community mitigation to dam and levee failure is enhanced based on the physical and social structures that ensure higher standards in design, better construction, continuous maintenance, changes in land use, and urban development (National Academy of Sciences 2012). Additional comments from respondents voiced the need to integrate multiple agencies and increase planning to aid in dam maintenance and support. For example, one respondent noted: "I believe there is a need for a comprehensive long-term dam maintenance and preservation plan, developed by and involving county, state, and U.S. Army Corps personnel. It is my assessment that the staff assigned is understaffed to support necessary maintenance." Others were concerned that the USACE was overtasked and, therefore, unable to effectively regulate water to control upstream flooding.

Increased communication on the current conditions of dams, along with information on how land use has changed since the date of construction and plans to avoid, mitigate, or adapt to potential hazards associated with dam and levee failure are necessary among local stakeholders, dam managers, dam owners, and community members (National Academy of Sciences 2012). Updated flood zone maps are essential in communicating associated flood risks near dams; however, nearly half of counties in Kansas do not have access to digitized flood zone maps available on Kansas Floodplain Viewer as of September 2021.

Those interested in talking about flood risk perception and dam management were eager to share their opinions on the "importance" of the study. Despite my removed location during this research, the sense of familiarity and rapport that I had developed with many watershed managers in previous years provided a good foundation when speaking with individuals. Local watershed experts who lived near or were familiar with the dam appreciated being able to speak about something so "close to home." I believe there would have been an even more significant advantage to meeting with people had I been able to travel during the interview process, which unfortunately coincided with the COVID-19 pandemic and wide-scale shutdowns.

As I interviewed public officials, there were agencies obviously unfamiliar with local dam information in the same counties. In several instances, I was referred to the local extension agencies to provide additional details on flood risks, potential dam breaches, or detailed maps on flood data. Two extension agents could not find the information I requested. I followed the statement by asking if a member of the community had a similar question, where would they recommend that person go to find that information. In both instances, the extension agents said they would still recommend that people come to them for information first, however there were no further recommendations or resources provided. If two out of 10 don't know potential flood conditions, how many out of 6,000 don't know? More than once I was told that I would be contacted once they had the information, but never was.

Digitally available online hydrological models are still lacking in providing accessible data to users. From a research perspective, it appears that many of the FEMA maps show the reservoir as a permanent water structure and rarely account for intentional releases or dam failures. A FEMA publication on the Guidance for Flood Risk Analysis and Mapping: Dams/Reservoirs and Non-Dam Features (2019) states that risk assessments concerning the possibility of a dam break are not considered (p.3). Certain areas within Special Flood Hazards Areas (SFHA) are not identified even when there is evidence of protection from a flood control structure. The flood risk products, such as Flood Risk Map (FRM), Flood Risk Report (FRR), and Flood Risk Database (FRD) that are available to select communities, are non-regulatory resources that are only meant to supplement the flood hazard information. Some digital mapping has been updated, but most available information is, at best, time-consuming to find, difficult to understand, and information dense. While these maps provide helpful information to experts and those familiar with flood hazards, it's an overstatement to call these products helpful to the general public. In an attempt to use the FEMA *National Flood Hazard Layer (NFHL) Viewer* with *Web AppBuilder for ArcGIS*, I experienced difficulty typing in an address and getting the address to stay in that location as I zoomed out to view it on a larger scale. As someone with experience using digital maps with layers, I found this frustrating and challenging to manage. There is a need to make these applications more user-friendly, perhaps even a simplified version, that allows accurate and readable information for the nonprofessional user. Risk maps have the potential to be used as communication tools to raise flood risk awareness but currently lack the proficiency to do so.

Hindsight

Climate Change

The questionnaire used for this study relied heavily on the impacts of predicted climate change in eastern Kansas as a justification for the need to focus on potential dam failures in the area. The questions were designed to better understand how residents perceive flood risk based on their current understanding and exposure to common weather events. Given that climate change was so prominent in the literature, there are fewer than five questions that attempt to link flood risk perception to climate data. Questions on preparedness, the likelihood of flooding, the likelihood of flooding in the coming year, and concern over major flood events barely touched the surface on how those respondents might perceive flood risk given current climatic conditions. Additional research linking flood risk perception to climate awareness would be beneficial.

High Hazard Dams

Despite this study using high hazard dams and Emergency Action Plans (EAP) as part of the research selection criteria, it was hard to tell whether respondents knew that the USACE had identified the dam in their area as a high hazard dam. Dam safety professionals use EAPs as a way to reduce flooding due to uncontrolled and controlled flows from dams (National Academy of Sciences 2012). Still, they do not rely on these as instruments for communication. Although I asked generalized questions on their knowledge of the dam in their area, there was never a question or statement discussing high-hazard dams or EAP. This could have served as a vital component to examining whether people perceived their dam as a high hazard or not or whether they were aware that the dam already had an EAP in place.

Mental Maps

Inspired by the work of O’Neill et al. (2016) on the role distance from flood exposure plays in the impact of flood risk perception using cognitive mapping, I believe this component was missing from my study. Given more resources, I would have liked to interview participants from my selected study sites using the questionnaire and providing them with the resources to provide a mental map of their perceived risk. Not only would this identify any misperception among participants, but it would also have been an excellent resource for flood-risk managers. This may serve as a fruitful area of future research.

Can we actually change flood risk perception?

Throughout this study, I identified areas of potential risk based on both the physical structure of the dams and the vulnerability of their nearby populations. Based on respondent participation, I concluded that the interest in dams varies both spatially and temporally and can be categorized into three different “ways of life.” It is without question that many agencies are lacking the information and resources to be ablet to effectively communicate with populations who live near dams. The question of aging and capacity of dams will continue to increase over time and will only become more of a risk as time goes on. The short answer is yes.

In order to change flood risk perception, efforts should begin at the local level, which includes making information on dams easier to access and understand. Next, policy changes in at-risk areas will be crucial to ensuring the public’s safety and providing a framework on how to handle the large number of aging dams statewide. As a final suggestion, there is still work to be done in terms of gaining a greater understanding of flood risk perception near aging dams in Kansas.

First, agencies responsible for disseminating information to the public need to become easier at the local level. This begins with having dam information kept on file and education on where to find information on dams in their local area. While the National Inventory Dams database provides a substantial amount of information about dams, there is a clear distinction between information available for federal versus state- and privately-owned dams. Non-federal dams are less likely to report when the last dam inspection occurred, details on Emergency Action Plans including action plans, revision dates and emergency contact information. There is no indication whether state- and privately-owned dams meet FEMA guidelines. Federal dams also include a risk characterization summary and risk management measures, which state- and privately-owned dams do not. Any dam with an Emergency Action Plan should be public information that is easily attainable. Currently there are missed opportunities by local agencies to share this knowledge. I have identified a body of dams along several streams and their tributaries that will likely be impacted from dam failure in the near future. Digitizing dam information and updating flood maps in rural areas are imperative to local governments' ability to provide up-to-date and accurate information on the status of dams in one's area. Policy changes are likely needed in at- risk areas that will implement changes in how dams are being managed and what actions can be taken now to reduce the potential for loss of life or damage to property in the event of a dam failure. Additional policy changes should be required at the federal level to ensure that all flood maps include flood risk areas in the event of a dam failure. This is a component that is missing from most of the maps I examined during this research, particularly regarding intermediate-sized dams. At this point, the response from participants suggests that dam risk perception is not a priority for many individuals and may result from a lack of awareness, information, or interest. The current implication of dam risk perception among many participants was they were not worried about their property but feared for the community. With greater access and updated dam information including updated flood maps, this should increase awareness of those who may actually be at risk but do not perceive risk at this time.

Summary

Results of this study identified intermediate-size dams in eastern Kansas that are most at risk of dam failure, how local populations' perceptions and vulnerabilities to at-risk dams vary, and how risk communication can be improved among vulnerable populations. Media attention will undoubtedly focus on the large dams, but thousands of small dams across the United States likely will fail in the coming years, with the potential to cause significant damage and loss of life.

This study identified eighteen intermediate-size dams in eastern Kansas that are most at risk of dam failure based on the research criteria presented in Chapter 3, with other special dams of interest along select waterways and their tributaries in Brown, Atchinson, Chautauqua, Butler, and Greenwood counties. At least 18 percent of dams missing completion dates, which indicate the age of the dam, are used for flood control purposes. Hazard classifications for dams are typically assigned based on the potential impact a dam failure or breach would have on downstream areas. State and local governments complete periodic safety inspections to determine the dam's hazard potential, the physical condition of the dam, and whether an emergency action plan is in place should the dam fail. State and local governments are responsible for enforcing and maintaining safety regulations for all non-federal dams. Federal dams, including most of the larger dams in Kansas and across the United States, are built, maintained, and inspected by the federal funding agency. Dam inspections are meant to ensure expected performance, identify deficiencies, assess the dam's integrity, and determine if the dam is being properly operated and maintained (USACE 2014). However, ratings are subjective and not always publicly disclosed. Under-inspected dams result from an underfunded and understaffed system in water resource management. Conditions thus vary with physical, locational characteristics as well as social conditions.

The results from this study also indicate that respondents are generally confident in their ability to react to a flood event or dam breach, despite their physical location in a flood zone and without updated flood zone information easily accessible.

Flood risk is specific to the community – in the way that no two dams are built exactly alike, in the same circumstances, and with the same number of people in potential flood areas. This line of thinking correlates with spatial and temporal variations in risk perception, where people are less likely to perceive risk the further they are removed from the source or through a false sense of security. Using cultural theory to understand how individuals perceive flood risk perception, this study found that most respondents leaned towards hierarchies, where their attitudes and actions indicated a reliance on expert or authoritative information and mistrust in the climate over the actual dam. Increasing the accuracy of flood risk perception and effectiveness of communication is dependent on understanding how local dams will affect residents' property, town, and for many, livelihoods. While there is a need for more generalized and overarching information to be available, real work needs to begin at the local level.

Additionally, by completing interviews with water-management experts, I found that risk communication could be improved for vulnerable populations. Currently, requesting information on dam data can be challenging when approaching it from the outlook of the general public. Missing data and lack of available information to the public by water-management experts contributes to the need to understand how dam safety and risk communication can be improved in Kansas. Information must be continually updated and widely accessible, mainly as budget constraints will prevent many dams from receiving the mitigation and rehabilitation measures necessary to maintain the dam's intended purpose. Every dam in the state of Kansas should have an updated comprehensive risk assessment available at their county offices that includes characteristics of the dam, flood risk data should there be a breach in the dam, and publicly available reports on dam inspections.

As I completed this study, several promising opportunities presented themselves that would significantly contribute to the fields of geography, natural hazards, and topics in risk perception. This includes additional research linking flood risk perception to climate change, using mental maps to understand perception through cognitive mapping, and an emphasis on understanding how risk communication can change if dam safety professionals use emergency action plans or classify high-hazard dams. This chapter concludes by discussing the viability of changing flood risk perception, and the short answer is yes, perception can be changed. Making information on dams easier to access and understand should begin at the local level, with a shift towards policy changes that can address how to handle the significant number of aging dams in Kansas.

Chapter 7 - Conclusions

Kansas dams provide flood control for downstream populations, agricultural production, water supply, and recreation for its 2.9 million residents. In order to do this, Kansas relies heavily on the large number of dams constructed during the 30-year period between 1970 and 2000 to provide a sense of security despite changing climatic conditions. However, as for most of the dams in the United States, Kansas now faces an aging problem. Intermediate dams receive less attention than their more prominent and often federal counterparts. Aging, intermediate-size dams unknowingly put many residents at risk. Kansas dams are no longer operating at full capacity due to increased demands, changes in the physical environment, dam sedimentation, budget/workforce constraints, and the deterioration of dam construction materials. Rural areas in Kansas face unique circumstances to potential dam failures where there is a greater potential to affect human and animal health through disease and water contamination. Smaller communities often lack the resources to deal with floodwater, particularly following significant rainfall events. Extreme weather events exacerbated by climate change indicate an upward trend in extreme precipitation totals and shifts in hydrologic events that will affect dam function and other runoff control structures. In this final chapter a brief summarization of the findings uncovered in this study, their implications, and observations regarding this research are undertaken. The limitations of the research also are explored, in addition to possibilities for future inquiry.

Thanks to water resource capture and design innovation, many waterways across Kansas have been managed for uses including flood control, water supply, irrigation, and recreation. The significant number of dams constructed between 1970 and 2000 was so effective at providing these resources that a generation has grown up with the safety of dams and their benefits, often with little thought to their hazard implications. The evolution of natural hazards research links complex social components with understanding of the physical processes that contribute to hazardous events. Geographers and natural hazard researchers have made tremendous strides in recognizing how flooding has affected physical environments and human societies. Some researchers have focused on understanding how the probability of risk affects society (Mitchell 1990, IPCC 2014, Paul 2011), others have focused on understanding how vulnerability (Klinenberg 2002, Pelling 200, Brooks 2003), resilience (National Research Council 2012, Seebauer and Bibcicky 2017, Cutter et al. 2016), behavior (Terpstra et al. 2009, Mehta et al. 2020, Wasson 2016), and communication (Mileti 1999, Slovic et al. 2000, Cutter et al. 2003, Burton et al. 1993) contribute to risk perception. Researchers have focused on the benefit/cost ratios to understand why vulnerable populations continue to live in flood-prone areas (Starr 1976, Nelson 2014, Burningham et al. 2007), while others have focused on how public risk perception influences flood risk management (Kellens et al. 2011, Atreya and Ferreira 2012, Terpstra et al. 2009, Mehta et al. 2020). The most available and abundant data on dams, including their associated risks, tends to only be available for larger dams, mainly federally funded dams representing a very small portion of the vast number of dams in Kansas and the United States in general. However, the vantage point of the residents who live near aging dams, their perceptions of potential dam failure, and their associated risks have received little attention.

Summarization of Findings

As of 2020, more than half of the over 5,000 dams registered in Kansas had reached their life expectancy. Once mostly rural dams, dams across the state are experiencing population changes that affect the dam’s designed intention. In some areas, the appeal of suburban life has extended beyond city centers, resulting in increased populations near aging dams. Residents in other communities have become more vulnerable as increases in poverty rates, median age, and employment affects the need for emergency response and preparedness. This study was divided into three research objectives: 1) understanding flood risk perceptions of populations at foreseeable risk, 2) comparing how perceptions related to physical risk vary, and 3) filling gaps in information related to at-risk infrastructure in addition to bridging risk communication gaps. These objectives were more specifically addressed via the following research questions: 1) Which intermediate-sized dams in eastern Kansas are most at risk of dam failure?; 2) How do local populations' perceptions of risk and vulnerability to at-risk dams vary? (Do perceptions align with factors related to failure risk?); and 3) How can risk communication be improved among vulnerable populations?

I employed an explanatory sequential mixed methods approach grounded in cultural theory to understand how flood risk is perceived near Kansas dams. During the first half of the study, 1,100 mailed questionnaires were sent to ten study sites in Kansas that had dams over 50 years old with a neighboring population, and that were likely to experience an increase in the frequency and magnitude of significant storm events. Semi-structured interviews were conducted with water resource experts, stakeholders, and government officials knowledgeable about the selected study sites. After data collection from the mailed questionnaires was complete, correlation and contingency analyses tested relationships among close-ended responses for statistical significance. Open-ended responses and interview transcriptions were coded within NVivo to provide depth to the close-ended material.

Key findings for intermediate-size dams in Kansas most at risk of dam failure

Through GIS analysis and secondary data, I could determine which dams in eastern Kansas are likely to be the riskiest for dam failure, given their age, location, and structure. Throughout the analysis, there were several inaccuracies and a need for completeness of current NID data. There is also a discrepancy in the classification of high hazards dams by the USACE and information at the state level. The lack of accuracy and completeness likely contributes to the communication breakdown between decision-makers and the local population.

Key findings for local populations' perceptions of risk and vulnerability to at-risk dams

The belief that "it'll never happen to me," as discussed by Burningham et al. (2008) was evident among most respondents and interviewees concerning dam structure and future effectiveness. Concern about flood risk was most associated with respondents who lived in a floodplain, had experienced previous flooding, and had been indirectly affected by flooding. A sense of higher risk was most associated with respondents who felt their livelihood would be affected in the event of a flood. Similarly, those not worried about a dam's design life were not concerned about flooding. Those confident in the assessment of dam knowledge may have a false sense of security based on their level of experience with flooding after the dam was constructed.

Upstream residents reported the most concern regarding potential dam failure (Figure 7.1) but felt less concerned about flooding (Figure 7.2) and reported not having very much information about their property. They also were neutral on most answers regarding preparedness, dam life expectancy, being at risk, and dam design. Significant differences (chi squares shown in Appendix L) between upstream and downstream residents suggest that downstream residents felt better prepared to handle a flood event, were more concerned that the community would be affected by a flood event, considered a potential flood event life-threatening, and could confidently explain the purpose of a dam as compared to upstream residents.

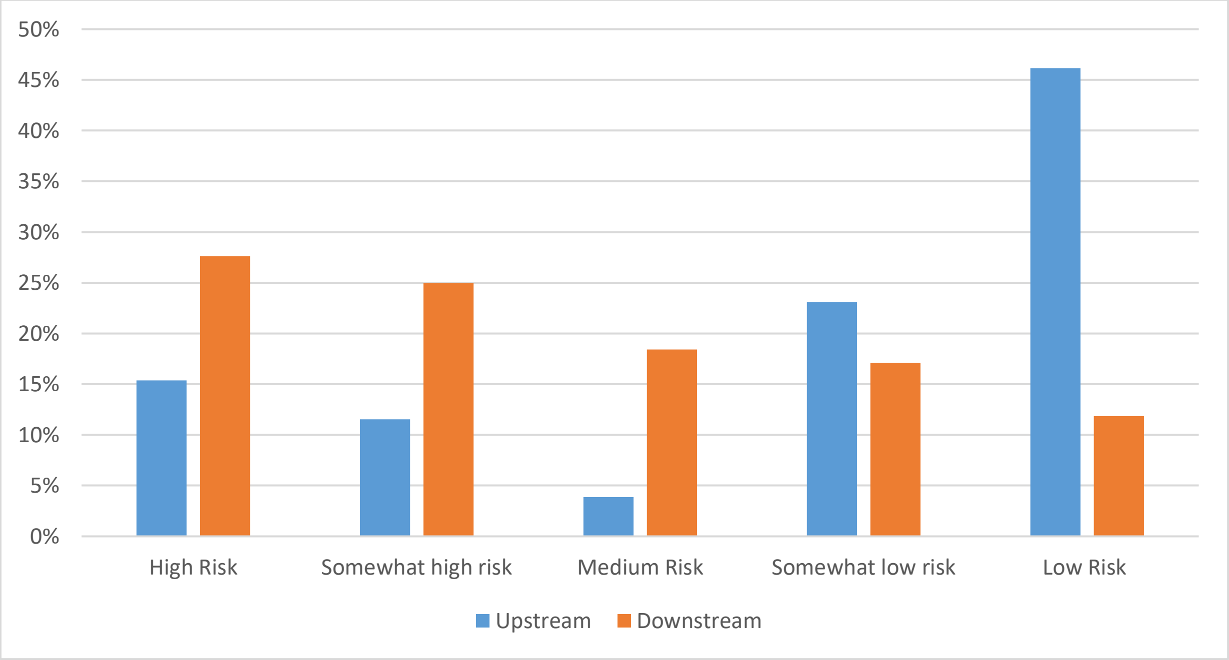


Figure 7.1. Concern over potential dam failure by upstream and downstream residents

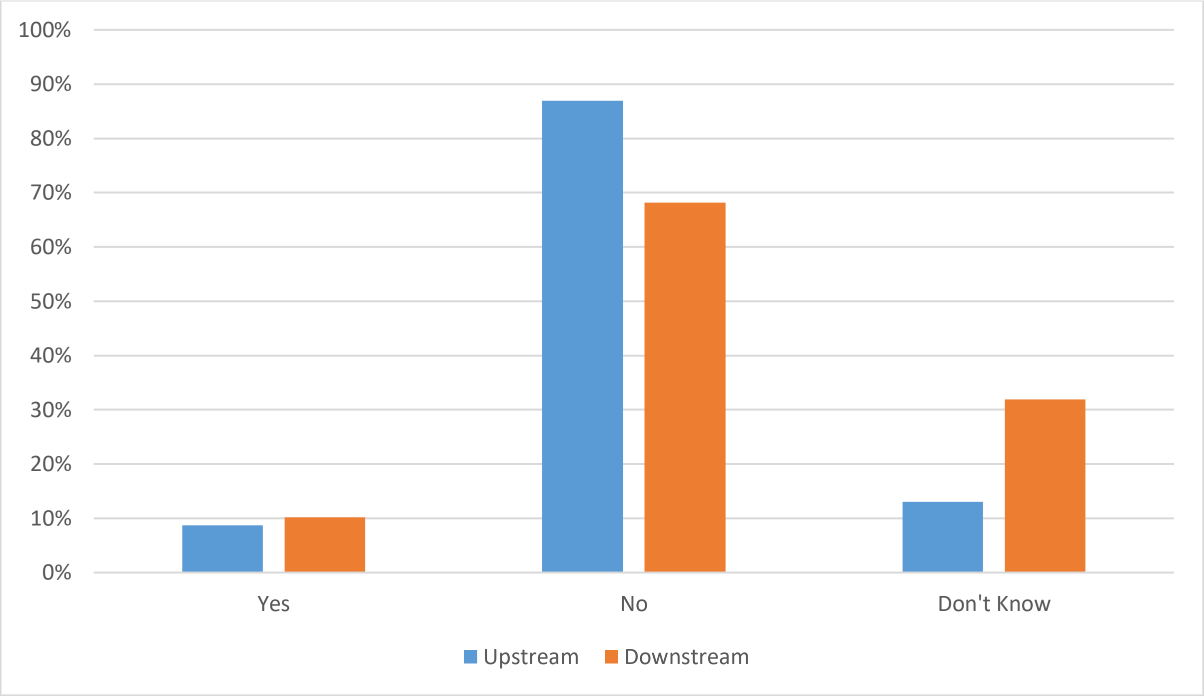


Figure 7.2. Response to Q8 by upstream and downstream residents.

Regarding whether perceptions align with factors related to variations in perception, the questionnaire results suggest that flood risk perception was higher among residents at actual risk of a flood event, as identified by flood zone maps, but with low regard for the dam creating the flood event. In other words, respondents were unsure that dams would provide flood control beyond the 50 to 100-year design life but were not worried or concerned that the dam would breach or fail despite its age or condition. One of the factors used to determine a dam's riskiness level is the construction date of the dam. Perceptions over whether a dam can provide flood control over a certain age align with one of these factors. Other factors such as social vulnerability, ruralness, and increased precipitation were not addressed in this questionnaire but have a strong potential for further exploration of how dams are perceived given these factors.

Overall, perceptions aligned with factors related to failure risk when dealing with recent events, such as the significant rain event that impacted Marion County. Otherwise, most respondents were not concerned with immediate flooding, risk of dam failure, or impacts from flood damage although they thought there might be flooding later on. In these instances, where dams have been providing flood control for over 50 years, respondents did not perceive an increased level of risk should the dam fail.

Key findings for potential improvements to risk communication.

A concern that emerged while conducting interviews was the lack of knowledge by the agencies that were supposed to be the public resources for dam information. Many agencies were unfamiliar with local dam information within their county and could not provide accurate information regarding the age, condition, or status of the selected dams. There is still a need for digitally available flood maps to be available for all rural areas, especially as these are areas that are likely to have a higher social vulnerability to extreme events like dam failure or flooding. There is still work that needs to be done in terms of understanding flood risk perception near aging dams in Kansas; however, current efforts should begin at the local level, followed by policy changes in at-risk areas as identified in this study to ensure the public's safety and to provide a framework for addressing a large number of aging dams throughout Kansas.

Additional Observations

Within the field of geography, this research contributes to the existing body of knowledge, particularly the subfield of hazards studies (a part of the human-environment relations focus of the discipline); examines and identifies policy implications; and supports the growth of public knowledge on local issues. As part of the existing body of knowledge, this research supports the object of uncertainty framework in practices (Dewulf and Biesbroeck

2018), contributes to the growth of knowledge on flood risk perceptions (Ridolfi et al. 2019), and highlights the importance of individual choices per Douglas' (1978) cultural theory. Policy implications identified in this research include the lack of sufficient funding, the lack of appropriate inspections, and the need to clarify hazard levels and expectations of EAP components. In order to support the growth of public knowledge on local issues, I plan to disseminate the findings presented in this research back to participants as part of increasing risk communication and awareness among public and water resource experts.

This work adds to the body of risk perception research by exploring how populations near aging dams perceive risk. Risk perception literature often focuses on flood risk perceptions, but there is a lack of research conducted on perceptions associated with aging infrastructure, and in particular dams. Furthermore, this work provides a comparison of how perceptions relate to physical risk based on location, social vulnerability, and general knowledge and awareness of flood risk and dam safety. Many respondents did not feel they were at risk of dam failure despite being in flood zones or flood-prone areas that would be inundated given a dam breach.

The research instrument used here could be more broadly applied within Kansas and has the potential to be useful in other places given a larger sample size. This work also contributes to rural geography by identifying how the changes in population size and characteristics of rural places can influence the infrastructure and hazards in rural areas. Additionally, it contributes to the recognition of the lack of information and resources available within rural areas when it comes to major flood events. There is still a significant need for updated and digitized flood maps, a need for more dam managers, and easier access to emergency and financial resources. Increased communication measures and techniques, as discussed in Chapter 6, address the gaps related to at-risk infrastructure and the communication gaps between experts and laymen, where dam information is inconsistent and largely unavailable. Due to budget constraints, the results of this study are very narrow, but still important in understanding how perception varies spatially and temporally. Mailed questionnaires were chosen because I could cover a greater area at relatively the same time using the same questions for each respondent. Being mindful of the participants' time and willingness to fill out the questionnaire limited the complexity of the questions and only allowed for brief and self-explanatory responses. Other general disadvantages of the mailed questionnaire were the low response rate, of which I had no control. Although I anticipated a somewhat low response rate due to the topic and general interest in flood risk perception and dam safety, I was pleased with the results from Marion Dam, which experienced a flood event during the time of the questionnaire and likely prompted individuals to respond based on the relevancy to them at the time.

Like many others, the pandemic quarantine shut down and movement from the workplace to home office put a strain on accessing non-essential employees. During the interview process, I experienced limited accessibility or difficulty contacting the "right person" to talk to. In a typical office setting, where someone might walk down the hallway for an answer, I was now waiting days to hopefully hear back from someone that might know the answer. In my opinion, it took several months for people to adjust to the new norm during the pandemic, which slowed down the interview process.

Future Research

Ideas for future research arise based on project findings, the use of different data, and potential for building on my findings from this study. Dams are part of a very complex social-ecological system that leaves the door open for a multitude of future studies that can build off of the research conducted for this study. For example, there is a need to improve the ways we currently use maps for risk communication, to evaluate how flood risk perception changes over time and space within a society that experiences more extreme weather events, and to gain a greater understanding on the public perception of aging Kansas dams across a broader area, as well as aging dams in other parts of the country.

Visual means, such as maps, have the potential to be used for raising awareness, communicating different risk levels, actions to take, prevention, and preparedness as a form of direct risk communication, as was similarly addressed by Charriere et al. (2013) in their study on the effectiveness of flood risk communication. Understanding flood risk perception, in combination with social vulnerability, needs to be further explored and on a greater scale to improve risk communication and safety of those near aging dams. In a Netherlands study on the implications for flood risk management, the Dutch government responded to rising flood levels and population growth near the river by adopting a “room for the river” policy which allows rivers to rise and drop, as they do naturally. Not only does this prevent the government from fighting climate change and finding funds needed to strengthen the levees, but it also protects downstream low-lying areas from accidental flooding (Baan and Klijn 2004). Filling the gap between flood risk perception and flood risk near dams should address major issues like climate change/major weather events and statewide public interest. Additionally, this research should go beyond the scope of my selected dam sites and focus on all Kansas dams, particularly those that are approaching their designed life expectancy and have an emergency action plan enacted due to their hazard level. Comparisons with conditions and residential perceptions of dam-related hazards in other states also are desirable. Future studies should take into account the lack of visual means needed for effective risk communication by working with stakeholders who can recommend both case study specific and overall improvements for flood mapping.

As a result of the findings from this study, I found that hazard and risk information sources were highly likely to use social media as a means of communicating with the general public. Flood resource information, dam information, and other online products such as the Kansas Floodplain Risk Viewer, FEMA, and USACE NID websites allow users to access flood and dam information by simply inputting their address. Understanding who and how many people use products for flood and dam risk information would be insightful for decision makers. Exploration of what information sources influenced their decisions the most – the aforementioned products, family, friends, government, local institutions, extension agencies, television, radio, social media – and how those influences either increased or decreased public perception is desirable.

Building on my findings, a longitudinal study where residents are asked to evaluate their perception of flood risk on an annual basis, either through email or an internet-based survey, would indicate how flood risk perception changes as climatic conditions change and during major flood events. As with the case of Marion County, a greater number of responses came when the flood event occurred near the time of the questionnaire. It would also be interesting to see how respondents reply during major flood events in their area as timing is so critical. Eventually, this would also answer the question of whether dams are becoming more of a liability or if they are still providing sufficient economic good in comparison to potential costs.

Using different data, I would like to develop another questionnaire that identifies how people fall under each ‘way of life’ (nature perverse/tolerant (hierarchy), nature benign (individualistic), nature ephemeral (egalitarian), or nature capricious (fatalistic)) in order to determine how individuals or communities perceive, react, and manage flood risk particularly in relation to dams. Having a greater understanding of which kind of people share similar perceptions would allow for more effective responses from leaders in terms of policy changes and/or practical applications to dealing with flood risk near dams. There is also a need to determine public interest in the future of Kansas dams. What is the public opinion statewide on the future of Kansas dams? What does the population want in terms of removal, decommissioning, maintenance, rehabilitation, or new construction? Has there been a shift in the way the general population uses the watershed? Do spatial and demographic characteristics play a role in the general opinion of dam users?

Kansas plays a significant role in the agriculture industry in the United States. Further research should be conducted to determine how at-risk dams can directly affect rural farming communities in the state. Focusing specifically on the agriculture sector and farmers' risk perception regarding aging dams in Kansas would provide valuable information to risk managers and decision-makers on addressing potential concerns with agriculture production should these aging dams no longer be able to provide the services for which they were intended. This also has the potential to be used for applying for grants and financial resources that would keep Kansans aware and prepared to address the risks associated with aging dams and climate impacts.

Additional research focused on environmental governance would also serve to answer what formal and informal institutions exist to address risk associated with dam failures, as an appropriate approach for the development of policymaking concerns and communications with stakeholders. The spatial distribution of environmental hazards and cross-scale environmental governance transcends traditional political boundaries and has resulted in the creation of international agencies to manage decision making on multiple scales (Lemos and Agrawal 2006).

The technical complexities of developing and implementing policies to address environmental hazards that spread across different social networks prove challenging when dealing with uncertainty.

Socio-ecological relationships and uncertainties about environmental issues require action from decision makers by both public and private actors (Dewulf and Biesbrok 2018). At the same time, environmental governance often is seen as most effective at the local to regional level, and consideration of local knowledge and perceptions has grown in importance (Badenoch 2002). Geographically larger areas are often criticized for governance structure issues, where adaptive governance approaches (democratization, participation, transparency, and accountability) have fewer flexible outcomes when compared to smaller geographic areas (Akmani and Wilson 2011, Trebitz and Wulfhorst 2020).

Research focused on environmental governance has the potential to address three main principles related flood risk perception near aging dams: 1) transparency and access to information, 2) representation of minorities, elderly, and rural populations, and 3) financial accountability. Future research should identify ways that policy can amplify or reduce either risk itself or perceptions about risk, including the roles that institutions have in the perception of risk from dams in general. There is currently an over-reliance on technological dissemination that may not reach under-represented populations. Incomplete and inaccurate data on websites, unavailable data on current reservoir storage, and a need for increased resources (physical, human, intellectual, and financial) are areas of exploration that should be considered for future research.

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Appendix A - Dam Profiles

Cedar Creek Reservoir Dam

Cedar Creek Reservoir Dam has an estimated construction date of 1968 but is not officially listed within the NID data. Primary uses of Cedar Creek Reservoir Dam include flood risk reduction and water supply for the City of Garnett. Cedar Creek Reservoir Dam has Cedar Creek Reservoir Dam is a rockfill dam with a height of 70 feet and a length of 1,750 ft. Normal storage for Cedar Creek Reservoir Dam is 4,400 acre-feet with a maximum storage of 24,000 acre-feet. The drainage area is 63 square miles. Cedar Creek Reservoir Dam is classified as a High Hazard Dam, with a fair condition assessment, and requires an inspection frequency of every three years. As of July 2, 2018, the NID reported the last inspection date as of December 11, 2018. An Emergency Action Plan (EAP) has been prepared for Cedar Creek Reservoir with no date listed on the last EAP revision.

https://nid.sec.usace.army.mil/#/dams/system/486176/summary

Council Grove City Dam

Council Grove City Dam was constructed in 1942 for the City of Council Grove to serve as flood risk reduction, recreation, and water supply. Council Grove City Dam has a surface area of 387 acres and is located on Canning Creek in Morris County, Kansas. Council Grove City Dam is an earthen dam, with a height of 75 feet and a length of 2,700 feet. Normal storage for the Council Grove City Dam is 9,985 acre-feet but has a maximum storage of 14,613 acre-feet. The drainage area covers 7.97 square miles. Council Grove City Dam is classified as a High Hazard Dam, with a fair condition assessment, and requires an inspection frequency of every three years. As of April 9, 2021, the NID reported the last inspection as of March 8, 2018. An Emergency Action Plan (EAP) has been prepared for FRD No 23, with no date listed on the last EAP revision. https://nid.sec.usace.army.mil/#/dams/system/482437/summary

Fall River Dam

The United States Army Corps of Engineers (USACE) completed construction of the federally funded Fall River Dam in 1948 with the primary purpose to reduce flooding in downstream communities, including Fall River, Fredonia, Neodesha, and Coffeyville, Kansas. Fall River Dam has a surface area of 2,329 acres and is located on the Fall River in Greenwood County, Kansas. Fall River Dam is a gravity-fed dam constructed from an earth-fill embankment with a rock and soil foundation. The National Inventory of Dams reports the structural height at 94 feet with a dam length of 6,015 feet. Normal storage for Fall River Dam is 22,627 acre-feet but has a maximum storage of 256,400 acre-feet. The drainage area covers 585 square miles.

Fall River Dam is classified as a High Hazard Dam and requires an inspection frequency every five years. As of February 21, 2022, the NID reported the last inspection as of July 31, 2018. An Emergency Action Plan (EAP) has been prepared for Fall River Dam under FEMA guidelines meeting the Federal Guidelines for Dam Safety requirements, Emergency Action Planning for Dams, FEMA 64. The last revision occurred on May 6, 2021 In February 2019, the USACE completed a risk assessment for Fall River Dam based on the potential for a rare flood that would result in the dam overtopping due to erosion and breach of the embankment dams. The report found possible water seeping along the foundation as a result of water diversion during the construction of the dam could potentially contribute to the risk of the dam. The USACE found that the most likely flooding scenario would occur during normal operation with intended large releases through the spillway gates, resulting in significant widespread flooding and loss of life and economic impacts. This scenario would result in less flooding than a dam failure. As part of their risk management measures, the Fall River Dam is equipped with instrumentation and a monitoring system to allow USACE staff to evaluate the dam for changing conditions. The USACE also plans to conduct routine inspections, address the EAP annually, and identify available equipment needed during an emergency response. Consequence estimates for Fall River indicate no risk to people (daytime/nighttime) or buildings at normal high pool or top of active storage pool during a non-breach scenario. Actual risk increases during non-breach scenarios when the pool elevation exceeds an intermediate high pool of 995 feet and during all breach scenarios at the normal high pool, security, top of active storage, intermediate high pool, and maximum high pool.

https://nid.sec.usace.army.mil/#/dams/system/550333/summary

FRD NO 23 (White Clay Brewery WS Dam 23)

The USDA NRCS (also known as the USDA SCS) completed construction of the locally funded FRD No 23 for the City of Atchison in 1962 with the primary purposes of flood risk reduction, recreation, fire protection, stock, or small fish pond. FRD No 23 is regulated, permitted, inspected, and enforced by the Kansas Department of Agriculture. FRD No 23 has a surface area of 38 acres and is located on Brewery Creek in Atchison County, Kansas.

FRD No 23 is an earth dam with a structural height of 52 feet and a dam length of 1,313 feet. The normal storage for FRD No 23 is 24 acre-feet with a maximum storage of 2,660 acre-feet. The drainage area is 2.84 square miles. Fall River Dam is classified as a High Hazard Dam, with a satisfactory condition assessment, and requires an inspection frequency every three years. As of May 24, 2021, the NID reported the last inspection as of March 22, 2018. An Emergency Action Plan (EAP) has been prepared for FRD No 23, with no date listed on the last EAP revision.

https://nid.sec.usace.army.mil/#/dams/system/482294/summary

Lake Parsons Dam

Lake Parsons Dam was completed in 1959 for the City of Parsons for the purposes of water supply, recreation, and flood risk reduction. Lake Parsons Dam is owned by the local government and is regulated, permitted, inspected, and enforced by the Kansas Department of Agriculture. Lake Parsons Dam has a surface area of 980 acres and is located on Labette Creek in Neosho County, Kansas. Lake Parsons Dam is an earth dam with a structural height of 52 feet and a dam length of 5,650 feet. The normal storage for Lake Parsons Dam is 10,050 acre-feet with a maximum storage of 38,000 acre-feet. The drainage area is 37.11 square miles. Lake Parsons Dam is classified as a High Hazard Dam, with a fair condition assessment, and requires an inspection frequency every three years. As of April 9, 2021, the NID reported the last inspection as of April 16, 2020. An Emergency Action Plan (EAP) has been prepared for Lake Parsons Dam, with no date listed on the last EAP revision.

https://nid.sec.usace.army.mil/#/dams/system/482439/summary

Little Kaw Creek Dam

Little Kaw Creek Dam, also known as Bear Lake Dam, was completed for the purposes of flood risk reduction near the city of Mahon, Kansas. There is no year completion date listed within the National Inventory Dams (NID) database. The dam is privately owned by the Bear Lake Home Association and is regulated, permitted, inspected, and enforced by the Kansas Department of Agriculture. Little Kaw Creek Dam has a surface area of 63.1 acres and is located on the Kaw Creek in Leavenworth County, Kansas. Little Kaw Creek Dam is an earth dam with a structural height of 41, and a dam length of 900 feet. The normal storage for Little Kaw Creek Dam is
610.7 acre-feet with a maximum storage of 1,738.1 acre-feet. The drainage area is 4.36 miles. Little Kaw Creek Dam is classified as a High Hazard Dam, with a fair condition assessment, and requires an inspection frequency of every three years. As of May 4, 2021, the NID reported the last inspection as of December 14, 2017. An Emergency Action Plan (EAP) has been prepared for Little Kaw Creek Dam, with no date listed on the last EAP revision.

https://nid.sec.usace.army.mil/#/dams/system/482029/summary

Marion Dam

Marion Dam was completed in 1968 with the primary purpose to reduce flooding in downstream communities, as well as provide water quality, water supply, fish and wildlife habitat, and recreation. The dam is federally owned by USACE - Tulsa District. Marion Dam has a surface area of 6,210 acres and is located on the Cottonwood River in Marion County, Kansas. Marion Dam is an earth dam with a structural height of 67 and a dam length of 8,375 feet. The normal storage for Marion Dam is 80,680 acre-feet with a maximum storage of 189,200 acre-feet. The drainage area is 200 square miles. According to the USACE, Marion Dam is used to hold back excess water during large storm events to reduce downstream flooding, before being released from the gated spillway. Mario Dam is classified as a High Hazard Dam, with a required inspection frequency of every five years. As of February 22, 2022, the NID reported the last inspection as of June 25, 2019. An Emergency Action Plan (EAP) has been prepared for Fall River Dam under FEMA guidelines, meeting the Federal Guidelines for Dam Safety requirements, Emergency Action Planning for Dams, FEMA 64. The last revision occurred on May 21, 2021. This is not a state regulated dam.

USACE completed a risk assessment for Marion Dam in 2014, and classified the risk associated with the dam as low. Failure of the dam would include downstream flooding resulting in loss of life and economic impacts to the towns of Marion, Florence, Cedar Point, Elmdale, and Strong City.

https://nid.sec.usace.army.mil/#/dams/system/550317/summary

Sedan Dam

Sedan Dam, also referred to as DD No 6-28, is a state regulated dam that was completed in 1965 and serves the primary purposes of flood risk reduction and water supply. The dam is owned by the city of Sedan, and enforced by the State of Kansas. Sedan Dam has a surface area of 75 acres and is located on Deer Creek in Chautauqua County, Kansas. This is an earthen dam with a structural height of 60 feet, and a dam length of 1,585 feet. The normal storage for Sedan Dam is 780 acre-feet with a maximum storage of 3,250 acre-feet. The drainage area is 7.03 miles Sedan Dam is classified as a High Hazard Dam, with a fair condition assessment, and requires an inspection frequency of every three years. As of May 4, 2021, the NID reported the last inspection as of May 26, 2020. An Emergency Action Plan (EAP) has been prepared for Sedan Dam, with no date listed on the last EAP revision.

https://nid.sec.usace.army.mil/#/dams/system/482748/summary

Switzler Creek Dam

Switzler Creek Dam was completed in 1962 for the primary purpose of flood risk reduction near the city of Osage, Kansas. The dam is owned by Watershed District No. 63 and is regulated, permitted, inspected, and enforced by the Kansas Department of Agriculture. Switzler Creek Dam has a surface area of 34.2 acres and is located on the Hoover Branch in Osage County, Kansas. This is an earthen dam with a structural height of 43 feet, and a dam length of 2,100 feet. The normal storage for Swtizler Creek Dam 171 acre-feet with a maximum storage of 4,537 acre-feet. The drainage area is 4.89 square miles. Sedan Dam is classified as a High Hazard Dam, with a fair condition assessment, and requires an inspection frequency of every three years. As of May 4,2021, the NID reported the last inspection as August 28, 2019. An Emergency Action Plan (EAP) has been prepared for Switzler Creek, with no date listed on the last EAP revision.

https://nid.sec.usace.army.mil/#/dams/system/482152/summary

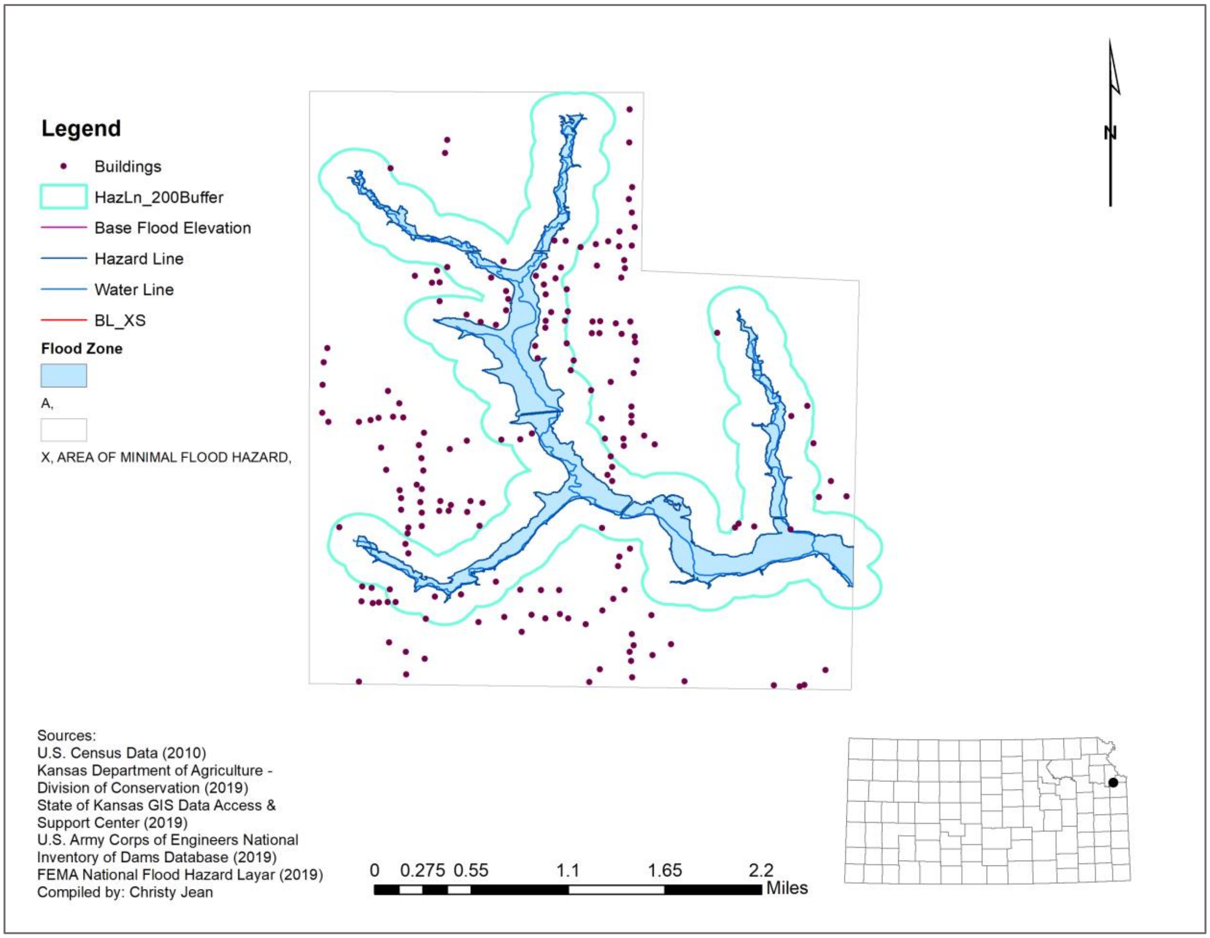
Toronto Dam

Toronto Dam was completed in 1960 for the primary purposes of flood risk reduction and water water supply near the city of Coyville, Kansas. The dam is owned by the United States Army Corps of Engineers (USACE)– Tulsa District and is regulated, permitted, inspected, and enforced by the USACE. Toronto Dam has a surface area 2,660 acres and is located on the Verdigris River in Woodson County, Kansas. This is a gravity, earthen dam with a structural height of 90 feet, and a dam length of 4,712 feet. The normal storage for Toronto Dam is 21,000 acre-feet. The drainage area is 730 square miles. Toronto Dam is classified as a High Hazard Dam, with an inspection frequency of every five years. As of May 2021, the NID reported the last inspection as August 18, 2018. An Emergency Action Plan (EAP) has been prepared for Toronto Dam with the Date of the last EAP revision on May 30, 2021. The last EAP Exercise date was on August 18, 2022 with emergency contacted updated on July 14, 2022. The EAP meets FEMA guidelines. Additional information on the Toronto Dam as reported by the NID includes a risk characterization summary and risk management measures.

https://nid.sec.usace.army.mil/#/dams/system/550347/summary

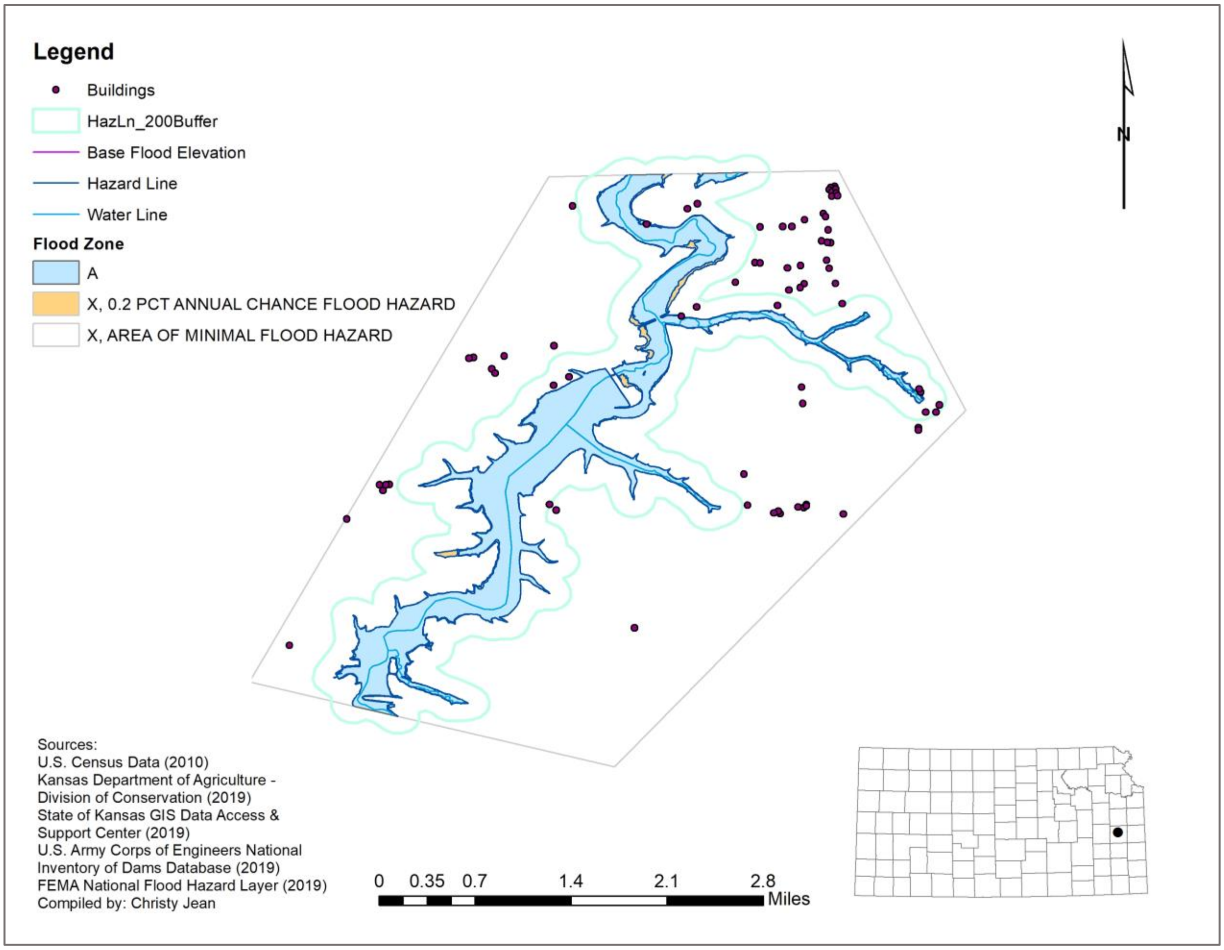
Appendix B - Study Locales

Imagery is from the FEMA Flood Plain Viewer. (Sedan, Fall River, and Toronto did not have flood zone maps.)

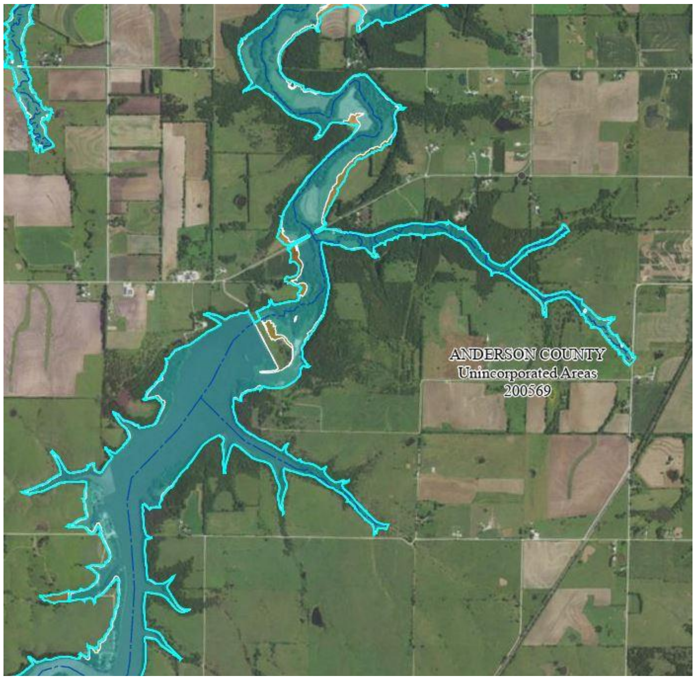


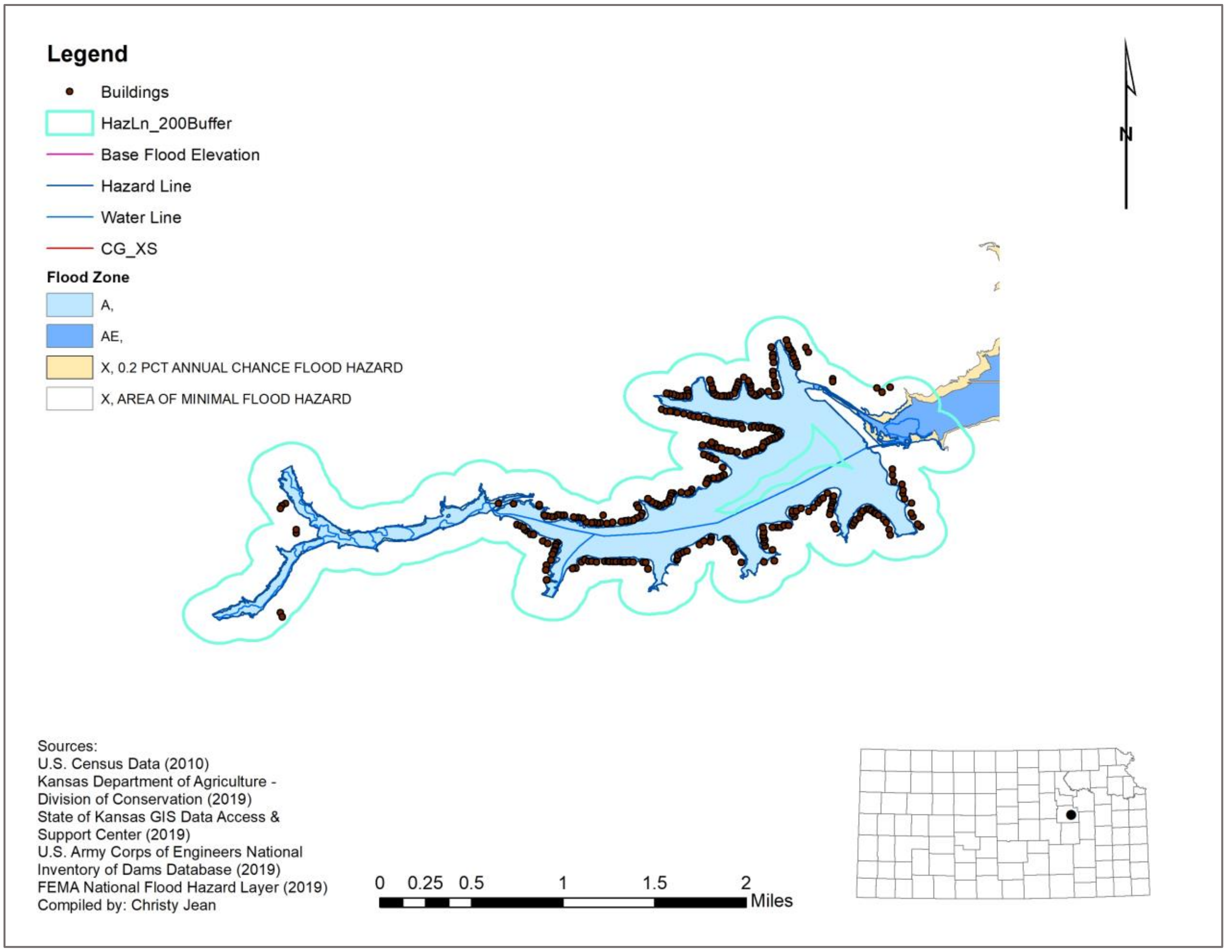
Sources:
U.S. Census Data (2010)
Kansas Department of Agriculture - Division of Conservation (2019)
State of Kansas GIS Data Access & Support Center (2019)
U.S. Army Corps of Engineers National Inventory of Dams Database (2019)
FEMA National Flood Hazard Layar (2019)
Compiled by: Christy Jean

Bear Lake: Little Kaw Creek Dam (aka Bear Lake Dam)



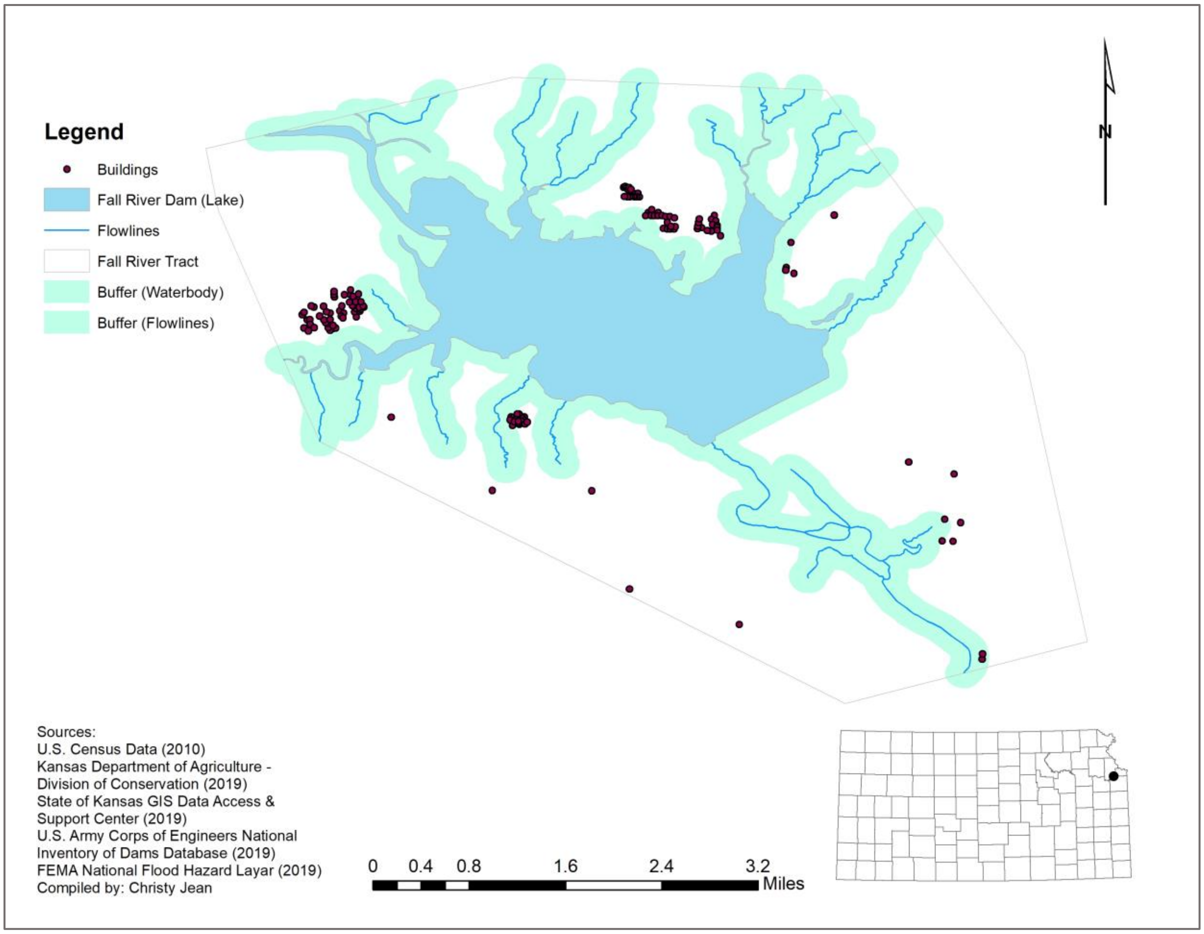
Cedar Creek: Cedar Creek Reservoir Dam



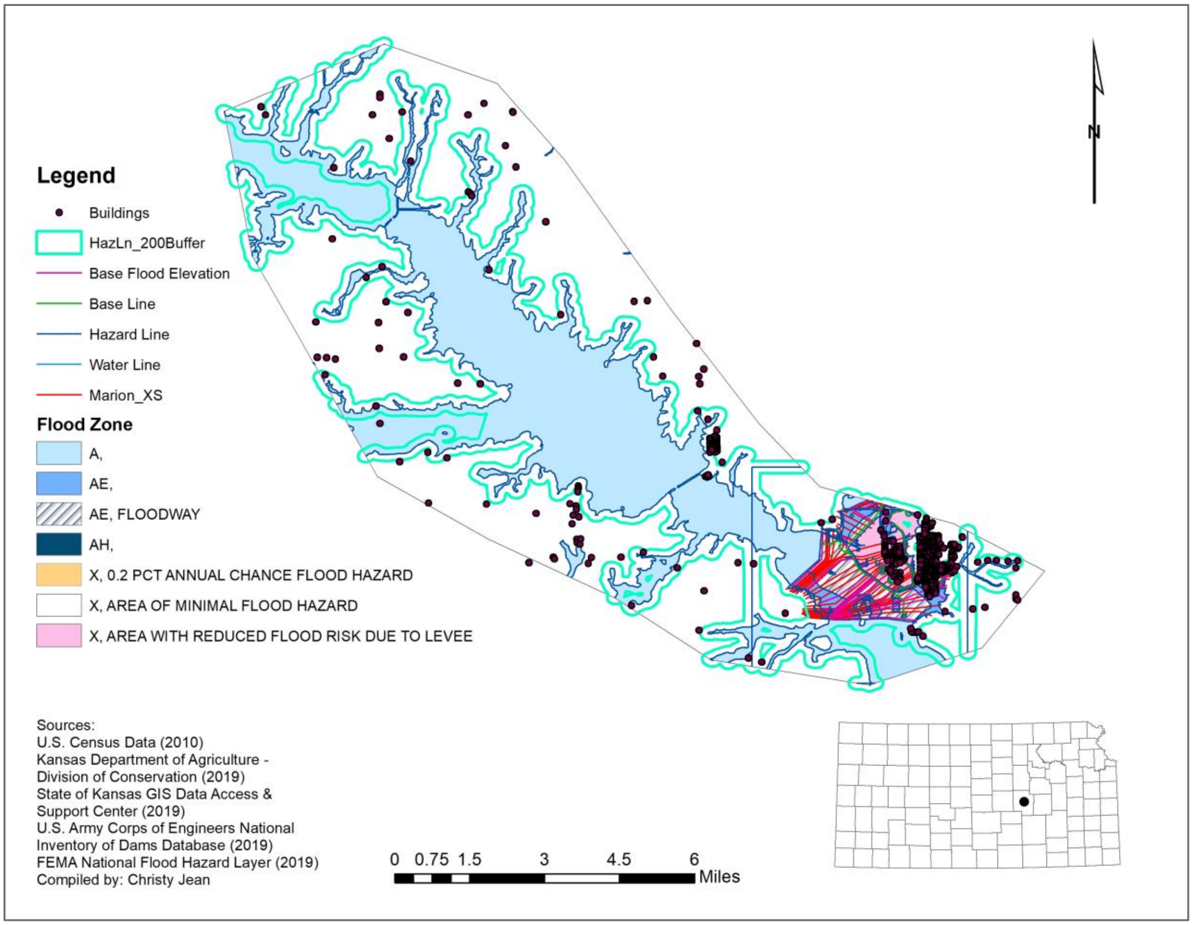


Sources:
U.S. Census Data (2010)
Kansas Department of Agriculture - Division of Conservation (2019)
State of Kansas GIS Data Access & Support Center (2019)
U.S. Army Corps of Engineers National Inventory of Dams Database (2019)
FEMA National Flood Hazard Layer (2019)
Compiled by: Christy Jean

Council Grove: Council Grove City Dam

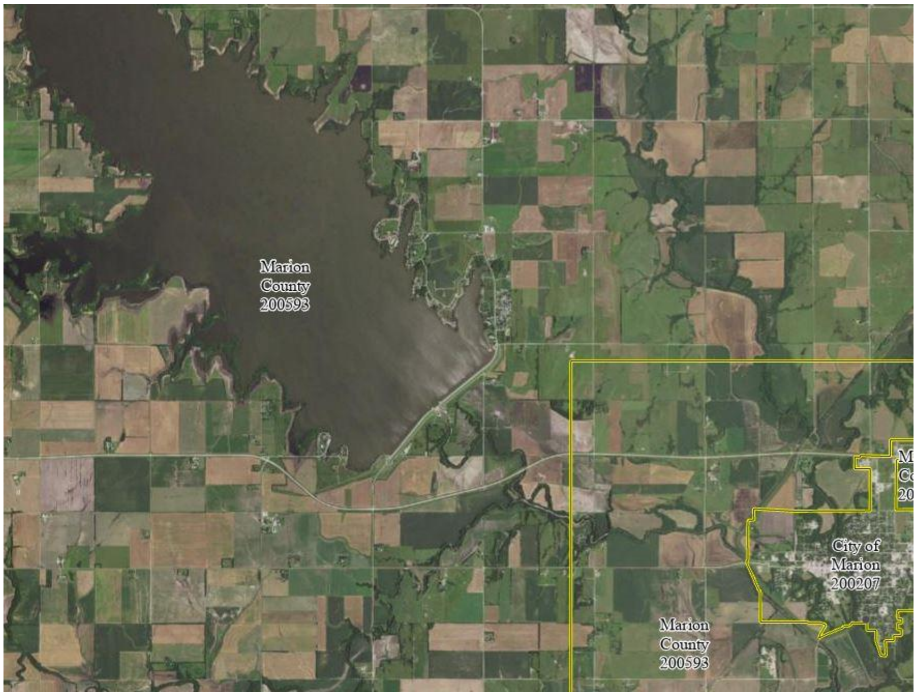


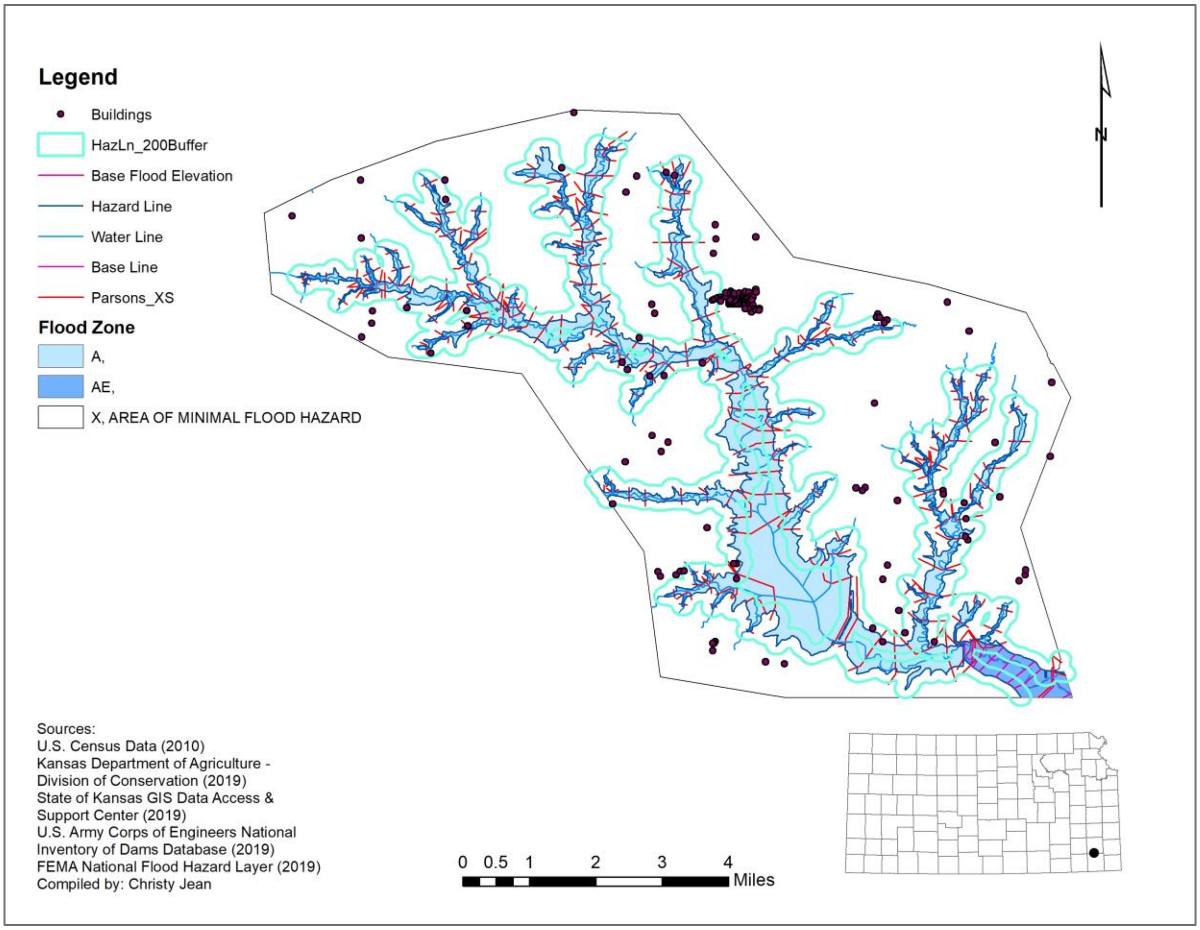
Fall River: Fall River Dam



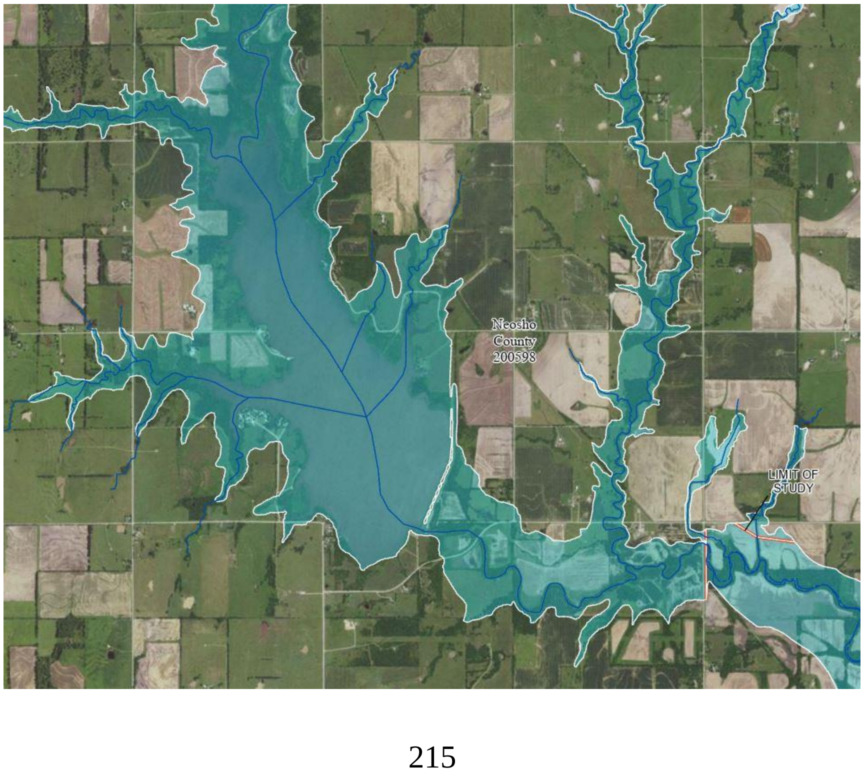
Sources:
U.S. Census Data (2010)
Kansas Department of Agriculture - Division of Conservation (2019)
State of Kansas GIS Data Access & Support Center (2019)
U.S. Army Corps of Engineers National Inventory of Dams Database (2019)
FEMA National Flood Hazard Layer (2019)
Compiled by: Christy Jean

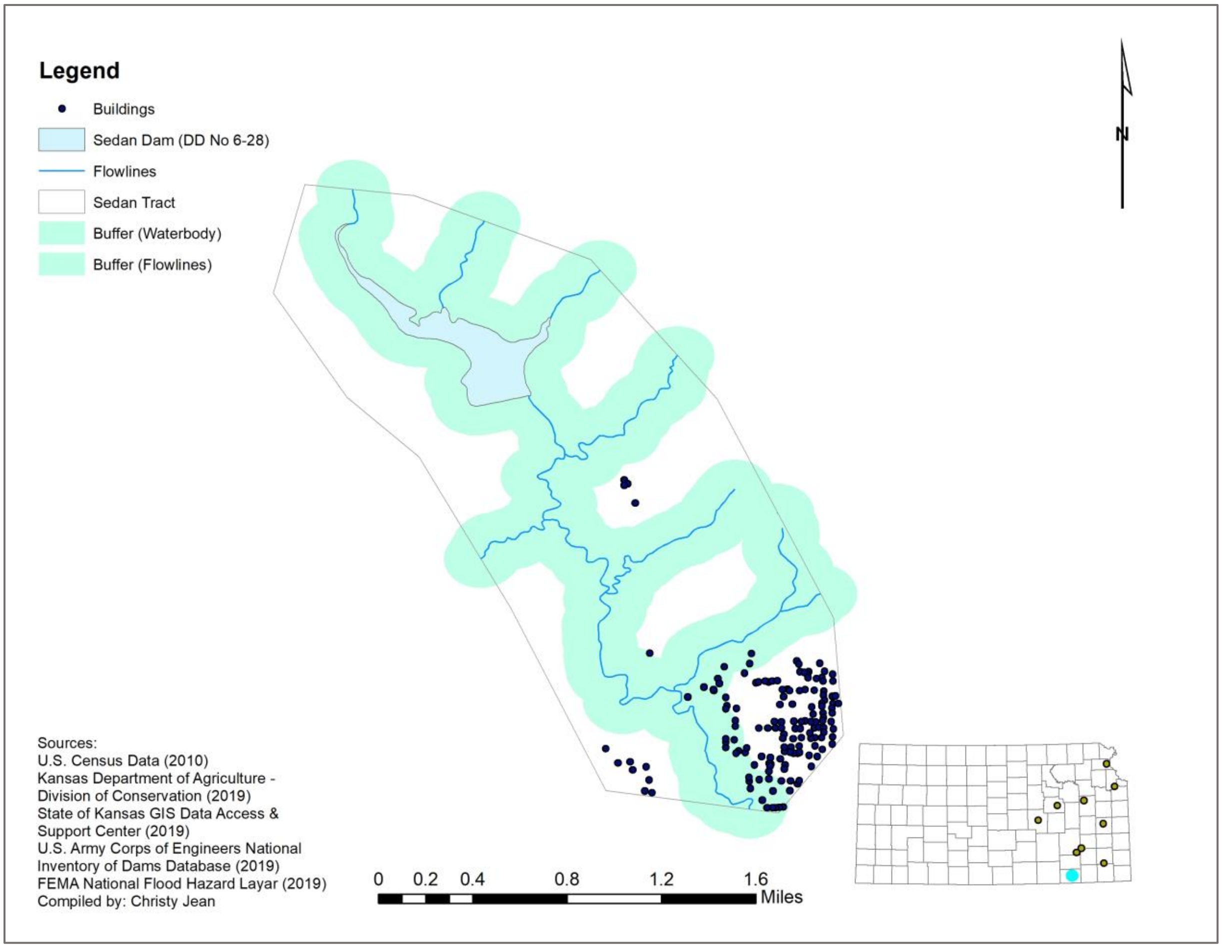
Marion: Marion Dam





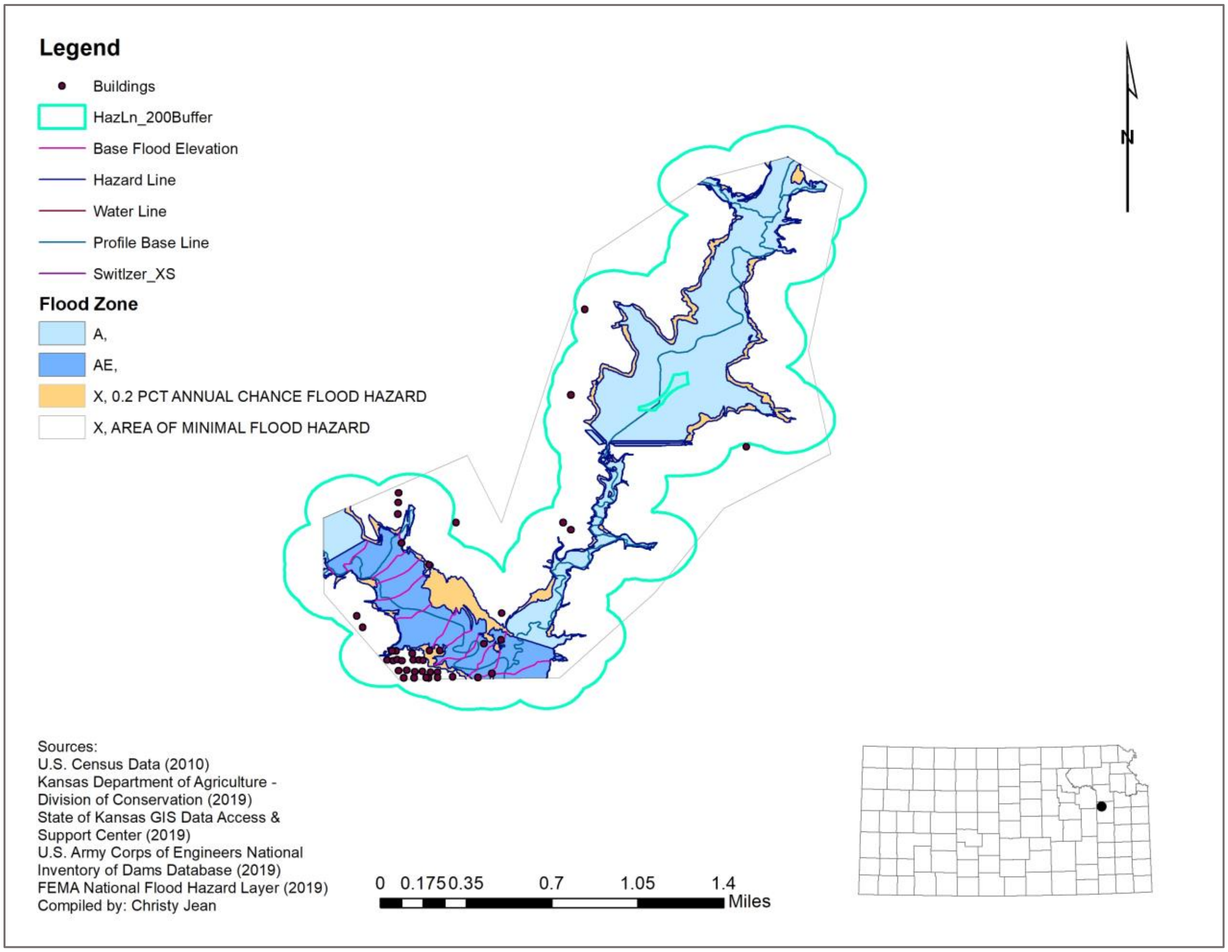
Parsons: Lake Parsons Dam



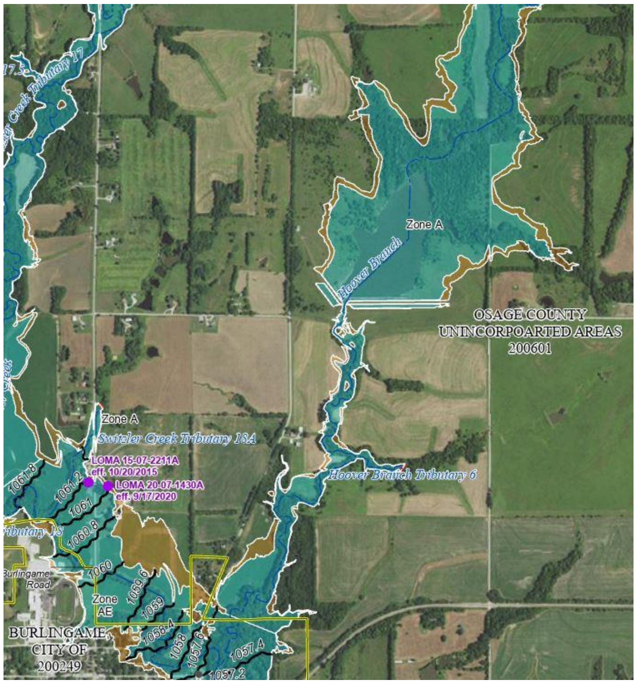


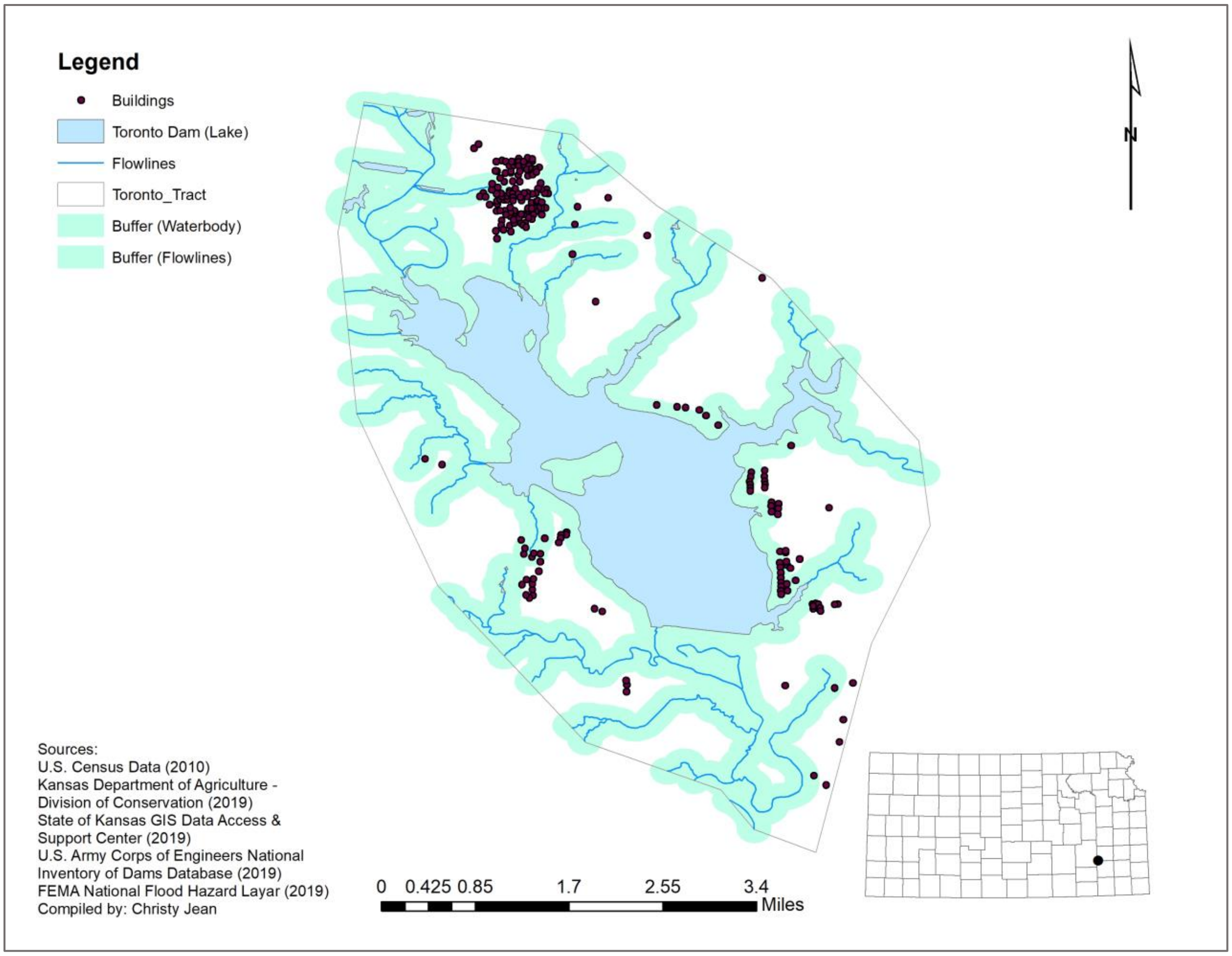
Sources:
U.S. Census Data (2010)
Kansas Department of Agriculture - Division of Conservation (2019)
State of Kansas GIS Data Access & Support Center (2019)
U.S. Army Corps of Engineers National Inventory of Dams Database (2019)
FEMA National Flood Hazard Layar (2019)
Compiled by: Christy Jean

Sedan: Sedan Dam (aka DD No 6-28)

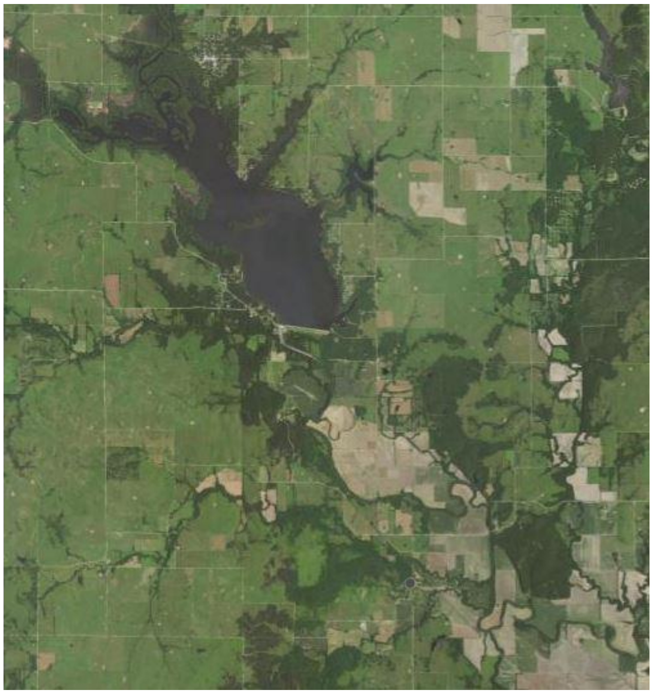


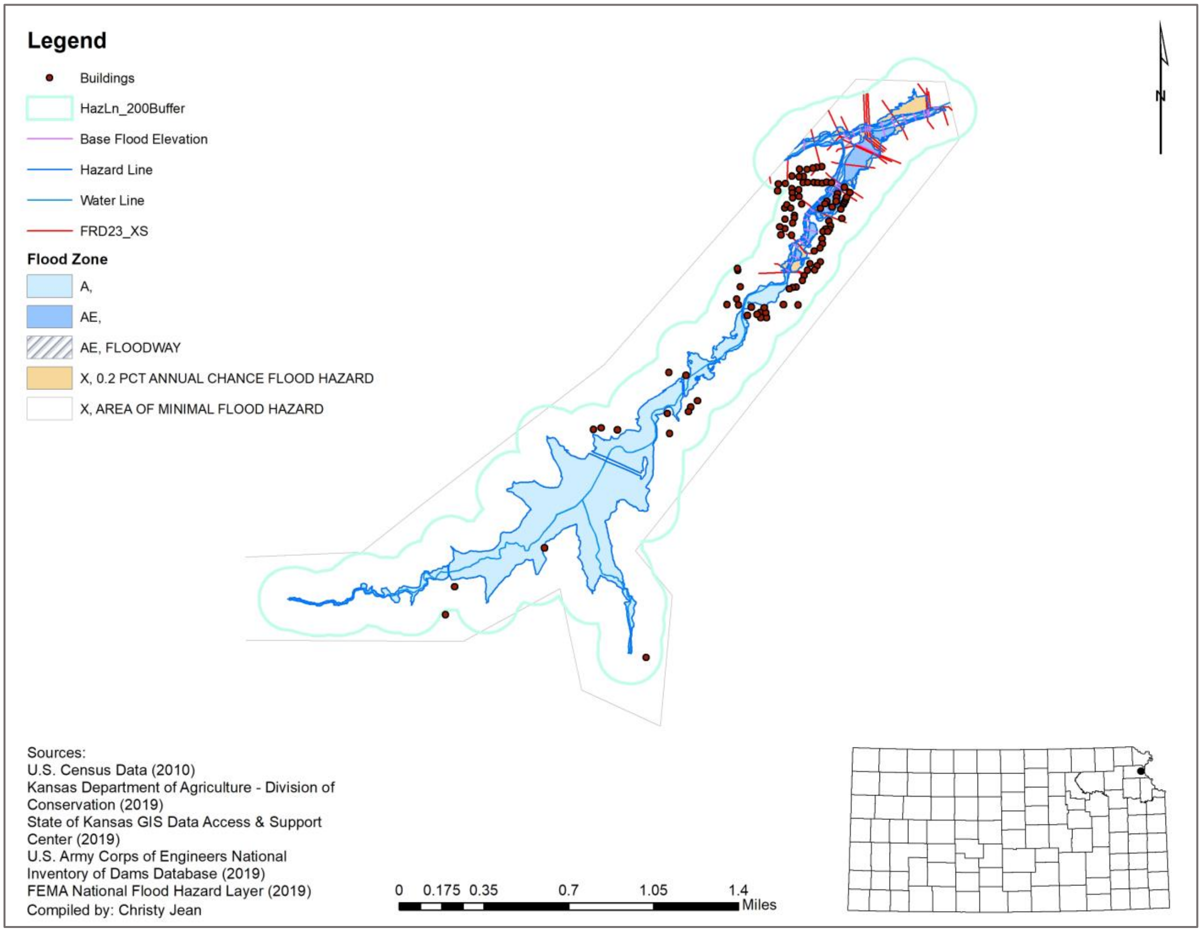
Switzler: Switzler Creek Dam



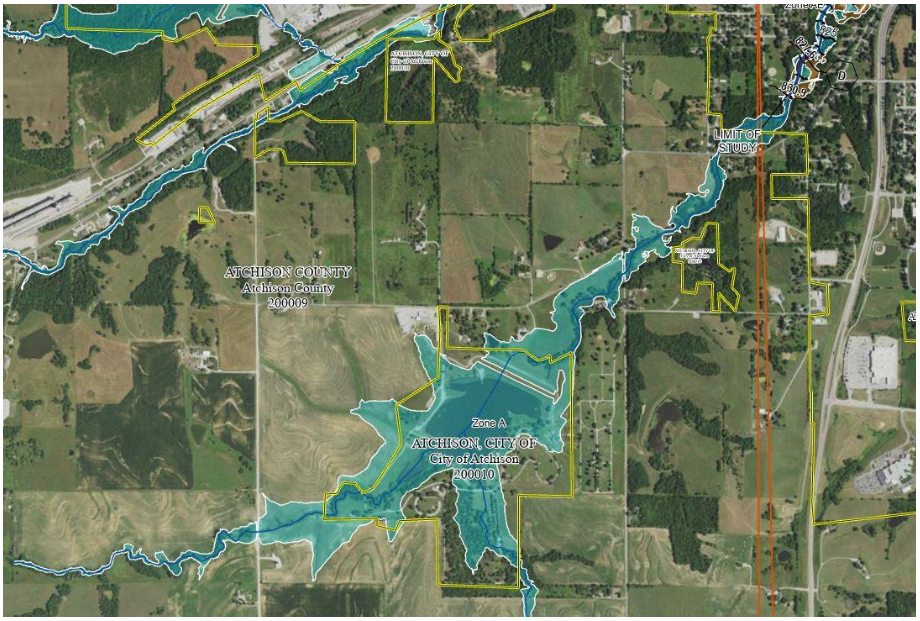


Toronto: Toronto Dam





White Clay Brewery Watershed: FRD NO 23 (aka White Clay Brewery WS Dam 23)



Appendix C - Metadata

Q. #	Question	Coding	Type of Data
	Location to Dam	1 = Upstream 2 = Downstream	Nominal
	Floodzone	1 = A 2 = AE 3 = AE, Floodway 4 = AH 5 = AO 6 = Future 1% Annual Chance (100-year) Floodplain 7 = 0.2% Annual Chance (500-year) Floodplain 8 = Levee Failure Inundation Area (100-year) 9 = 50-100m buffer 10 = 100-200m buffer 11 = Floodmap not available	Nominal
	Dam ID	1 = KS00006 2 = KS00011 3 = KS0003 4 = KS01248 5 = KS02010 6 = KS02409 7 = KS02451 8 = KS02512 9 = KS02514 10 = KS07006	Nominal
1	Do you live in a floodplain?	1 = Yes 2 = No 3 = Don't know	Nominal
2	Is your property below the water level of the nearby river?	1 = Yes 2 = No 3 = Don't know	Nominal
3	Has your property ever flooded before?	1 = Yes 2 = No 3 = Don't know	Nominal
3a	If so, please explain	OPEN ENDED	

4	Do you purchase flood insurance for your home?	1 = Yes 2 = No 3 = Don’t know	Nominal
5	Has flooding ever affected you indirectly (such as hearing/reading about hazards; impacts affecting friends, relatives, or neighbors)?	1 = Yes 2 = No 3 = Don’t know	Nominal
6	How prepared would you feel in the event of a major flood?	5 = Very prepared 4 = Somewhat prepared 3 = Neither prepared or unprepared 2 = Somewhat unprepared 1 = Very unprepared	Likert Scale Ordinal
7	What are you most likely to experience if there is a major flood event in your area?	1 = Water in the yard but not in the house 2 = Standing water in the house 3 = Standing water above 5 inches in the house 4 = Standing water above waist level in the house 5 = First floor in many houses would be flooded 6 = I’m not sure	Likert Scale Ordinal
8	Has anyone ever told you that your property is at risk of flooding?	1 = Yes 2 = No 3 = Don’t know	Nominal
9	Have you ever felt concerned that your property was at risk during a flood event?	1 = Very concerned 2 = Somewhat concerned 3 = Not concerned at all	Likert Scale Ordinal
10	I think my community would be affected by flooding.	5 = Completely agree 4 = Agree 3 = Neither agree or disagree 2 = Disagree 1 = Completely disagree	Likert Scale Ordinal
11	I think my community could be affected by flooding in the coming year.	5 = Completely agree 4 = Agree 3 = Neither agree or disagree 2 = Disagree 1 = Completely disagree	Likert Scale Ordinal
12	My property could be affected by flooding from the river	5 = Completely agree 4 = Agree 3 = Neither agree or disagree 2 = Disagree 1 = Completely disagree	Likert Scale Ordinal

13	If there is a flooding event, it would affect my livelihood	5 = Completely agree 4 = Agree 3 = Neither agree or disagree 2 = Disagree 1 = Completely disagree	Likert Scale Ordinal
14	If there is a flooding event, daily life would be disturbed for a long time.	5 = Completely agree 4 = Agree 3 = Neither agree or disagree 2 = Disagree 1 = Completely disagree	Likert Scale Ordinal
15	If there is a flooding event, it would be a life-threatening situation for my and my family.	5 = Completely agree 4 = Agree 3 = Neither agree or disagree 2 = Disagree 1 = Completely disagree	Likert Scale Ordinal
16	Where is your property located in relation to the nearest dam? (upstream/downstream, distance, etc.)	OPEN ENDED	
17	How confident are you that you could explain the purpose of a dam?	5 = Very confident 4 = Somewhat confident 3 = Neither confident or unconfident 2 = Somewhat unconfident 1 = Very unconfident	Likert Scale Ordinal
18	Rank the top 3 purposes of the dam in your area	1 = Flood Control 2 = Fire Protection 3 = Stock or small fish pond 4 = Fish and wildlife pond 5 = Debris Control 6 = Hydroelectric 7 = Irrigation 8 = Recreation 9 = Water Supply 10 = Don’t know/Other	Likert Scale Ordinal
19	I think the dam is well maintained by the responsible party.	5 = Strongly agree 4 = Agree 3 = Neither agree or disagree 2 = Somewhat disagree 1 = Strongly disagree	Likert Scale Ordinal

20	I think the dam will protect against flooding.	5 = Completely agree 4 = Agree 3 = Neither agree or disagree 2 = Disagree 1 = Completely disagree	Likert Scale Ordinal
21	I think the dam will provide sufficient flood control beyond its designed life expectancy.	5 = Completely agree 4 = Agree 3 = Neither agree or disagree 2 = Disagree 1 = Completely disagree	Likert Scale Ordinal
22	I am not worried about the designed life expectancy of the dam.	5 = Completely agree 4 = Agree 3 = Neither agree or disagree 2 = Disagree 1 = Completely disagree	Likert Scale Ordinal
23	How would you rate the risk of dam failure in your area?	5 = High risk 4 = Somewhat high risk 3 = Medium risk 2 = Somewhat low risk 1 = Low Risk	Likert Scale Ordinal
24	In the event of a dam failure, would you be concerned about flood risk your area?	5 = Very concerned 4 = Somewhat concerned 3 = Neither concerned or unconcerned 2 = Somewhat unconcerned 1 = Very unconcerned	Likert Scale Ordinal
25	Are you more at risk to dam failure/flood damage than others in your area?	5 = Much more at risk 4 = Moderately at risk 3 = Somewhat at risk 2 = Slightly at risk 1 = Not at risk	Likert Scale Ordinal
26	My property would be affected if there is a dam failure.	5 = Strongly agree 4 = Somewhat agree 3 = Neither agree or disagree 2 = Somewhat disagree 1 = Strongly disagree	Likert Scale Ordinal
27	Do you feel confident in your ability to protect 1) yourself and family, 2) property in the event of a dam failure?	5 = Very confident 4 = Somewhat Confident 3 = Neither 2 = Somewhat unconfident 1 = Very unconfident	Likert Scale Ordinal

28	Who should be held responsible in the event a dam is no longer able to provide flood control?	OPEN ENDED	Open-Ended
28	Who should be held responsible in the event a dam is no longer able to provide flood control?	1 = Land/Property Owners 2 = Watershed District/Department 3 = City 4 = County 5 = State 6 = Federal Government 7 = Government 8 = U.S. Army Corps of Engineers 9 = More than 1 answer 10 = Unsure 11 = Other	Nominal Common Responses
29	How would you describe your home?	1 = Single family home, 1 story 2 = Single family home, 2 stories 3 = Multiple family home (ex: duplex) 4 = Mobile home 5 = Apartment building	Likert Scale Ordinal
30	Do you own or rent your current residence?	1 = Own 2 = Rent	Nominal
31	How long have you lived here?	OPEN ENDED	Nominal
31	How long have you lived here?	1 = Less than 1 year 2 = 1-5 years 3 = 6-10 years 4 = 11-20 years 5 = 21-30 years 6 = 31-40 years 7 = 41-50 years 8 = 51-60 years 9 = More than 60 years	Nominal Common Responses
32	What town do you live in or near?	OPEN ENDED	Nominal
33	What county do you live in?	OPEN ENDED	Nominal
34	In what year were you born?	OPEN ENDED	Nominal

34	Age	1 = 18-24 2 = 25-34 3 = 35-44 4 = 45-54 5 = 55-64 6 = 65-74 7 = 75+	Nominal
35	What is your current employment status?	1 = Employed full time (30+ hours per week) 2 = Employed part-time 3 = Homemaker 4 = Unemployed, seeking work 5 = Unemployed, not seeking work 6 = Retired	Nominal
36	What is your gender?	1 = Female 2 = Male	Nominal
37	What is your marital status?	1 = Single 2 = Married 3 = Divorced or Separated 4 = Widowed 5 = Domestic Partner	Nominal
38	What is your ethnicity?	1 = White 2 = Black 3 = Hispanic 4 = Asian 5 = Native American 6 = More than one ethnicity	Nominal
39	What kind of work do you do?	OPEN ENDED	
40	What is your annual household income?	1 = $80,000 or above 2 = $60,000 to $79,999 3 = $40,000 to $59,999 4 = $20,000 to $39,999 5 = Under $20,000	Nominal

Appendix D - Questionnaire

KANSAS STATE UNIVERSITY | College of Arts and Sciences
Department of Geography

Flood Risk near Kansas Dams

Participation in this study is completely voluntary and should take no more than 20 minutes to complete. Your answers are confidential and will not be reported in a way that can identify you personally. You may freely withdraw from this study at any time without repercussions. There are no known or anticipated risks associated with participating in this study. By returning this survey form you are consenting to the inclusion of your answers in this study.

This research seeks to understand how your experiences with floods may have been impacted by nearby dam(s) in your area. Questions about "your area" refer to your home and its nearby surroundings. You will also be asked for your opinion on the potential of future flooding risks associated with development or other physical changes near dams. The front and back inside covers have intentionally been left blank if you would like to provide any additional comments.

Q1. Do you live in a floodplain?

☐ Yes
☐ No
☐ Don't know

Q2. Is your property is below the water level in the nearby river.

☐ Yes
☐ No
☐ Don't know

Q3. Has your property ever flooded before? If so, please explain *(for example: approximate date, affected property, depth of water)*.

☐ Yes
☐ No
☐ Don't know

Q4. Do you purchase flood insurance for your home?

☐ Yes
☐ No
☐ Don't know

Q5. Has flooding ever affected you indirectly (such as hearing/reading about hazards impacts affecting friends, relatives, or neighbors)?

☐ Yes
☐ No
☐ Don't know

Q6. How prepared would you feel in the event of a major flood?

- ☐ Very prepared
- ☐ Somewhat prepared
- ☐ Neither prepared or unprepared
- ☐ Somewhat unprepared
- ☐ Very unprepared

Q7. What are you most likely to experience if there is major flood event in your area?

- ☐ Water in the yard but not in the house
- ☐ Standing water in the house
- ☐ Standing water above 5 inches in the house
- ☐ Standing water above waist level in the house
- ☐ First floor in many houses would be flooded
- ☐ I’m not sure

Q8. Has anyone ever told you that your property is at risk of flooding?

- ☐ Yes
- ☐ No
- ☐ Don’t know

Q9. Have you ever felt concerned that your property was at risk during a flood event?

- ☐ Very concerned
- ☐ Somewhat concerned
- ☐ Not concerned at all

	Completely agree	Agree	Neither agree or disagree	Disagree	Completely disagree
Q10. I think my community would be affected by flooding.	☐	☐	☐	☐	☐
Q11. I think my community could be affected by flooding in the coming year.	☐	☐	☐	☐	☐

	Completely agree	Agree	Neither agree or disagree	Disagree	Completely disagree
Q12. My property could be affected by flooding from the river.	☐	☐	☐	☐	☐
Q13. If there is a flooding event, it would affect my livelihood.	☐	☐	☐	☐	☐
Q14. If there is a flooding event, daily life would be disturbed for a long time.	☐	☐	☐	☐	☐
Q15. If there is a flooding event, it would be a life-threatening situation for me and my family.	☐	☐	☐	☐	☐

Q16. Where is your property located in relation to the nearest dam?
(upstream/downstream, distance, etc.)

Q17. How confident are you that you could explain the purpose of a dam?

- ☐ Very confident
- ☐ Somewhat confident
- ☐ Neither confident or unconfident
- ☐ Somewhat unconfident
- ☐ Very unconfident

Q18. Rank the top 3 purposes of the dam in your area (1,2, and 3).

- ☐ Flood Control
- ☐ Fire Protection
- ☐ Stock or small fish pond
- ☐ Don't know/Other ______________________________
- ☐ Fish and wildlife pond
- ☐ Debris control
- ☐ Hydroelectric
- ☐ Irrigation
- ☐ Recreation
- ☐ Water supply

Q19. I think the dam is well maintained by the responsible party

- ☐ Strongly agree
- ☐ Agree
- ☐ Neither agree or disagree
- ☐ Somewhat disagree
- ☐ Strongly disagree

	Completely agree	Agree	Neither agree or disagree	Disagree	Completely disagree
Q20. I think the dam will protect against flooding.	☐	☐	☐	☐	☐
Q21. I think the dam will provide sufficient flood control beyond its designed life expectancy.	☐	☐	☐	☐	☐
Q22. I am not worried about the designed life expectancy of the dam.	☐	☐	☐	☐	☐

Dam failure is defined as a catastrophic breakdown of a dam, characterized by the uncontrolled release of impounded water which may impact downstream human life, cause property damage, lifeline disruption, and/or environmental concerns (FEMA 2004).

Q23. How would you rate the risk of dam failure in your area?

☐ High risk
☐ Somewhat high risk
☐ Medium risk
☐ Somewhat low risk
☐ Low risk

Q24. In the event of a dam failure, would you be concerned about flood risk in your area?

☐ Very concerned
☐ Somewhat concerned
☐ Neither concerned or unconcerned
☐ Somewhat unconcerned
☐ Very unconcerned

Q25. Are you more at risk to dam failure/flood damage than others in your area?

☐ Much more at risk
☐ Moderately at risk
☐ Somewhat at risk
☐ Slightly at risk
☐ Not at risk

Q26. My property would be affected if there is a dam failure.

- ☐ Strongly agree
- ☐ Somewhat agree
- ☐ Neither agree or disagree
- ☐ Somewhat disagree
- ☐ Strongly disagree

Q27. Do you feel confident in your ability to protect 1) yourself and family, 2) property in the event of a dam failure?

- ☐ Very confident
- ☐ Somewhat confident
- ☐ Neither confident or unconfident
- ☐ Somewhat unconfident
- ☐ Very unconfident

Q28. Who should be held responsible in the event a dam is no longer able to provide flood control?

☐

Q29. How would you describe your home?

- ☐ Single family home, 1 story
- ☐ Single family home, 2 stories
- ☐ Multiple family home (ex: duplex)
- ☐ Mobile home
- ☐ Apartment building

Q30. Do you own or rent your current residence?

☐ Own ☐ Rent

Q31. How long have you lived here? ☐

Q32. What town do you live in or near? ☐

Q33. What county do you live in? ☐

Q34. In what year were you born? ☐

Q35. What is your current employment status?

☐ Employed full time (30+ hours per week)
☐ Employed part-time
☐ Homemaker
☐ Unemployed, seeking work
☐ Unemployed, not seeking work
☐ Retired

Q36. What is your gender? ☐ Female ☐ Male

Q37. What is your marital status?

☐ Single
☐ Married
☐ Divorced or Separated
☐ Widowed
☐ Domestic partner

Q38. What is your ethnicity?

☐ White
☐ Black
☐ Hispanic
☐ Asian
☐ Native American
☐ More than one ethnicity

Q39. What kind of work do you do? (If retired, what kind of work did you do to earn an income, if you were been employed for pay. If you've been a homemaker, please note this.)

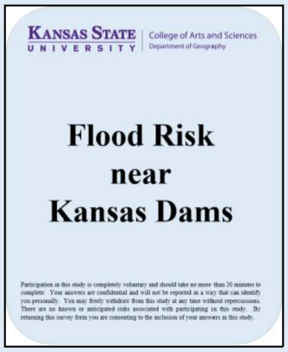
☐

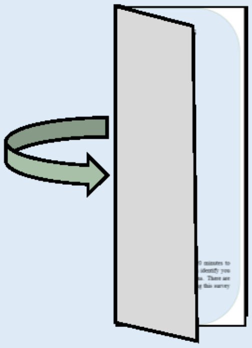
Q40. What is your annual household income?

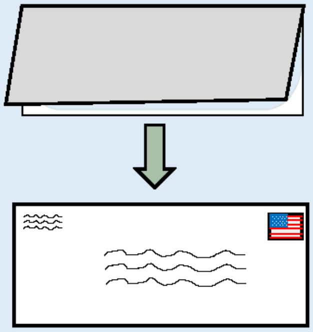
☐ $80,000 or above
☐ $60,000 to $79,999
☐ $40,000 to $59,999
☐ $20,000 to $39,999
☐ Under $20,000

Are there any additional comments you would like to make?

Thank you very much for your time and input in this study. To return your questionnaire, please fold it in half as shown and place it in the included self-addressed stamped envelope for your local mail carrier.







If you have any questions about this study or require further information, please contact Christy Jean (cjean@ksu.edu or 785-477-0614) or Dr. Lisa Harrington (lbutlerh@ksu.edu or 785-532-341). Due to military obligations, mailed correspondence should be directed to Christy Jean, 1025 Lee Rd 197, Phenix City AL 36870. This study has been reviewed and approved by the Institutional Review Board at Kansas State University [File #: __________]. If you have any comments or concerns about your rights as a research participant, please contact the University Research Compliance Office at 785-532-3224.

Appendix E - Introductory Letter

KANSAS STATE UNIVERSITY | College of Arts and Sciences
Department of Geography

December 2018

Dear Kansas Resident:

We are requesting your cooperation in completing the enclosed survey of persons who reside in parts of Kansas. Nearly 82 years have passed since the Flood Control Act of 1936, which allowed federal, state, and local governments to fund dam projects across the country and your experiences, as well as your opinions about Kansas dams, may have changed since then. Your response allows us to obtain useful information in understanding people's viewpoints on the functionality and purpose of Kansas dams, especially as the majority of them are near 50 years old. This survey strives to understand how those opinions may be different for different people across the state and how we, as researchers, can help bridge communication gaps between the people who live near dams, and the people who make decisions about them.

You have been randomly selected to participate and your participation is voluntary: you may refuse to participate, you may refuse to answer any questions you do not wish to answer, and you may stop at any time. This survey should take no more than 20 minutes to complete. It consists of questions about past flood experiences, current flood awareness, and insights on potential risks, if any, associated with development or other physical changes near dams. All your responses are confidential and will be shared only between the student conducting the research and her advisor. We will not identify you in any report or presentation from this research.

Project Description

This study is being conducted by Christy Jean, a graduate student in the Department of Geography at Kansas State University, as partial fulfillment of the requirements for a doctoral degree. The study contributes to understanding flood risk perceptions near Kansas dams. Results may contribute to generating a framework to better understand flood risk perceptions and improve risk communication. Results of the study will be published, and presented at academic conferences.

Questions or Feedback

If you have questions about this study, please contact Christy Jean, 785-477-0614 (cjean@ksu.edu), or Dr. Lisa Harrington, 785-532-6727 (lbutlerh@ksu.edu). Due to military obligations, we have recently been reassigned to a new duty station. Mailed correspondence can be sent to Christy Jean, 1025 Lee Rd 197, Phenix City, AL 36870. If you would like to receive the results of this study, please contact one of us and we will provide a summary at the conclusion of the study.

If you have any questions or concerns about this project, please report them to the Chair of Kansas State University's Internal Review Board, Rick Scheidt, 785-532-1483 (rscheidt@ksu.edu), or to the University Research Compliance Office at 785-532-3224 (comply@ksu.edu).

Christy Jean
PhD Candidate
Department of Geography
Kansas State University

Appendix F - Post Card

You should have recently received a questionnaire seeking your opinions about flood risk near Kansas dams. Your name was drawn randomly from a list of households for this survey.

If you have already completed and returned the questionnaire, thank you for participating. Your responses go a long way in helping us to obtain useful information in understanding flood risk perception and risk communication.

If you haven't had the opportunity to complete or return your questionnaire, please do as soon as possible. We would really appreciate your contribution to this study.

If you did not receive a questionnaire, or if it was misplaced, please call me at (785) 477-0614 or send an email to cjean@ksu.edu and we will get another copy in the mail to you right away.

Sincerely,

Christy Jean, Graduate Student Researcher
Department of Geography - Kansas State University - Manhattan, KS 66506

C. Jean/L. Harrington
KANSAS STATE UNIVERSITY | College of Arts and Sciences
Department of Geography

Appendix G - Semi-structured Interview Questions

Selection: Purposeful sampling of experts related to the construction, maintenance, and safety of dams and water resource management

Process: Zoom/Phone Interviews, designed to take approximately 30 minutes. Written informed consent was provided via email and reviewed verbally prior to the interview. All interviews were recorded and transcribed with participant approval.

Hazard: Dam Failure/Flooding

Location: Eastern Kansas; 10 selected study sites

Topic	Questions
Flood/Dam Awareness	Do you think [the dam] is well maintained by the [responsible party]?
Flood/Dam Awareness	Has [the dam] historically protected downstream locations from flooding? If so, for how long?
Flood/Dam Awareness	Do you think [the dam] will protect against flooding?
Risk Perception	How long do you anticipate [the dam] will protect against flooding?
Risk Perception	Do you think [the dam] has reached its life expectancy yet?
Risk Perception	Do you think [the dam] will provident sufficient flood control beyond its designed life expectancy?
Risk Perception	Are you worried about the designed life expectancy of [the dam]?
Risk Perception	Would you consider [the dam] to be at high risk?
Flood Vulnerability	Do you think local residents underestimate or overestimate the risks associated with flooding?
Flood Vulnerability	Do you think the majority of the public knows where to access information on dam safety and flood risk preparedness? Where would you recommend they go?
Flood Vulnerability	Who, if anyone, should be held responsible in the event a dam is no longer able to provide flood control?
Flood Vulnerability	Risk communication has proven to be essential for preparing communities for high risk situations,
Risk Communication	In what ways has your department excelled at providing that information? Are there any improvements that could be made?

Flood Vulnerability	Have residents near dams been informed about flooding risk/dam breach in their area?
Risk Perception	Do detailed maps exist? Are people aware of these maps?
Flood Vulnerability	What is the probability [selected area] would receive considerable damage from a flood or dam breach?

Appendix H - Informed Consent

KANSAS STATE UNIVERSITY | College of Arts and Sciences
Department of Geography

Flood Risk Perception near Kansas Dams

Informed Consent

You have been asked to participate in an interview on flood risk perception near Kansas dams. Your participation is voluntary: you may refuse to participate, you may refuse to answer any questions you do not wish to answer, and you may stop at any time. The interview will be recorded for the sole purpose of transcription and analysis. Audio recordings and written notes will be destroyed following the completion of the study. Identifying information will be changed to maintain confidentiality in reporting results.

This interview should take about 30 minutes to complete. It consists of questions about past flood experiences, current flood awareness, and insights on potential risks, if any, associated with development or other physical changes near dams. All your responses are confidential and will be shared only between the student conducting the research and her advisor. We will not identify you in any report or presentation from this research.

Project Description

This study is being conducted by Christy Jean, a graduate student in the Department of Geography at Kansas State University, as partial fulfillment of the requirements for a doctoral degree. The study contributes to understanding flood risk perceptions near Kansas dams. Results may contribute to generating a framework to better understand flood risk perceptions and improve risk communication.

It is necessary to obtain useful information in understanding people's viewpoints on the functionality and purpose of Kansas dams, especially as the many of them are near 50 years old, approaching their designed life expectancy. This research strives to understand how those opinions may be different for different people across the state and how we, as researchers, can help bridge communication gaps between the people who live near dams, and the people who make decisions about them.

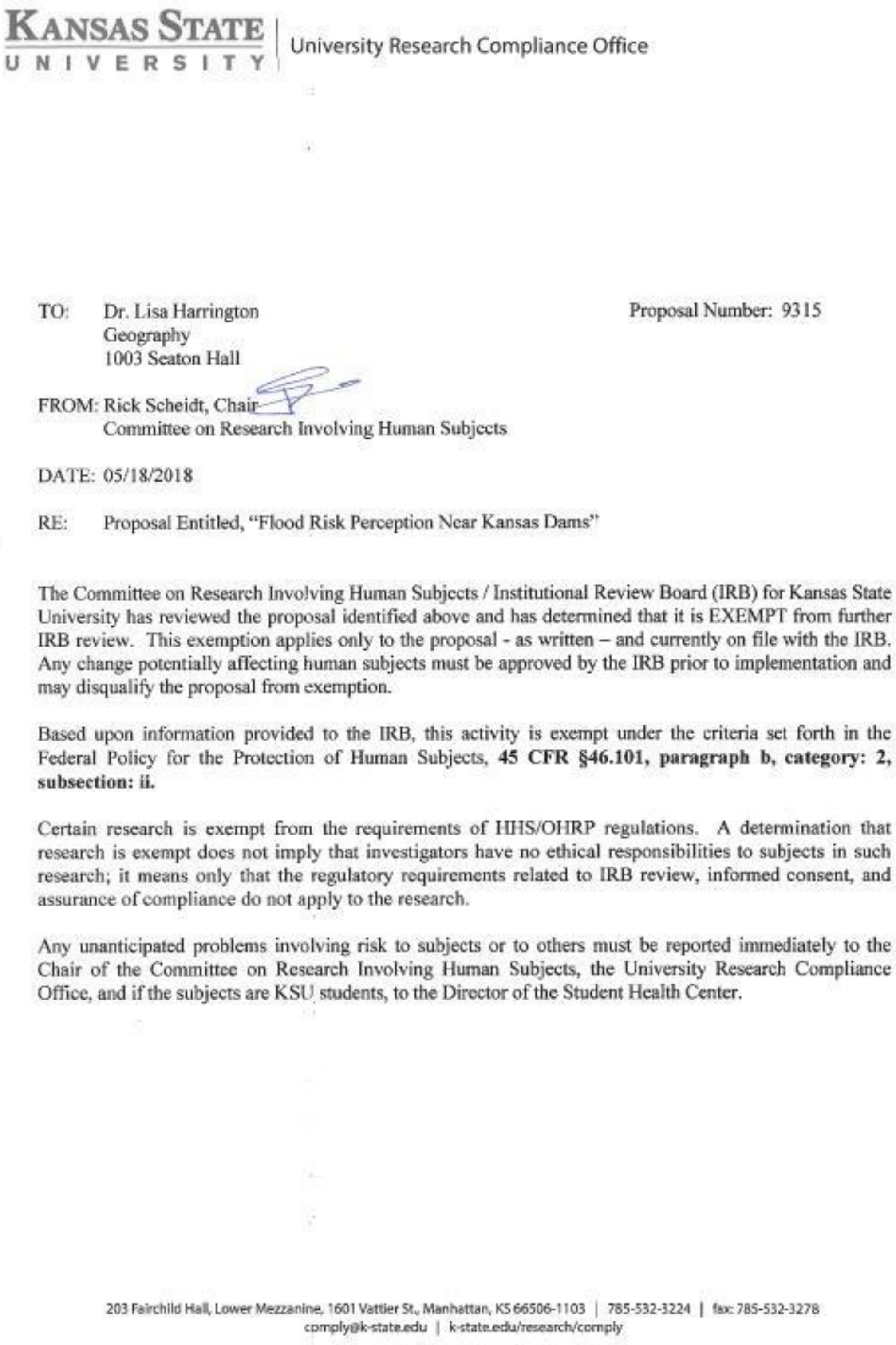
Questions or Feedback

If you have questions about this study, please contact Christy Jean, 785-477-0614 (cjean@ksu.edu), or Dr. Lisa Harrington, 785-532-6727 (lbutlerh@ksu.edu). Due to military obligations, we have recently been reassigned to a new duty station. Mailed correspondence can be sent to Christy Jean, 1025 Lee Rd 197, Phenix City, AL 36870. If you would like to receive the results of this study, please contact one of us and we will provide a summary at the conclusion of the study.

If you have any questions or concerns about this project, please report them to the Chair of Kansas State University's Internal Review Board, Rick Scheidt, 785-532-1483 (rscheidt@ksu.edu), or to the University Research Compliance Office at 785-532-3224 (comply@ksu.edu).

Christy Jean
PhD Candidate
Kansas State University

Appendix I - IRB Approval



KANSAS STATE UNIVERSITY | University Research Compliance Office

TO: Dr. Lisa Harrington
Geography
1003 Seaton Hall

Proposal Number: 9315

FROM: Rick Scheidt, Chair
Committee on Research Involving Human Subjects

DATE: 05/18/2018

RE: Proposal Entitled, "Flood Risk Perception Near Kansas Dams"

The Committee on Research Involving Human Subjects / Institutional Review Board (IRB) for Kansas State University has reviewed the proposal identified above and has determined that it is EXEMPT from further IRB review. This exemption applies only to the proposal - as written – and currently on file with the IRB. Any change potentially affecting human subjects must be approved by the IRB prior to implementation and may disqualify the proposal from exemption.

Based upon information provided to the IRB, this activity is exempt under the criteria set forth in the Federal Policy for the Protection of Human Subjects, **45 CFR §46.101, paragraph b, category: 2, subsection: ii.**

Certain research is exempt from the requirements of HHS/OHRP regulations. A determination that research is exempt does not imply that investigators have no ethical responsibilities to subjects in such research; it means only that the regulatory requirements related to IRB review, informed consent, and assurance of compliance do not apply to the research.

Any unanticipated problems involving risk to subjects or to others must be reported immediately to the Chair of the Committee on Research Involving Human Subjects, the University Research Compliance Office, and if the subjects are KSU students, to the Director of the Student Health Center.

203 Fairchild Hall, Lower Mezzanine, 1601 Vattier St., Manhattan, KS 66506-1103 | 785-532-3224 | fax: 785-532-3278
comply@k-state.edu | k-state.edu/research/comply

Appendix J - Descriptive Statistics

Variable	Total Count	N	N*	CumN	Percent	CumPct	Mean	SE Mean
Location	102	102	0	102	100.000	100.000	1.7549	0.0428
Flood zone	102	102	0	102	100.000	100.000	7.775	0.327
Dam	102	102	0	102	100.000	100.000	4.559	0.338
Floodplain	102	100	2	100	98.039	98.039	1.830	0.101
Water level	102	101	1	101	99.020	99.020	2.614	0.190
Prior flooding	102	100	2	100	98.039	98.039	1.7800	0.0613
Insurance	102	101	1	101	99.020	99.020	1.9307	0.0254
Indirect flooding	102	101	1	101	99.020	99.020	1.3267	0.0509
Preparedness	102	101	1	101	99.020	99.020	3.307	0.116
Likelihood	102	95	7	95	93.137	93.137	2.379	0.216
Warning	102	100	2	100	98.039	98.039	1.8500	0.0557
Concern of risk	102	102	0	102	100.000	100.000	2.4706	0.0678
Comm. affected	102	101	1	101	99.020	99.020	4.1386	0.0975
Comm. affected coming year	102	100	2	100	98.039	98.039	3.330	0.101
Property affected	102	100	2	100	98.039	98.039	2.800	0.146
Livelihood	102	100	2	100	98.039	98.039	2.820	0.128
Daily life	102	100	2	100	98.039	98.039	3.100	0.124
Life-threatening	102	99	3	99	97.059	97.059	2.273	0.109
Open-Ended: Yes/No	101	100	1	100	99.010	99.010	1.1000	0.0302
Open-Ended: Location to dam	98	65	33	65	66.327	66.327	1.8000	0.0665
Explain dam purpose	102	99	3	99	97.059	97.059	4.131	0.105
Primary Purpose	102	98	4	98	96.078	96.078	2.480	0.308
Secondary Purpose	102	86	16	86	84.314	84.314	6.488	0.265
Tertiary Purpose	101	79	22	79	78.218	78.218	7.835	0.237
Well maintained	102	98	4	98	96.078	96.078	3.653	0.112
Dam efficacy	102	99	3	99	97.059	97.059	3.6667	0.0974
Operative beyond design	102	99	3	99	97.059	97.059	3.2929	0.0955
Not worried about design life	102	98	4	98	96.078	96.078	3.265	0.116
Rate risk of dam failure	102	97	5	97	95.098	95.098	2.258	0.119

Concern after dam failure	102	99	3	99	97.059	97.059	3.859	0.136
More at risk than others	102	99	3	99	97.059	97.059	2.313	0.137
Property affected by dam failure	102	101	1	101	99.020	99.020	3.129	0.147
Protect family/property	102	100	2	100	98.039	98.039	3.810	0.119
Coded: Responsible	102	82	20	82	80.392	80.392	6.939	0.299
Home	102	101	1	101	99.020	99.020	1.4158	0.0568
Own/Rent	102	101	1	101	99.020	99.020	1.0792	0.0270
How long	102	99	3	99	97.059	97.059	4.444	0.204
Coded: Town	102	101	1	101	99.020	99.020	8.277	0.425
County	102	101	1	101	99.020	99.020	5.901	0.295
Age	102	90	12	90	88.235	88.235	5.244	0.152
Employment	102	97	5	97	95.098	95.098	3.268	0.242
Gender	102	99	3	99	97.059	97.059	1.6364	0.0486
Marital Status	102	99	3	99	97.059	97.059	2.2525	0.0817
Ethnicity	102	99	3	99	97.059	97.059	1.0505	0.0505
Profession	102	92	10	92	90.196	90.196	6.370	0.317
Annual HHI	102	91	11	91	89.216	89.216	2.692	0.146

Variable	TrMean	StDev	Variance	CoefVar	Sum	Sum of Squares	Minimum
Location	1.7826	0.4323	0.1869	24.63	179.0000	333.0000	1.0000
Flood zone	7.967	3.303	10.909	42.48	793.000	7267.000	1.000
Dam	4.457	3.417	11.675	74.95	465.000	3299.000	1.000
Floodplain	1.744	1.006	1.011	54.95	183.000	435.000	1.000
Water level	2.330	1.913	3.659	73.19	264.000	1056.000	1.000
Prior flooding	1.7556	0.6127	0.3754	34.42	178.0000	354.0000	1.0000
Insurance	1.9780	0.2552	0.0651	13.22	195.0000	383.0000	1.0000
Indirect flooding	1.2857	0.5120	0.2622	38.59	134.0000	204.0000	1.0000
Preparedness	3.341	1.164	1.355	35.20	334.000	1240.000	1.000
Likelihood	2.247	2.110	4.451	88.68	226.000	956.000	1.000
Warning	1.8333	0.5573	0.3106	30.13	185.0000	373.0000	1.0000
Concern of risk	2.5217	0.6851	0.4694	27.73	252.0000	670.0000	1.0000
Comm. affected	4.2308	0.9801	0.9606	23.68	418.0000	1826.0000	1.0000
Comm. affected coming year	3.344	1.006	1.011	30.20	333.000	1209.000	1.000
Property affected	2.778	1.456	2.121	52.02	280.000	994.000	1.000
Livelihood	2.800	1.282	1.644	45.47	282.000	958.000	1.000
Daily life	3.111	1.235	1.525	39.84	310.000	1112.000	1.000
Life-threatening	2.191	1.086	1.180	47.80	225.000	627.000	1.000
Open-Ended: Yes/No	1.0556	0.3015	0.0909	27.41	110.0000	130.0000	1.0000
Open-Ended: Location to dam	1.7797	0.5362	0.2875	29.79	117.0000	229.0000	1.0000
Explain dam purpose	4.225	1.046	1.095	25.33	409.000	1797.000	1.000
Primary Purpose	2.159	3.050	9.304	123.01	243.000	1505.000	1.000
Secondary Purpose	6.628	2.458	6.041	37.88	558.000	4134.000	1.000
Third Purpose	8.085	2.109	4.447	26.91	619.000	5197.000	1.000
Well maintained	3.727	1.104	1.219	30.22	358.000	1426.000	1.000
Dam efficacy	3.7191	0.9689	0.9388	26.42	363.0000	1423.0000	1.0000
Operative beyond design	3.3146	0.9503	0.9031	28.86	326.0000	1162.0000	1.0000
No worries about design life	3.295	1.145	1.310	35.06	320.000	1172.000	1.000
Rate risk of dam failure	2.172	1.175	1.381	52.05	219.000	627.000	1.000

Concern after dam failure	3.955	1.355	1.837	35.13	382.000	1654.000	1.000
More at risk than others	2.236	1.360	1.850	58.80	229.000	711.000	1.000
Property affected by dam failure	3.143	1.481	2.193	47.33	316.000	1208.000	1.000
Protect family/property	3.900	1.187	1.408	31.14	381.000	1591.000	1.000
Coded: Responsible	7.041	2.710	7.342	39.05	569.000	4543.000	1.000
Home	1.3736	0.5704	0.3253	40.29	143.0000	235.0000	1.0000
Own/Rent	1.0330	0.2714	0.0737	25.15	109.0000	125.0000	1.0000
How long	4.404	2.031	4.127	45.71	440.000	2360.000	1.000
Coded: Town	8.319	4.273	18.262	51.63	836.000	8746.000	1.000
County	5.846	2.965	8.790	50.24	596.000	4396.000	1.000
Age	5.350	1.440	2.074	27.46	472.000	2660.000	1.000
Employment	3.241	2.383	5.677	72.91	317.000	1581.000	1.000
Gender	1.6517	0.4835	0.2338	29.55	162.0000	288.0000	1.0000
Marital Status	2.2135	0.8124	0.6601	36.07	223.0000	567.0000	1.0000
Ethnicity	1.0000	0.5025	0.2525	47.84	104.0000	134.0000	1.0000
Profession	6.293	3.044	9.269	47.80	586.000	4576.000	2.000
Annual HHI	2.654	1.388	1.926	51.55	245.000	833.000	1.000

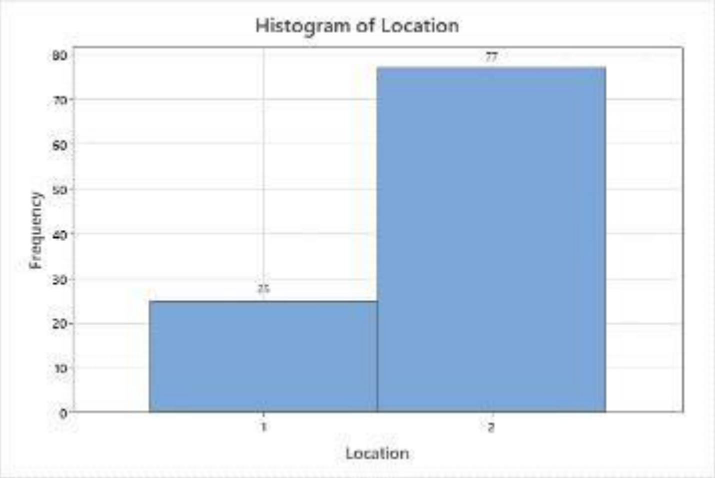
Variable	Q1	Median	Q3	Maximum	Range	IQR	Mode	N for Mode
Location	1.7500	2.0000	2.0000	2.0000	1.0000	0.2500	2	77
Flood zone	8.000	9.000	10.000	11.000	10.000	2.000	9	37
Dam	1.000	4.000	8.250	10.000	9.000	7.250	1	35
Floodplain	1.000	2.000	2.000	9.000	8.000	1.000	2	45
Water level	2.000	2.000	2.000	9.000	8.000	0.000	2	81
Prior flooding	1.0000	2.0000	2.0000	3.0000	2.0000	1.0000	2	58
Insurance	2.0000	2.0000	2.0000	2.0000	1.0000	0.0000	2	94
Indirect flooding	1.0000	1.0000	2.0000	3.0000	2.0000	1.0000	1	70
Preparedness	3.000	3.000	4.000	5.000	4.000	1.000	4	36
Likelihood	1.000	1.000	5.000	6.000	5.000	4.000	1	62
Warning	2.0000	2.0000	2.0000	3.0000	2.0000	0.0000	2	67
Concern of risk	2.0000	3.0000	3.0000	3.0000	2.0000	1.0000	3	59
Comm. affected	4.0000	4.0000	5.0000	5.0000	4.0000	1.0000	5	45
Comm. affected coming year	3.000	3.000	4.000	5.000	4.000	1.000	3	46
Property affected	2.000	2.000	4.000	5.000	4.000	2.000	2	27
Livelihood	2.000	3.000	4.000	5.000	4.000	2.000	2	30
Daily life	2.000	3.000	4.000	5.000	4.000	2.000	4	27
Life-threatening	1.000	2.000	3.000	5.000	4.000	2.000	2	39
Open-Ended: Yes/No	1.0000	1.0000	1.0000	2.0000	1.0000	0.0000	1	90
Open-Ended: Location to dam	1.0000	2.0000	2.0000	3.0000	2.0000	1.0000	2	44
Explain dam purpose	4.000	4.000	5.000	5.000	4.000	1.000	5	46
Primary Purpose	1.000	1.000	1.000	10.000	9.000	0.000	1	78
Secondary Purpose	4.000	8.000	8.000	10.000	9.000	4.000	8	31
Third Purpose	8.000	8.000	9.000	10.000	9.000	1.000	8, 9	28
Well maintained	3.000	4.000	4.000	5.000	4.000	1.000	4	39
Dam efficacy	3.0000	4.0000	4.0000	5.0000	4.0000	1.0000	4	44
Operative beyond design	3.0000	3.0000	4.0000	5.0000	4.0000	1.0000	3	44
Not worried about design life	2.000	3.000	4.000	5.000	4.000	2.000	3	30
Rate risk of dam failure	1.000	2.000	3.000	5.000	4.000	2.000	1	33
Concern after dam failure	3.000	4.000	5.000	5.000	4.000	2.000	5	44

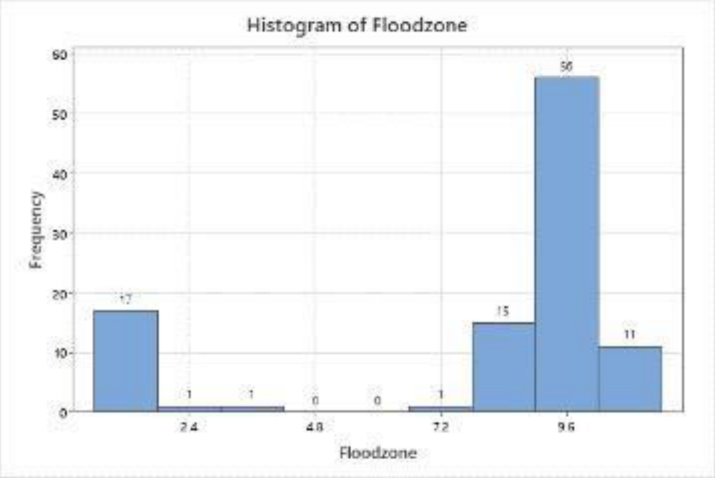
More at risk than others	1.000	2.000	3.000	5.000	4.000	2.000	1	36
Property affected by dam failure	2.000	3.000	4.500	5.000	4.000	2.500	5	25
Protect family/property	3.000	4.000	5.000	5.000	4.000	2.000	4	38
Coded: Responsible	5.000	8.000	9.000	11.000	10.000	4.000	8	28
Home	1.0000	1.0000	2.0000	4.0000	3.0000	1.0000	1	62
Own/Rent	1.0000	1.0000	1.0000	2.0000	1.0000	0.0000	1	93
How long	3.000	4.000	6.000	9.000	8.000	3.000	4, 5	19
Coded: Town	4.500	9.000	11.000	15.000	14.000	6.500	11	24
County	4.000	7.000	7.000	12.000	11.000	3.000	7	33
Age	4.000	5.000	6.000	7.000	6.000	2.000	5	24
Employment	1.000	2.000	6.000	6.000	5.000	5.000	1	45
Gender	1.0000	2.0000	2.0000	2.0000	1.0000	1.0000	2	63
Marital Status	2.0000	2.0000	2.0000	5.0000	4.0000	0.0000	2	66
Ethnicity	1.0000	1.0000	1.0000	6.0000	5.0000	0.0000	1	98
Profession	3.000	7.000	8.000	13.000	11.000	5.000	3	28
Annual HHI	1.000	3.000	4.000	5.000	4.000	3.000	1	25

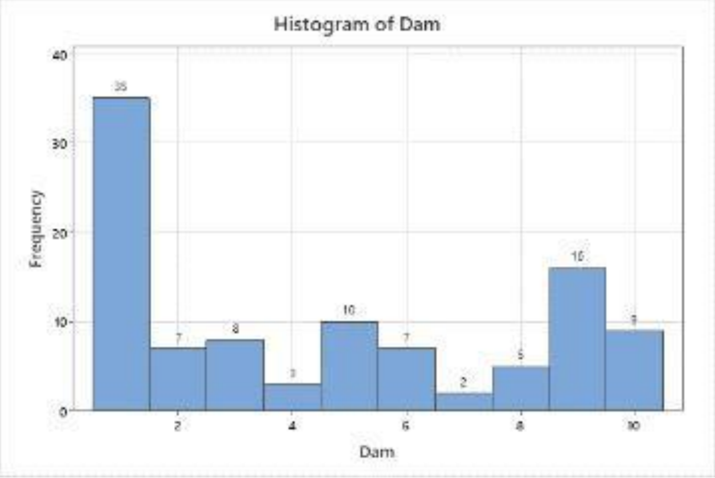
Variable	**Skewness**	**Kurtosis**	**MSSD**
Location	-1.20	-0.56	0.0693
Flood zone	-1.38	0.37	5.089
Dam	0.35	-1.48	0.554
Floodplain	3.76	25.13	1.062
Water level	2.99	7.48	0.298
Prior flooding	0.16	-0.49	0.2732
Insurance	-3.44	10.05	0.0606
Indirect flooding	1.20	0.37	0.2172
Preparedness	-0.47	-0.52	1.328
Likelihood	1.03	-0.82	4.705
Warning	-0.05	0.06	0.2784
Concern of risk	-0.93	-0.34	0.3416
Comm. affected	-1.13	0.92	0.8838
Comm. affected coming year	0.08	-0.35	0.768
Property affected	0.24	-1.37	1.345
Livelihood	0.17	-1.13	1.294
Daily life	-0.13	-0.95	1.309
Life-threatening	0.85	0.40	1.089
Open-Ended: Yes/No	2.71	5.44	0.0918
Open-Ended: Location to dam	-0.15	0.04	0.2262
Explain dam purpose	-1.20	0.70	1.058
Primary Purpose	1.67	0.95	8.806
Secondary Purpose	-0.71	-0.74	3.904
Third Purpose	-1.97	3.48	4.844
Well maintained	-0.82	0.31	1.231
Dam efficacy	-0.66	0.30	0.9211
Operative beyond design	-0.19	0.05	0.7947
Not worried about design life	-0.12	-0.78	1.355
Rate risk of dam failure	0.66	-0.27	1.217
Concern after dam failure	-0.97	-0.41	1.584
More at risk than others	0.78	-0.65	1.674
Property affected by dam failure	-0.13	-1.41	1.768
Protect family/property	-0.92	-0.04	1.361
Coded: Responsible	-0.69	-0.44	6.854
Home	1.33	2.63	0.2828

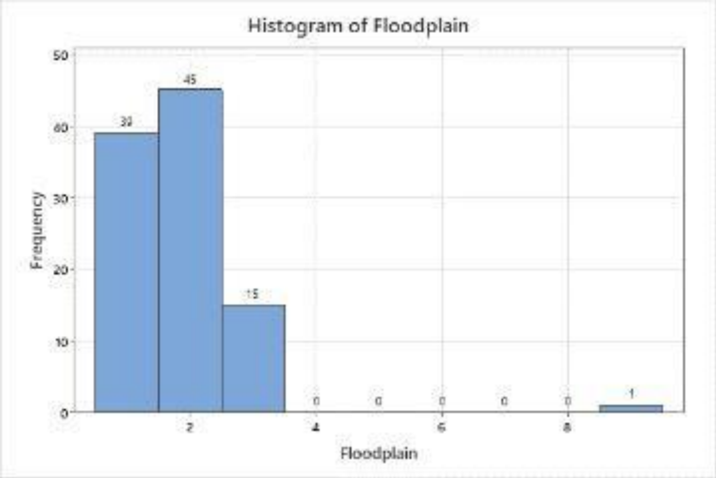
Own/Rent	3.16	8.17	0.0707
How long	0.28	-0.81	3.647
Coded: Town	-0.37	-1.11	5.303
County	0.08	-0.56	1.525
Age	-0.70	0.18	2.329
Employment	0.22	-1.91	6.176
Gender	-0.58	-1.70	0.1789
Marital Status	1.13	1.36	0.7158
Ethnicity	9.95	99.00	0.1316
Profession	0.18	-1.17	7.475
Annual HHI	0.24	-1.19	1.943

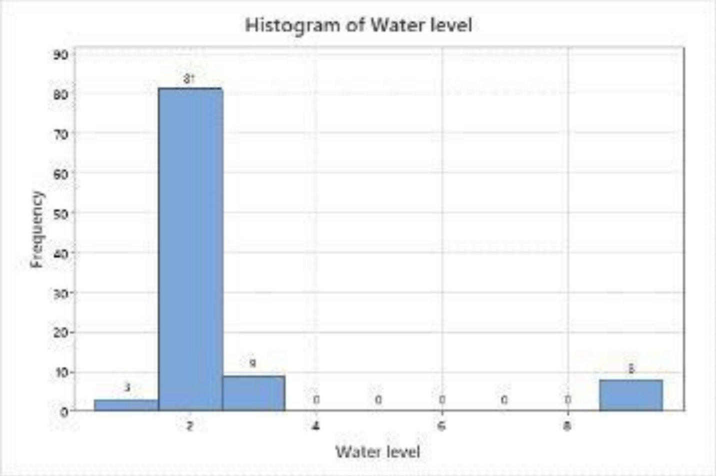
Appendix K - Histograms

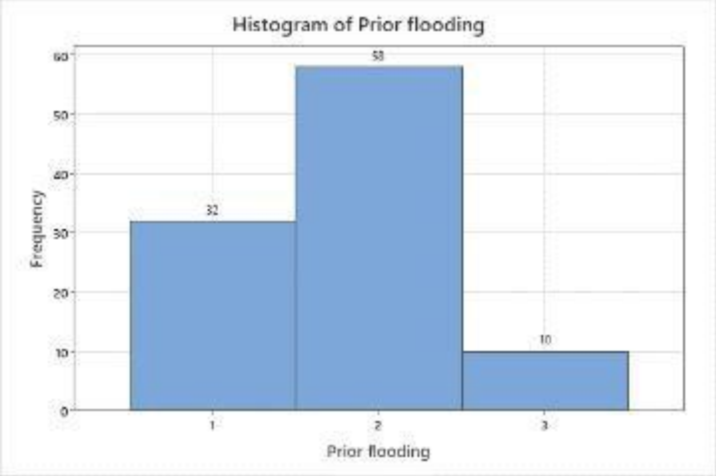


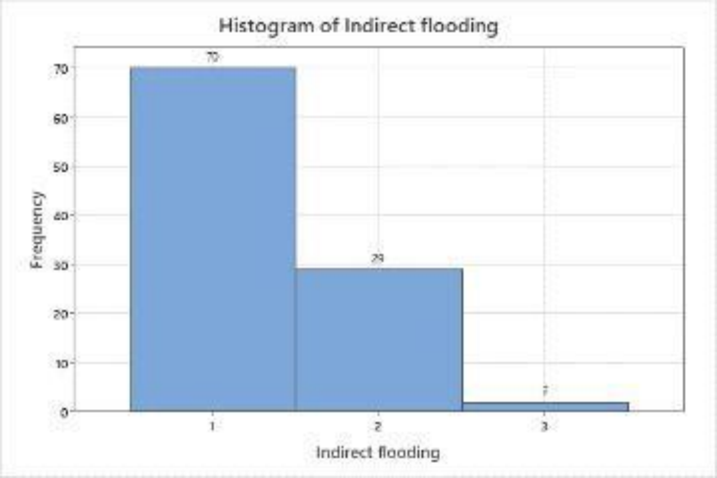


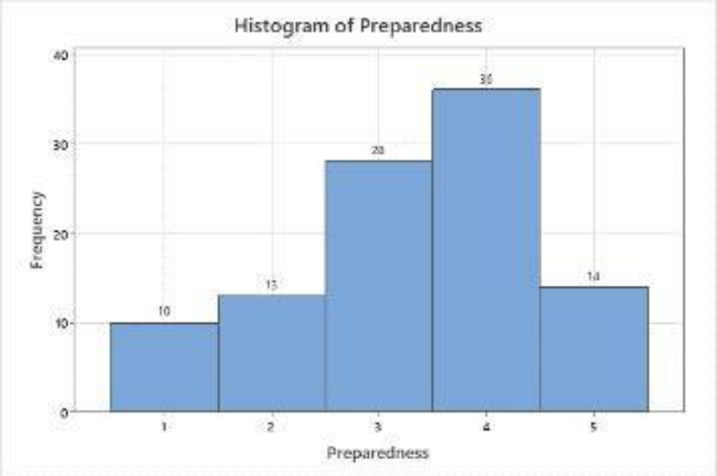


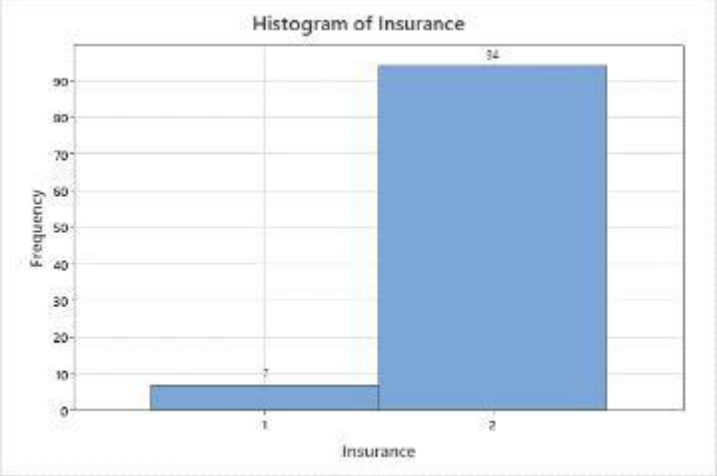

Histogram of Floodplain
Frequency
0
10
20
30
40
50
39
45
15
0
0
0
0
0
1
2
4
6
8
Floodplain

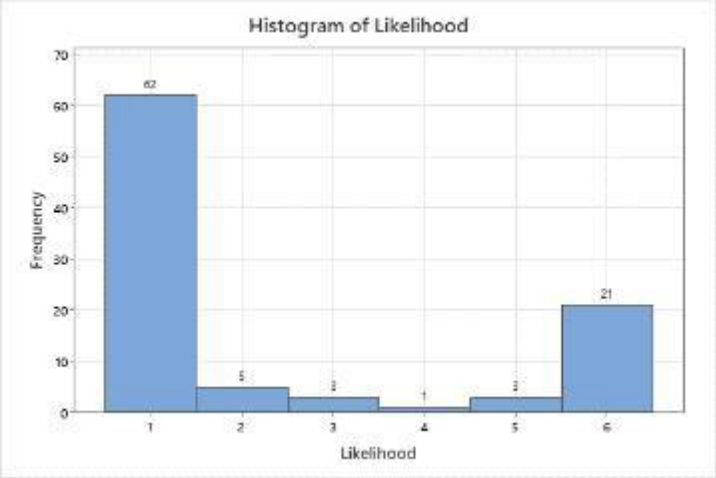

Histogram of Water level
Frequency
0
10
20
30
40
50
60
70
80
90
3
81
9
0
0
0
0
0
8
2
4
6
8
Water level

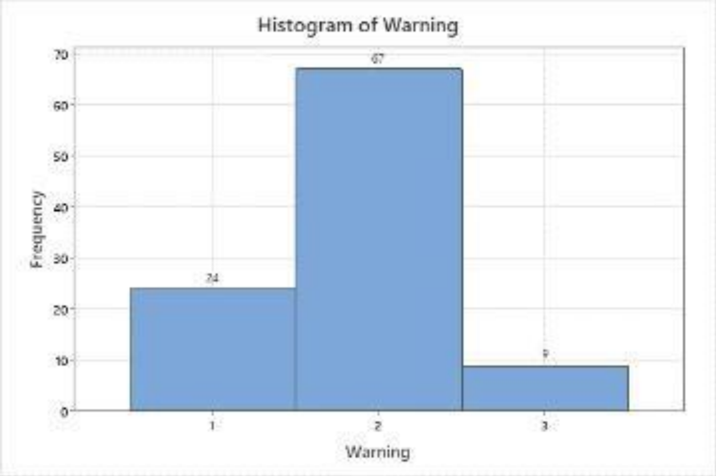

Histogram of Prior flooding
Frequency
0
10
20
30
40
50
60
32
58
10
1
2
3
Prior flooding

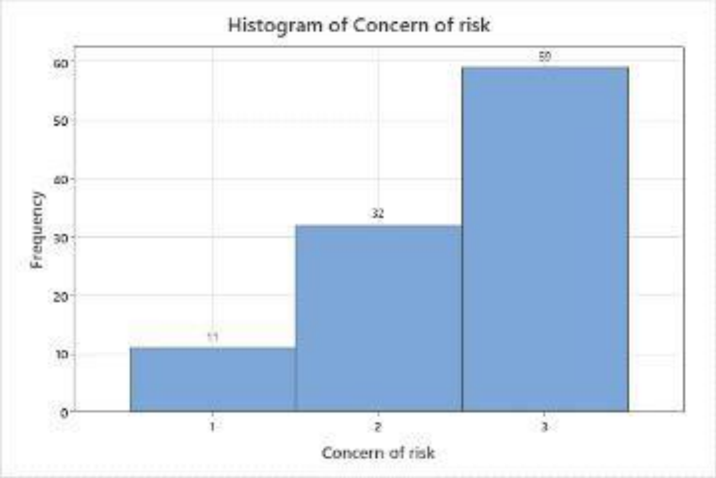

Histogram of Indirect flooding
Frequency
0
10
20
30
40
50
60
70
70
29
2
1
2
3
Indirect flooding

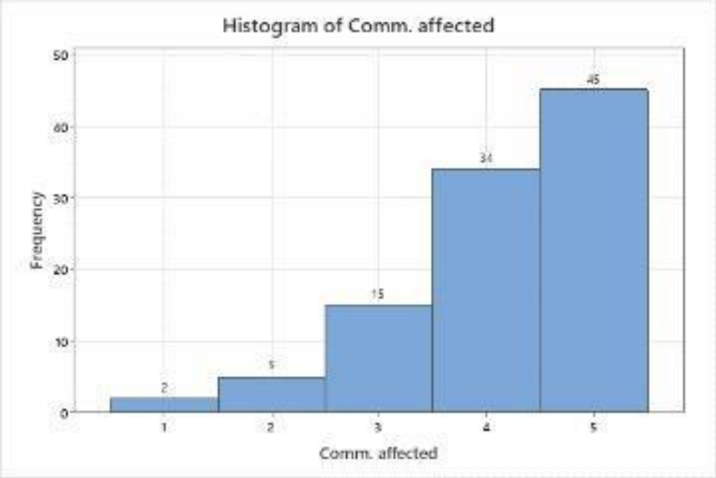

Histogram of Preparedness
Frequency
0
10
20
30
40
10
13
28
36
14
1
2
3
4
5
Preparedness

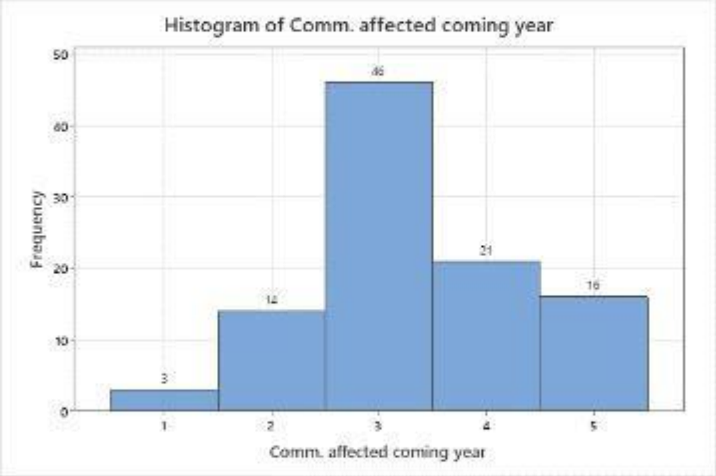

Histogram of Insurance
Frequency
0
10
20
30
40
50
60
70
80
90
7
94
1
2
Insurance

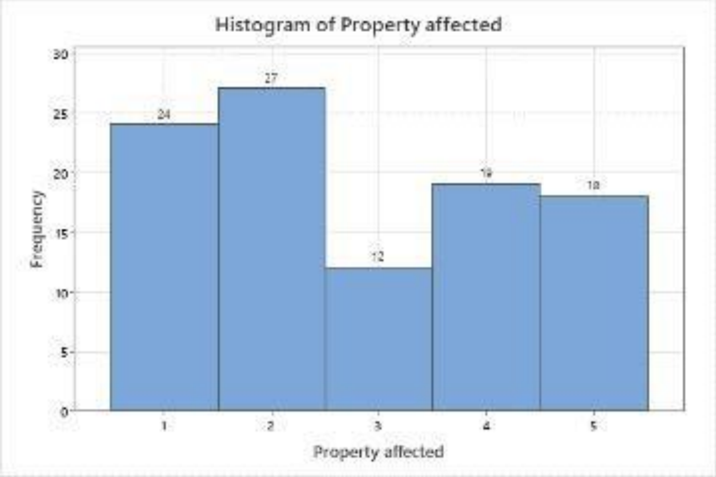

Histogram of Likelihood
Frequency
Likelihood
0
10
20
30
40
50
60
70
1
2
3
4
5
6
62
5
3
1
3
21

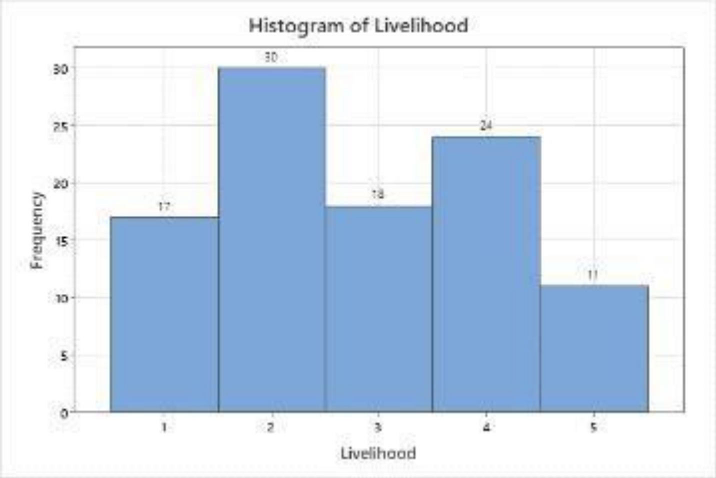

Histogram of Warning
Frequency
Warning
0
10
20
30
40
50
60
70
1
2
3
24
67
9

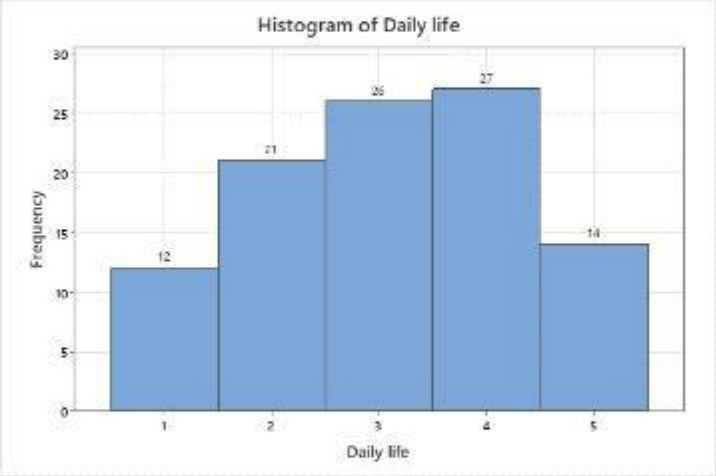

Histogram of Concern of risk
Frequency
Concern of risk
0
10
20
30
40
50
60
1
2
3
11
32
59

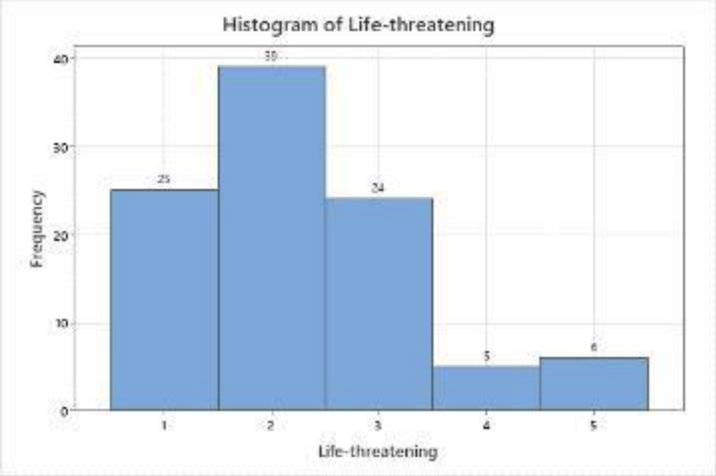

Histogram of Comm. affected
Frequency
0
10
20
30
40
50
2
5
15
34
45
1
2
3
4
5
Comm. affected

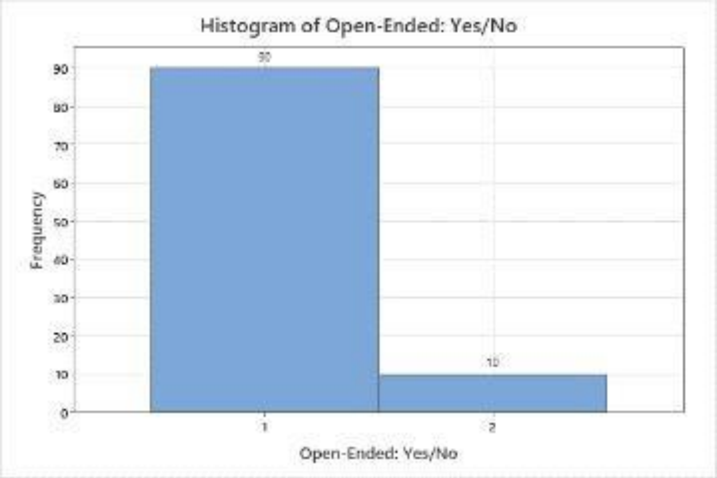

Histogram of Comm. affected coming year
Frequency
0
10
20
30
40
50
3
14
46
21
16
1
2
3
4
5
Comm. affected coming year

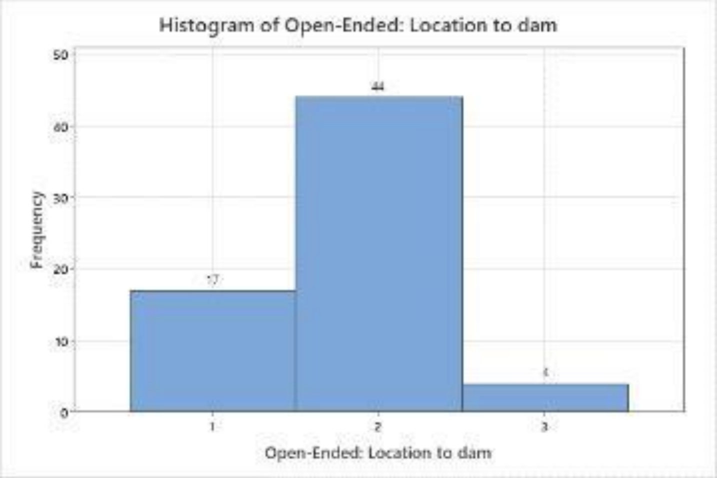

Histogram of Property affected
Frequency
0
5
10
15
20
25
30
24
27
12
19
18
1
2
3
4
5
Property affected

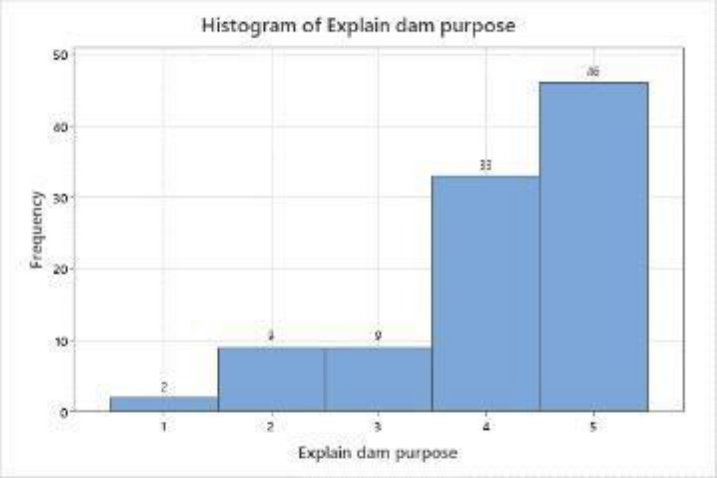

Histogram of Livelihood
Frequency
0
5
10
15
20
25
30
17
30
18
24
11
1
2
3
4
5
Livelihood

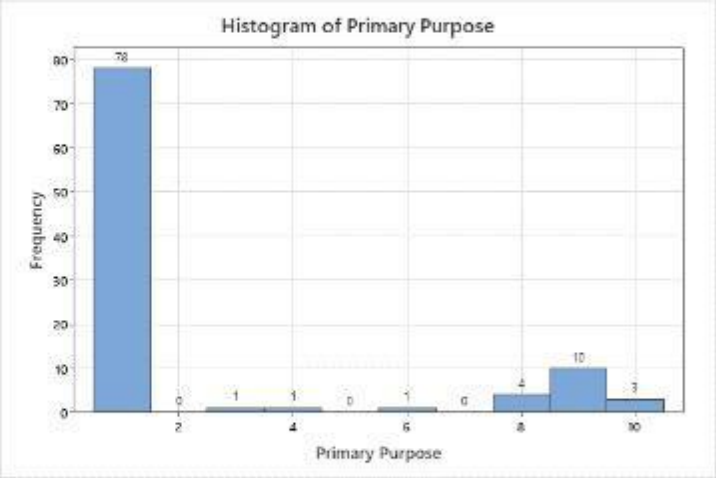

Histogram of Daily life
Frequency
0
5
10
15
20
25
30
12
21
26
27
14
1
2
3
4
5
Daily life

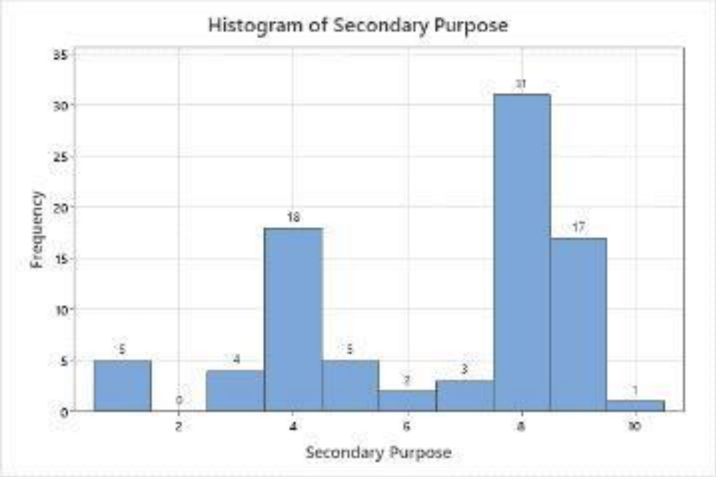

Histogram of Life-threatening
Frequency
0
10
20
30
40
25
39
24
5
6
1
2
3
4
5
Life-threatening

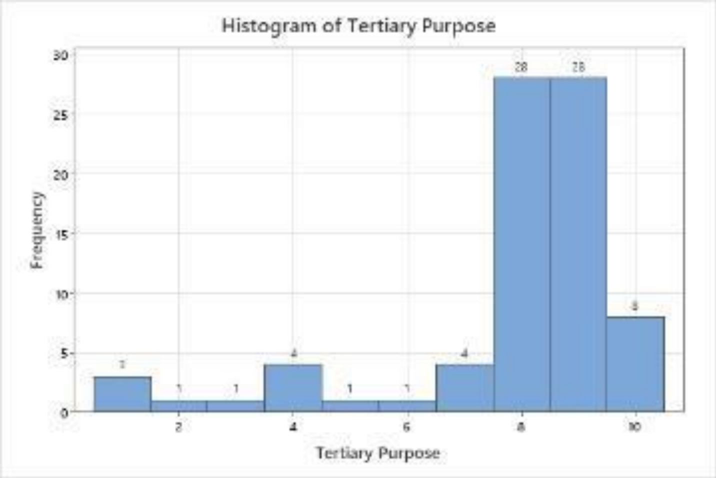

Histogram of Open-Ended: Yes/No
Frequency
90
80
70
60
50
40
30
20
10
0
90
10
1
2
Open-Ended: Yes/No

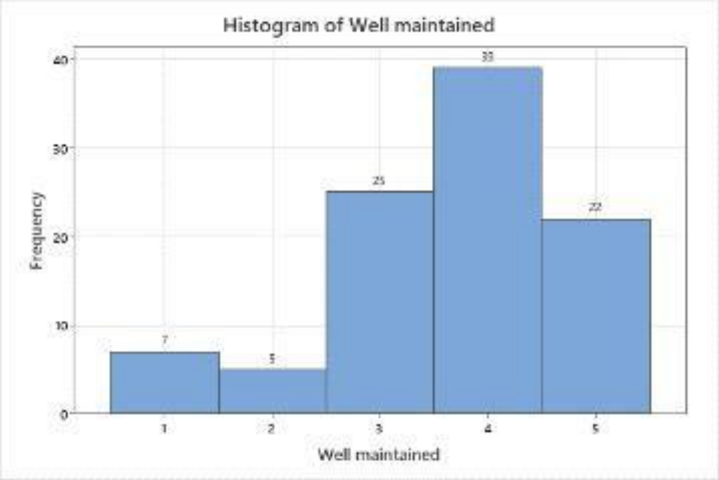

Histogram of Open-Ended: Location to dam
Frequency
50
40
30
20
10
0
17
44
4
1
2
3
Open-Ended: Location to dam

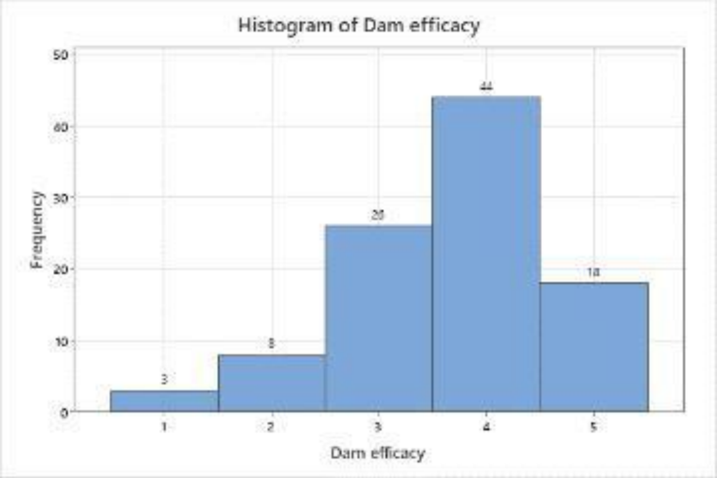

Histogram of Explain dam purpose
Frequency
50
40
30
20
10
0
2
9
9
33
46
1
2
3
4
5
Explain dam purpose

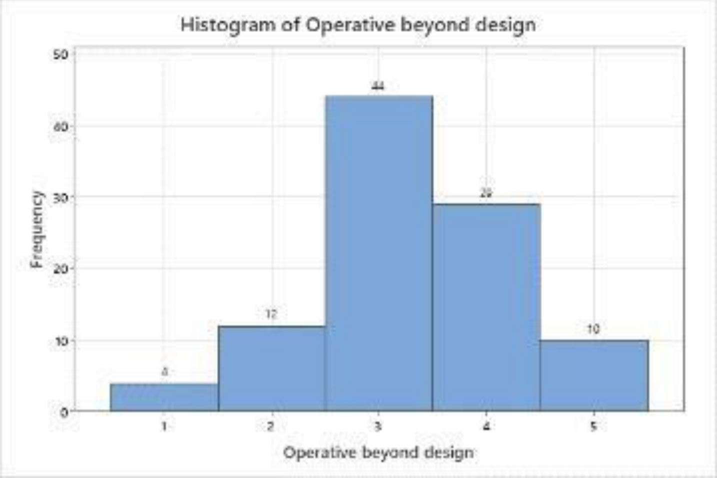

Histogram of Primary Purpose
Frequency
0
10
20
30
40
50
60
70
80
78
0
1
1
0
1
0
4
10
3
2
4
6
8
10
Primary Purpose

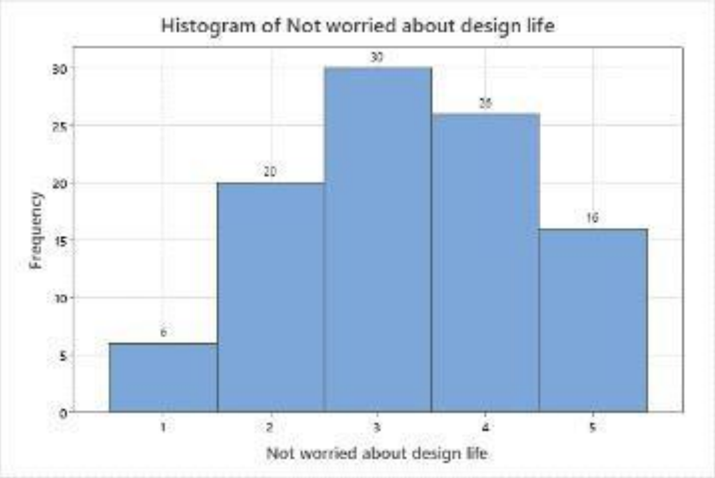

Histogram of Secondary Purpose
Frequency
0
5
10
15
20
25
30
35
5
0
4
18
5
2
3
31
17
1
2
4
6
8
10
Secondary Purpose

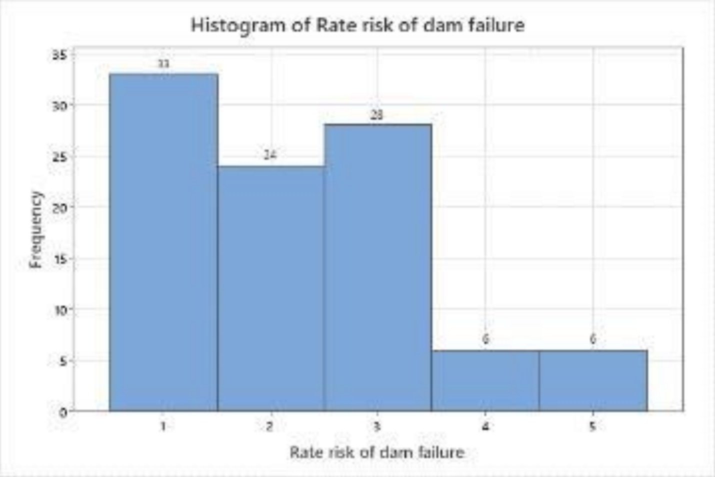

Histogram of Tertiary Purpose
Frequency
0
5
10
15
20
25
30
3
1
1
4
1
1
4
28
28
8
2
4
6
8
10
Tertiary Purpose

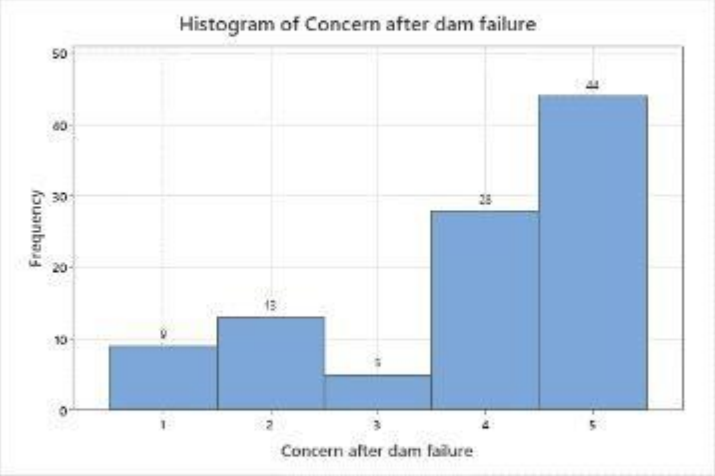

Histogram of Well maintained
Frequency
0
10
20
30
40
7
5
25
39
22
1
2
3
4
5
Well maintained

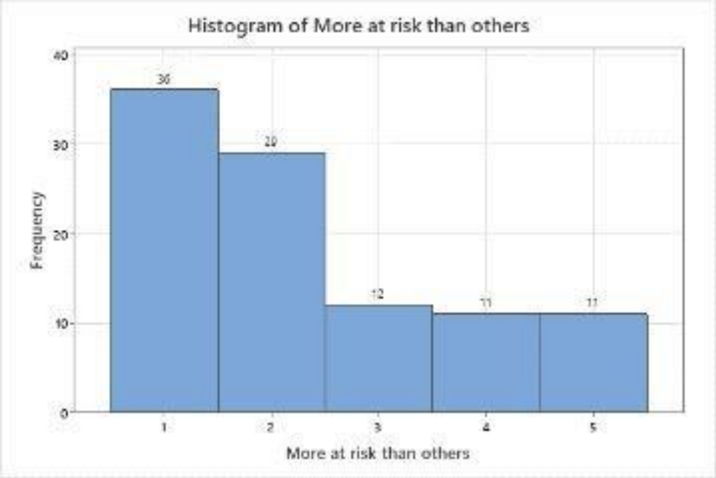

Histogram of Dam efficacy
Frequency
0
10
20
30
40
50
3
8
26
44
18
1
2
3
4
5
Dam efficacy

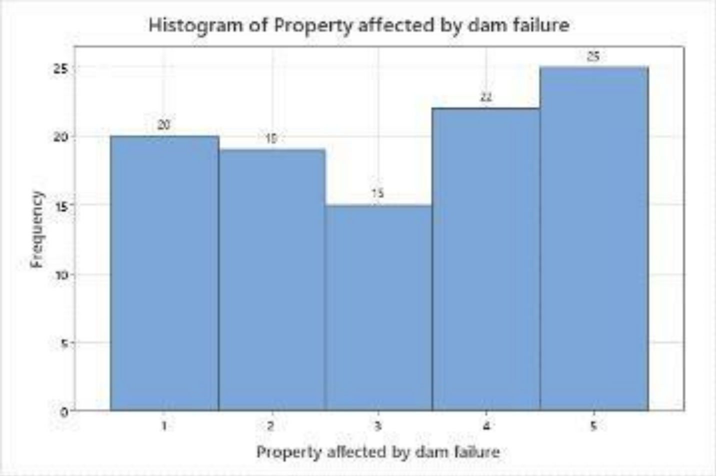

Histogram of Operative beyond design
Frequency
0
10
20
30
40
50
4
12
44
29
10
1
2
3
4
5
Operative beyond design

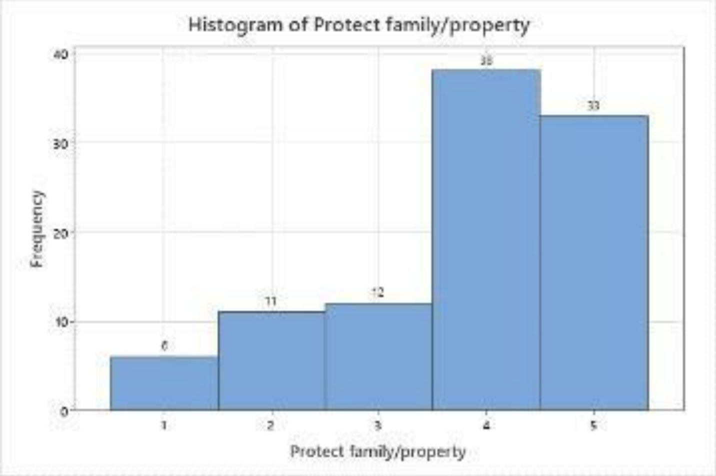

Histogram of Not worried about design life
Frequency
0
5
10
15
20
25
30
6
20
30
26
16
1
2
3
4
5
Not worried about design life

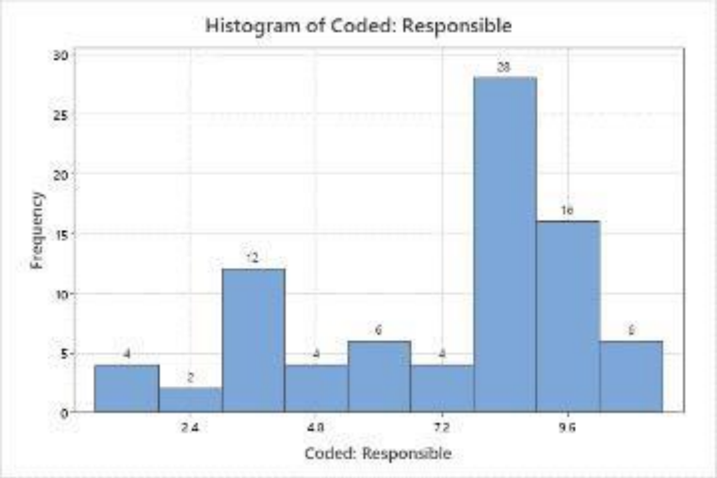

Histogram of Rate risk of dam failure
Frequency
0
5
10
15
20
25
30
35
33
24
28
6
6
1
2
3
4
5
Rate risk of dam failure

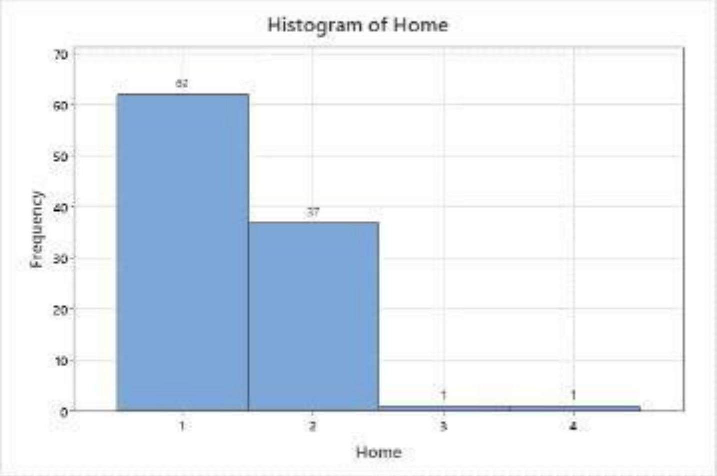

Histogram of Concern after dam failure
Frequency
0
10
20
30
40
50
9
13
5
28
44
1
2
3
4
5
Concern after dam failure


Histogram of More at risk than others
Frequency
0
10
20
30
40
36
29
12
11
11
1
2
3
4
5
More at risk than others


Histogram of Property affected by dam failure
Frequency
0
5
10
15
20
25
20
19
15
22
25
1
2
3
4
5
Property affected by dam failure


Histogram of Protect family/property
Frequency
0
10
20
30
40
6
11
12
38
33
1
2
3
4
5
Protect family/property


Histogram of Coded: Responsible
Frequency
0
5
10
15
20
25
30
4
2
12
4
6
4
28
16
6
2.4
4.8
7.2
9.6
Coded: Responsible


Histogram of Home
Frequency
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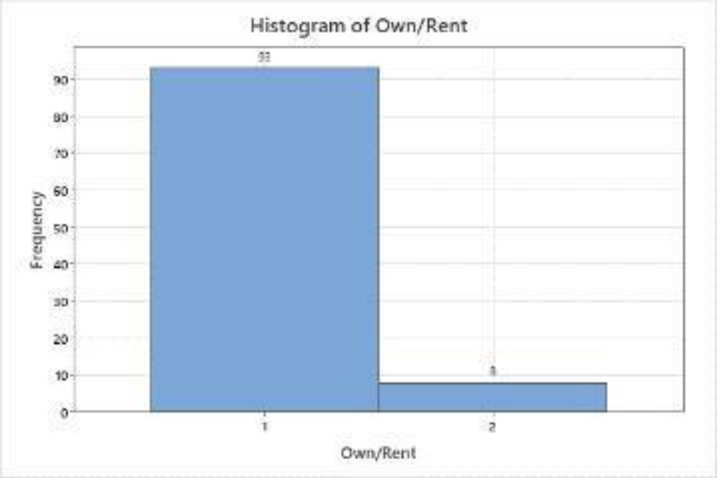
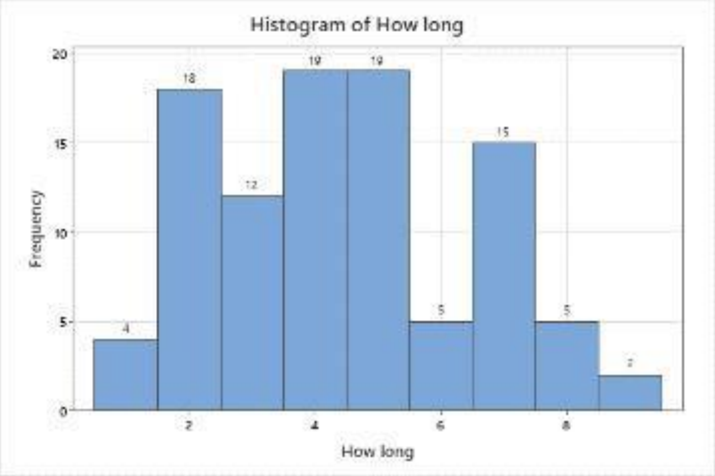
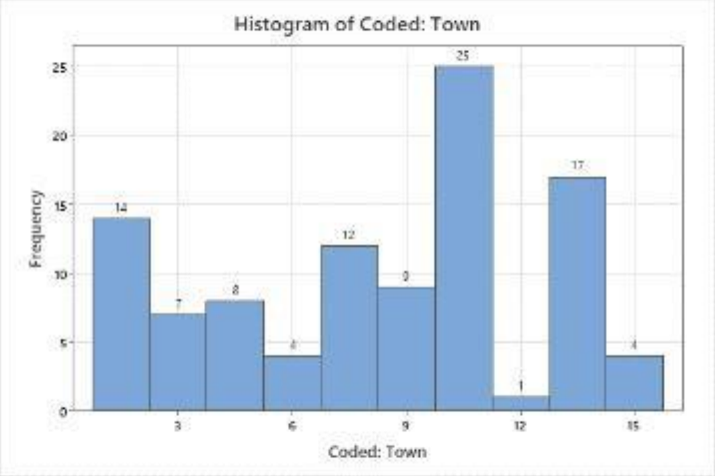
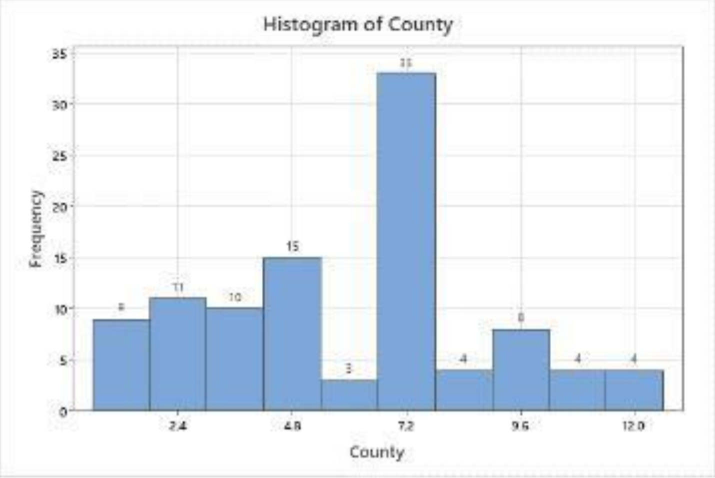
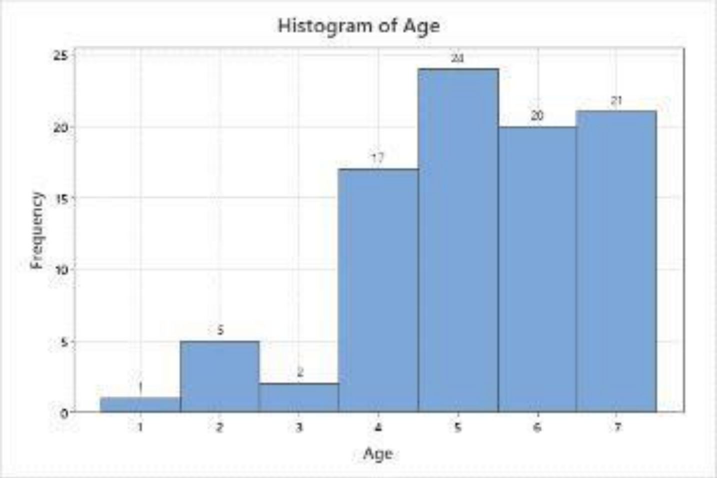
10
20
30
40
50
60
70
62
37
1
1
1
2
3
4
Home

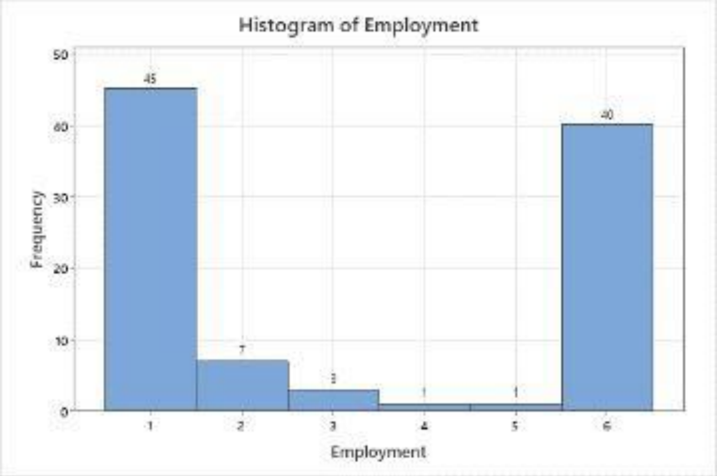

Histogram of Own/Rent
Frequency
0
10
20
30
40
50
60
70
80
90
93
8
1
2
Own/Rent

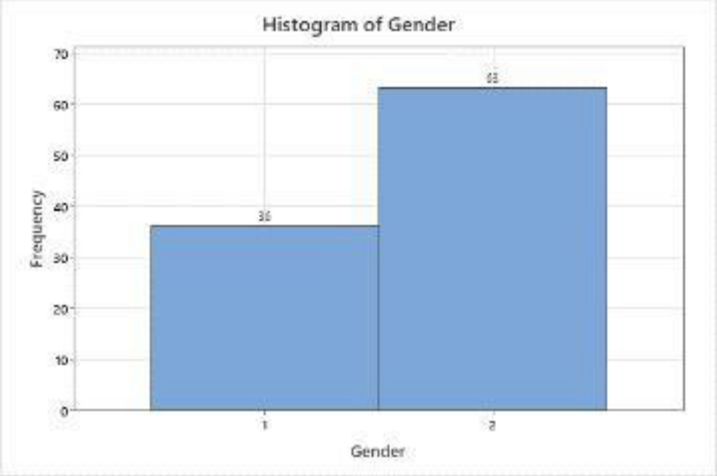

Histogram of How long
Frequency
0
5
10
15
20
4
18
12
19
19
5
15
5
2
2
4
6
8
How long

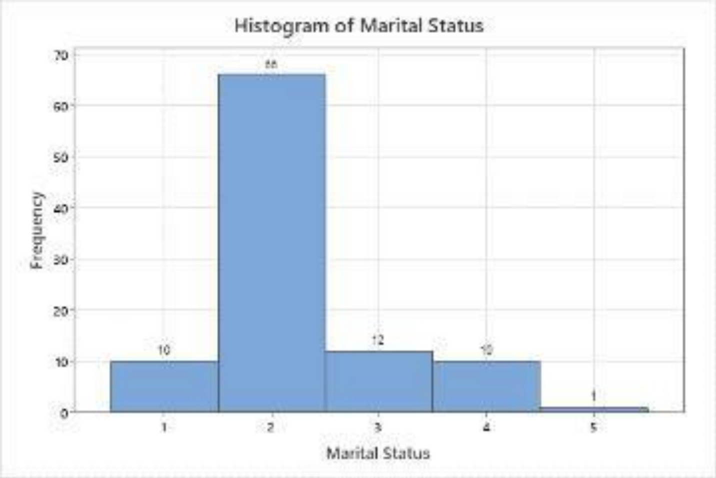

Histogram of Coded: Town
Frequency
0
5
10
15
20
25
14
7
8
4
12
9
25
1
17
4
3
6
9
12
15
Coded: Town


Histogram of County
Frequency
0
5
10
15
20
25
30
35
9
11
10
15
3
33
4
8
4
4
2.4
4.8
7.2
9.6
12.0
County


Histogram of Age
Frequency
0
5
10
15
20
25
1
5
2
17
24
20
21
1
2
3
4
5
6
7
Age


Histogram of Employment
Frequency
0
10
20
30
40
50
45
7
3
1
1
40
1
2
3
4
5
6
Employment


Histogram of Gender
Frequency
0
10
20
30
40
50
60
70
36
63
1
2
Gender


Histogram of Marital Status
Frequency
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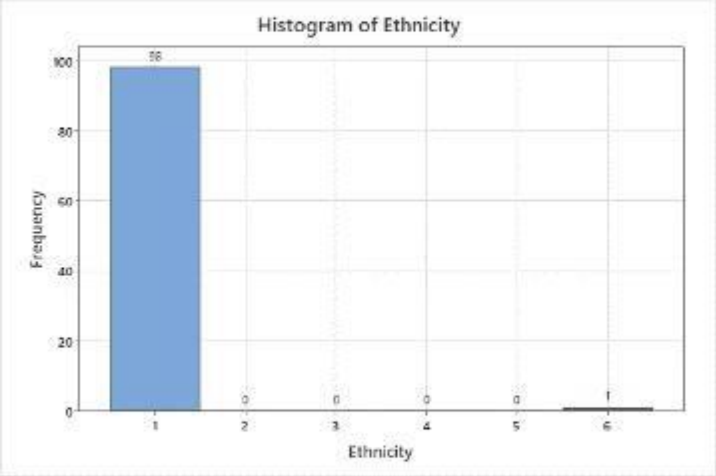
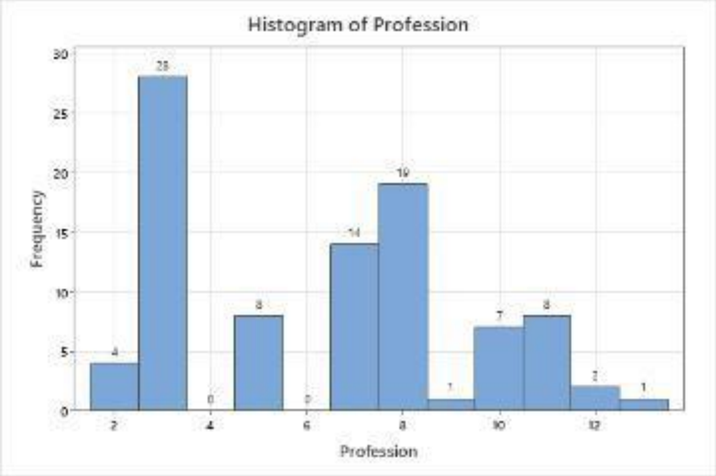
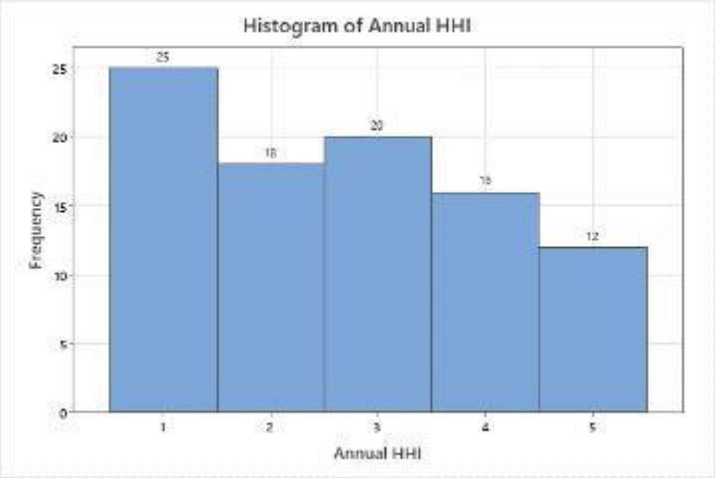
10
20
30
40
50
60
70
10
66
12
10
1
1
2
3
4
5
Marital Status


Histogram of Ethnicity
Frequency
0
20
40
60
80
100
98
0
0
0
0
1
1
2
3
4
5
6
Ethnicity


Histogram of Profession
Frequency
0
5
10
15
20
25
30
4
28
0
8
0
14
19
1
7
8
2
1
2
4
6
8
10
12
Profession


Histogram of Annual HHI
25
18
20
16
12
Frequency
0
5
10
15
20
25
1
2
3
4
5
Annual HHI

Appendix L - Chi-Square (Upstream vs Downstream)

Variable	Upstream	Downstream	df	Pearson's chi-square	p-value for the Pearson's chi-square test
Floodplain					
Yes	2.031	0.641	2	4.600	0.100
No	1.420	0.449			
Don't Know	0.044	0.014			
Property below water level					
Yes	0.089	0.029	2	3.708	0.157
No	0.226	0.074			
Don't know	2.475	0.814			
Flood Insurance			2	0.373	0.541
Yes	0.265	0.082			
No	0.020	0.006			
Don't know					
Indirectly affected by flooding			2	0.749	0.541
Yes	0.102	0.033			
No	0.462	0.152			
Don't know					
Preparedness			**4**	**12.918**	**0.012**
Very prepared	0.015	0.005			
Somewhat prepared	1.387	0.456			
Neither prepared or unprepared	3.708	1.220			
Somewhat unprepared	1.888	0.621			
Very unprepared	2.723	0.896			
Most likely to experience			5	5.418	0.367
Water in the yard but not in the house	0.390	0.118			
Standing water in the house	0.022	0.007			
Standing water above 5 inches in the house	2.450	0.739			

Standing water above waist level in the house	0.232	0.070			
First floor in many houses would be flooded	0.134	0.040			
I’m not sure	0.936	0.282			
Informed about property's risk					
Yes	2.562	0.832	2	4.703	0.095
No	0.988	0.321			
Don’t know					
Concern					
Very concerned	0.034	0.011	2	1.411	0.494
Somewhat concerned	1.031	0.335			
Not concerned at all					
Community would be affected			**4**	**65.634**	**0.000**
Completely agree	33.046	10.870			
Agree	4.605	1.515			
Neither agree or disagree	1.982	0.652			
Disagree	4.195	1.380			
Completely disagree	5.560	1.829			
Community affected (coming year)			**4**	**14.918**	**0.005**
Completely agree	8.100	2.700			
Agree	0.017	0.006			
Neither agree or disagree	0.022	0.007			
Disagree	0.800	0.267			
Completely disagree	2.250	0.750			
Personal property affected by flooding			4	6.329	0.176
Completely agree	0.500	0.167			
Agree	0.533	0.178			
Neither agree or disagree	1.333	0.444			
Disagree	0.880	0.293			
Completely disagree	1.500	0.500			
Livlihood affected			4	8.653	0.070
Completely agree	0.173	0.058			

Agree	0.833	0.278			
Neither agree or disagree	0.500	0.167			
Disagree	0.167	0.056			
Completely disagree	4.817	1.606			
Disrupted daily life			4	1.685	0.793
Completely agree	0.333	0.111			
Agree	0.011	0.004			
Neither agree or disagree	0.038	0.013			
Disagree	0.810	0.270			
Completely disagree	0.071	0.024			
Life threatening			**4**	**30.966**	**0.000**
Completely agree	2.593	0.830			
Agree	6.125	1.960			
Neither agree or disagree	0.240	0.077			
Disagree	7.042	2.253			
Completely disagree	7.459	2.387			
Location to nearest dam			**2**	**26.129**	**0.000**
Upstream	15.291	4.497			
Downstream	4.900	1.441			
Don't Know					
Confidence in explaining dam purpose			**4**	**50.056**	**0.000**
Very confident	12.824	4.104			
Somewhat confident	13.364	4.276			
Neither confident or unconfident	0.015	0.005			
Somewhat unconfident	2.506	0.802			
Very unconfident	9.212	2.948			
Top 3 Purposes			**9**	**66.365**	**0.000**
Flood Control	0.003	0.001			
Fire Protection	0.247				
Stock or small fish pond	1.483	0.487			
Fish and wildlife pond	0.304	0.100			
Debris Control	0.157	0.052			
Hydroelectric	0.989	0.325			

Irrigation	0.308	0.101			
Recreation	1.260	0.414			
Water Supply	0.187	0.061			
Don’t know/Other	59.887	0.000			
Properly maintained dam					
Strongly agree	1.463	0.475	4	6.231	0.183
Agree	8.717	2.827			
Neither agree or disagree	1.352	0.439			
Somewhat disagree	5.964	1.934			
Strongly disagree	1.715	0.556			
Dam efficacy					
Completely agree	4.455	1.425	4	9.103	0.059
Agree	15.591	4.989			
Neither agree or disagree	0.841	0.269			
Disagree	5.648	1.807			
Completely disagree	1.911	0.612			
Dam exceeding life expectancy			4	2.091	0.719
Completely agree	1.095	0.350			
Agree	3.030	0.970			
Neither agree or disagree	0.042	0.013			
Disagree	2.293	0.734			
Completely disagree	0.074	0.024			
Worry dam design			4	2.101	0.717
Completely agree	0.982	0.319			
Agree	0.004	0.001			
Neither agree or disagree	1.816	0.589			
Disagree	0.736	0.239			
Completely disagree	2.939	0.953			
Dam failure risk			4	5.373	0.2511
High risk	4.830	1.588			
Somewhat high risk	1.966	0.646			
Medium risk	0.620	0.204			
Somewhat low risk	3.454	1.135			

Low Risk	5.473	1.799			
Concern due to dam failure			4	6.110	0.191
Very concerned	11.821	3.994			
Somewhat concerned	1.325	0.448			
Neither concerned or unconcerned	0.055	0.018			
Somewhat unconcerned	2.497	0.844			
Very unconcerned	2.387	0.806			
More at risk than others			4	6.809	0.146
Much more at risk	3.521	1.127			
Moderately at risk	4.462	1.428			
Somewhat at risk	0.003	0.001			
Slightly at risk	0.108	0.035			
Not at risk	13.186	4.219			
Property affected due to dam failure			4	1.187	0.880
Strongly agree	0.190	0.063			
Somewhat agree	0.233	0.077			
Neither agree or disagree	1.982	0.652			
Somewhat disagree	0.006	0.002			
Strongly disagree	1.197	0.394			
Confidence in protecting oneself and others			4	7.979	0.0924
Very confident	12.100	4.033			
Somewhat Confident	4.500	1.500			
Neither	0.000	0.000			
Somewhat unconfident	5.879	1.960			
Very unconfident	1.457	0.486			
Responsible Party			10	8.662	0.565
Land/Property Owners	0.927	0.280			
Watershed District/Department	0.463	0.140			
City	1.758	0.530			
County	0.695	0.210			
State	0.927	0.280			
Federal Government	0.110	0.033			

Government	0.006	0.002
U.S. Army Corps of Engineers	0.040	0.012
More than 1 answer	0.535	0.161
Unsure	0.927	0.280
Other	0.267	0.081