4.6 DAM INCIDENT

4.6.1 Description

Dams are structures built for a variety of uses, including flood protection, power generation, agriculture, water supply, and recreation. Most dams are typically engineered to withstand a flood with a computed risk of occurrence, such as a 100-year flood which has a 1% probability of occurring in any given year. As inflow to the water pooled behind a dam approaches the design capacity, emergency measures can usually be taken to release excess water. Also, an emergency spillway is required to be built into dam structures to release excess water. If emergency measures are insufficient, the dam structure may be overtopped, which is when water passes over the top of the dam. Overtopping often leads to dam failure and is the primary cause of earthen dam failure in the United States. Dam failures can also result from a combination of causes, including:

- Failure of upstream dams on the same waterway,
- Improper maintenance,
- Negligent operation,
- Internal erosion caused by embankment or foundation leakage or piping, root growth, or rodent/wildlife activity,
- Earthquake/seismic activity,
- Prolonged periods of rainfall and flooding, which result in overtopping,
- Improper design,
- Inadequate spillway capacity resulting in excess overtopping flows, and
- Intentional structural attacks and cyberattacks.

Water released by a failed dam commonly causes a flood that is catastrophic to life and property. A catastrophic dam failure could challenge local emergency response capabilities and require evacuations to save lives. Impacts to life safety will depend on the warning time and the resources available to notify and evacuate the public. Major loss of life could result, as well as potentially catastrophic effects to roads, bridges, homes, and other infrastructure. Associated water quality and health concerns could also be issues. Factors that influence the potential severity of a full or partial dam failure are the amount of water impounded; the density, type, and value of development and infrastructure located downstream; the characteristics of the river channel, and the speed of failure.

Dam induced inundation can also occur from non-failure events when dam outflow exceeds the capacity of the downstream river channel. This can occur when emergency measures are taken to release water and prevent a dam failure due to heavy rains and/or high inflows. Emergency releases are typically considered controlled or designed and are done to protect the dam but can nevertheless result in flooding downstream. Additionally, outlets and spillways may release water in a different channel and create additional inundation areas.

Dams may be classified according to the type of construction material used, the methods used in construction, the slope or cross-section of the dam, the way the dam resists the forces of the water pressure behind it, the means used for controlling seepage, storage characteristics (on a watercourse, off-stream, above or below ground level), and occasionally, according to the purpose of the dam. The materials used for construction of dams include earth, rock, tailings from mining or milling, concrete, masonry, and combinations of these materials.

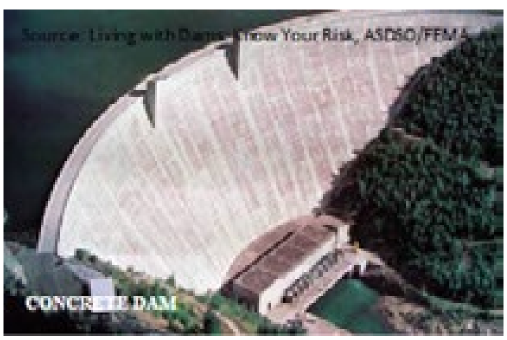
Types of Dams

Embankment dams are the most common type of dam in use today. Materials used for embankment dams include natural soil or rock or waste materials obtained from mining or milling operations. An embankment dam is termed an "earthfill" or "rockfill" dam depending on whether it is composed of compacted earth or mostly compacted rock. The ability of an embankment dam to resist the reservoir water pressure is primarily a result of the mass, type, and strength of the materials from which the dam is made.

Figure 4-24 Example of an Embankment dam

Concrete dams maybe categorized into gravity and arch dams according to the designs used to resist the stress due to reservoir water pressure. The most common type of concrete dam is a concrete gravity dam. The mass of concrete and friction resist the reservoir water pressure. A buttress dam is a specific type of gravity dam in which the large mass of concrete is reduced, and the forces are diverted to the dam foundation.

Figure 4-25 Example of a Concrete dam

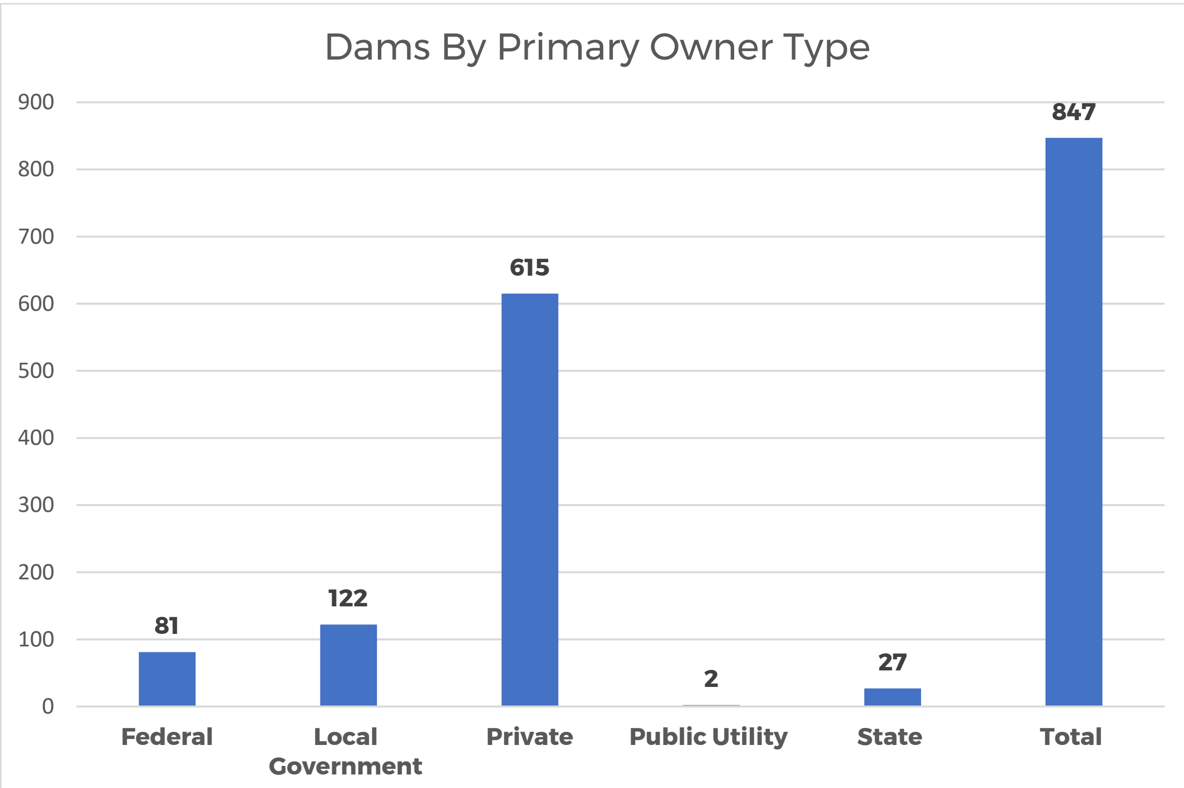


Ownership

Dams are owned and operated by many different types of owners. Sometimes they only serve the interest of the owner—such as for a neighborhood association that wants its homes built around a lake—and sometimes they serve the interest of communities—such as for a water supply utility. Downstream development affects a dam's risk. Dams that used to be located in rural areas, affecting minimal infrastructure, are now often affecting neighborhoods and industrial areas as a result of urbanization. Due to increased development, dam failure consequences have become much higher.

Dams are unique components of U.S. infrastructure in that most dams are privately owned. Dam owners are solely responsible for keeping their dams safe and financing maintenance, repairs, and upgrades, which can be expensive. Cost estimates for non-Federal dam rehabilitation projects commonly range from $100,000 to millions of dollars per dam, depending on the size, complexity, and condition of the dam. Such high costs place a huge burden on dam owners, many of whom cannot afford to maintain their dams (Living with Dams: Know Your Risk, ASDSO/FEMA). Figure 4-26 shows the dams by primary owner type in Utah. The highest number of dams are owned by private entities, with the 2nd highest being owned by local governments, and then dams owned by the federal government. Specific to high hazard dams, the numbers include 51 federal, 69 local government, and 143 privately owned dams, with two owned by the State and one by a public utility.

Figure 4-26 Dam Ownership in Utah



Source: National of Inventory Dams (2023)

4.6.2 Geographic Area

The Utah Division of Water Rights DAMVIEW Dam Safety Database Information Viewer, contains entries for over 6,500 dams of various types. Most of these dams are very small and in remote locations, such as ponds used for ranching or farming. Many of the dams are no longer used or have otherwise gone dry. Over 5,500 of these dams are classified as not inspected (5,298) or inactive (241). It is more useful in a hazard mitigation plan to discuss dams that are likely to be relevant to public safety. In the analysis the more relevant National inventory of Dams (NID) and the Utah Dam Inventory databases were used (Figure 4-27, Table 4-16). The slight discrepancy in the number of relevant dams in the NID and Utah Dam Inventory databases is an artifact of differently defined search parameters, as well as potential differences in timing of database updates.

The NID database contains 266 high hazard dams and 315 significant hazard dams in the state of Utah. The largest concentration of high and significant hazard dams is within the Wasatch Front counties, including Salt Lake City metropolitan area. Appendix F contains a full list of the high hazard potential dams including names, NID identification numbers, location by county and condition rating.

Figure 4-27 High and Significant Hazard Dam Locations in Utah

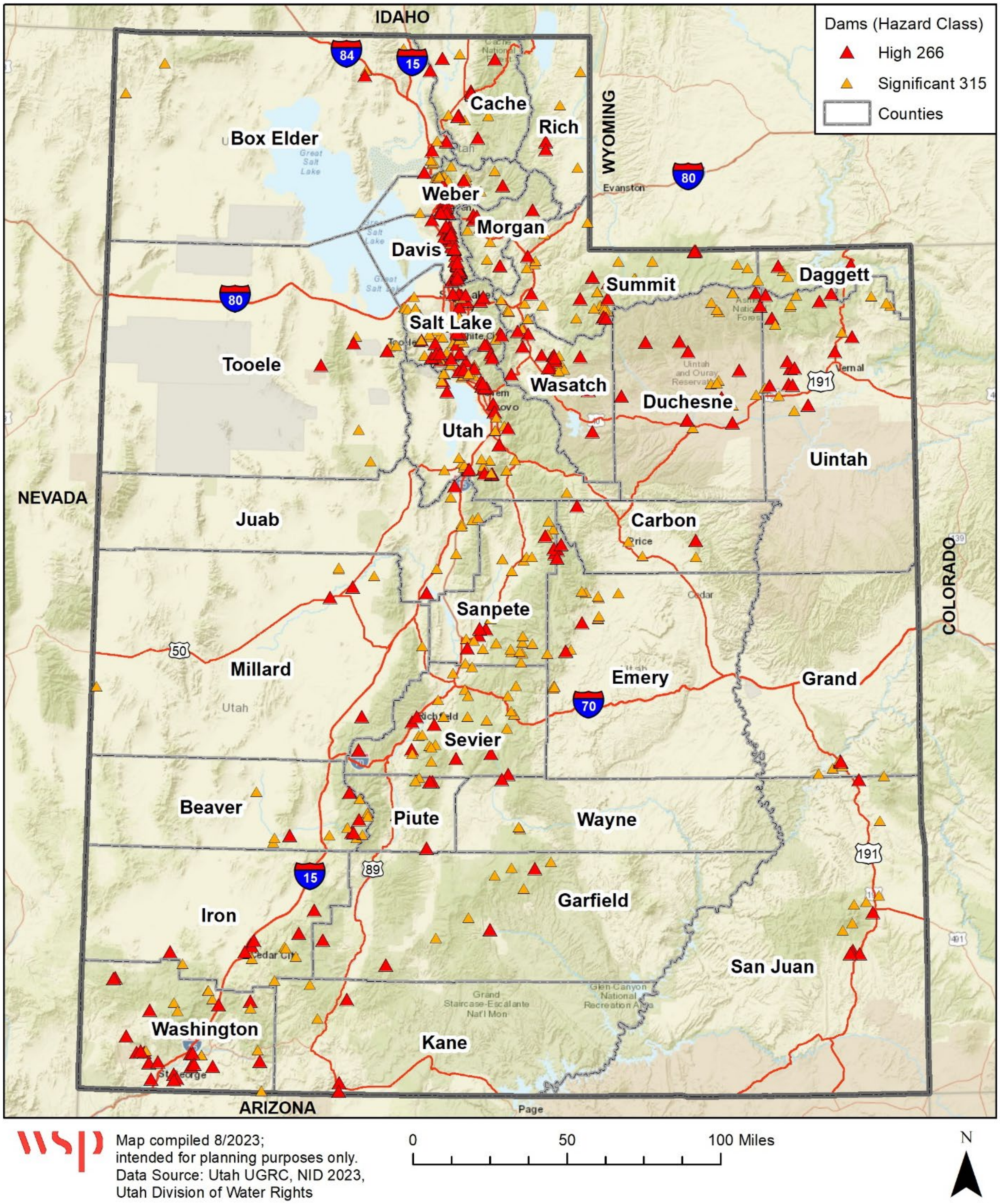


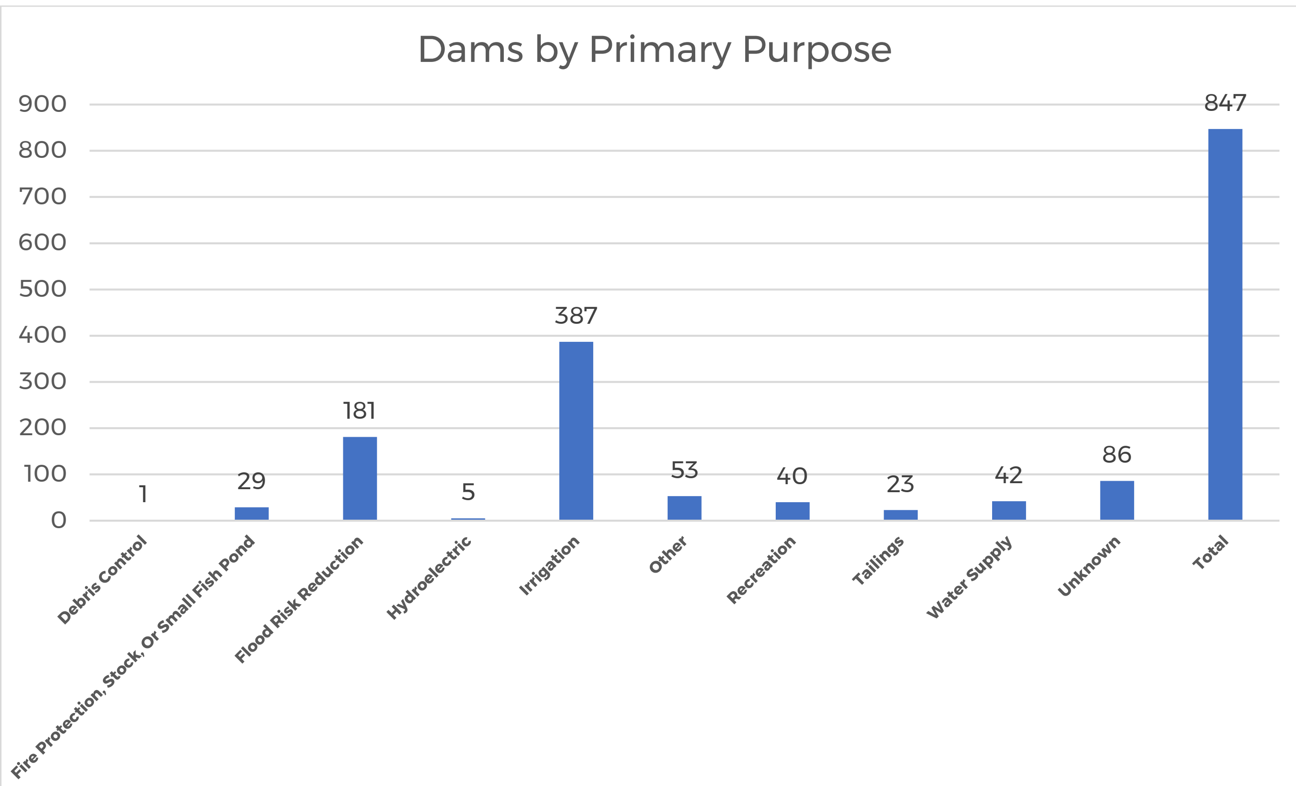
Table 4-16 State Dam Inventory and National Inventory of Dams Statistics for Utah

Dam Hazard Type	National Inventory of Dams	Utah Dam Inventory Database
High Hazard Dams	266	254
Significant Hazard Dams	315	222
Low Hazard Dams	262	322
Undetermined Hazard Dams	4	27
Total Dams	**847**	**825**

Source: Utah Division of Water Rights (2022), National Inventory of Dams (2023)

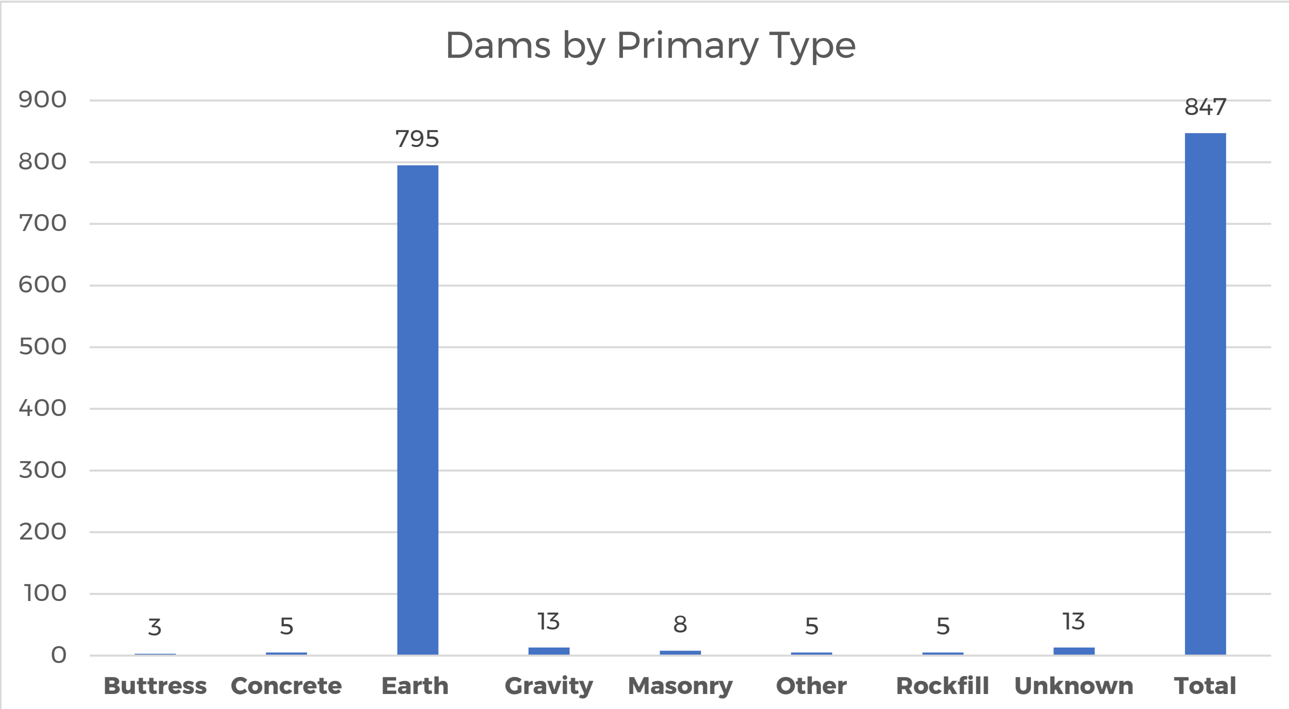
The NID database was used to categorize dam usage by primary purpose, by primary type, and the number of high and significant hazard dams with an Emergency Action Plan (EAP), see Figure 4-28 and Figure 4-29, respectively. Of the 847 total dams included from the NID database, 181 of the dams are used for Flood Risk Reduction purposes.

Figure 4-28 Utah Dams by Primary Purpose



Source: National of Inventory Dams (2023)

Figure 4-29 Utah Dams by Primary Type



Source: National of Inventory Dams (2023)

Table 4-17 shows the number of high hazard dams within Utah by county, including the percentage of dam ownership. Davis County has the highest number of high hazard dams (40), with 45% of those being privately owned. Salt Lake County has the second highest number of dams (28), with slightly over 60% being owned by local governments.

Table 4-17 High Hazard Dams by County and Owner Type in Utah

COUNTY	HIGH HAZARD DAMS	LOCAL GOVERNMENT	FEDERAL	PRIVATE	PUBLIC UTILITY	STATE
Beaver	5	-	-	100%	-	-
Box Elder	5	40%	20%	40%	-	-
Cache	7	14%	57%	29%	-	-
Carbon	2	-	50%	50%	-	-
Daggett	2	-	50%	50%	-	-
Davis	40	20%	35%	45%	-	-
Duchesne	12	-	33%	67%	-	-
Emery	5	-	-	100%	-	-
Garfield	4	-	-	100%	-	-
Grand	3	67%	-	33%	-	-
Iron	8	38%	-	63%	-	-
Juab	2	-	-	100%	-	-
Kane	3	-	-	100%	-	-
Millard	3	-	-	100%	-	-

COUNTY	HIGH HAZARD DAMS	LOCAL GOVERNMENT	FEDERAL	PRIVATE	PUBLIC UTILITY	STATE
Morgan	5	-	40%	60%	-	-
Piute	4	-	-	100%	-	-
Rich	2	-	-	100%	-	-
Salt Lake	28	61%	-	36%	4%	-
San Juan	6	67%	-	33%	-	-
Sanpete	7	-	-	100%	-	-
Sevier	8	50%	-	50%	-	-
Summit	13	-	62%	38%	-	-
Tooele	3	-	-	100%	-	-
Uintah	13	-	15%	77%	-	8%
Utah	24	79%	-	21%	-	-
Wasatch	14	7%	29%	57%	-	7%
Washington	21	19%	-	81%	-	-
Wayne	1	-	-	100%	-	-
Weber	16	25%	63%	13%	-	-

Source: National of Inventory Dams (2023)

4.6.3 Extent/Magnitude

Certain dams pose a hazard to people and property downstream. The Utah Dam Safety Program uses a three-tier hazard rating system that indicates the magnitude of the potential impact of an incident. Ratings are either high, moderate/significant, or low (damsafety.org, “Dam Safety, Performance Report for the State of Utah”). This rating system considers variables such as the concentration of life and property located downstream, the size, height, volume, and the incremental risk/damage assessments of dams.

High Hazard: is typically defined as a dam whose failure will cause loss of human life and significant property destruction.

Moderate/Significant Hazard: is typically defined as a dam whose failure or will cause significant property destruction.

Low Hazard: is typically defined as a dam whose failure will cause minimal property destruction.

The hazard rating does not reflect the condition of a dam or the likelihood of failure, but it does dictate how closely dams are monitored for safety concerns. Of the 266 High Hazard dams in Utah, all but one has an Emergency Action Plan (EAP) in place. 163 of 315 dams classified as a moderate hazard have an EAP in place. In addition, the Utah Dam Safety Program prioritizes inspections of dams with a hazard rating of ‘high,’ ideally inspecting these dams each year. Dams with a ‘moderate/significant’ hazard rating are inspected less frequently, ideally every two years. Dam safety inspection records are discussed in Section 4.6.5.

4.6.4 Past Occurrences

Despite well-developed safety programs, dam failures do occur in modern times. The history of dam failures in Utah provides lessons for decision makers. Below is a summary of notable incidents occurring in the past 75 years.

21 Mile Dam Failure (2017)

The 21 Mile Dam failed in Elko County, Nevada on February 8, 2017, due to heavy runoff from a rain-on-snow event. The earthen dam breached, causing flooding that damaged ranches and destroyed portions of state route 233 and a section of Union Pacific railroad. Floodwaters entered extreme northwestern Utah and caused road damage.

Laub Detention Dam Failure (2012)

Laub Detention Dam breached on September 11, 2012, flooding parts of Santa Clara and St. George and was declared a major disaster by President Obama. Internal erosion during a heavy precipitation event, likely initiated through animal burrows, led to the failure. No lives were lost. The Dam was rebuilt in 2013 and was renamed "Tuacahn Wash Lower Detention Basin."

Figure 4-30 Laub Detention Dam Failure

Quail Creek Dike Failure (1989)

Shortly after midnight on New Year's Day (January 1) 1989, an 80 to 90 foot tall and 300-foot-wide section of the Quail Creek Dike failed. The breach occurred less than four years after the dam was constructed and filled due to extensive foundation seepage caused by inadequate design and construction. Evacuation orders were issued up to 90 minutes in advance and no lives were lost, but the failure impacted 30 homes, 58 apartments, bridges and roads. The incident led to strengthening of dam safety regulations in Utah.

Trial Lake Dam Failure (1986)

Trial Lake Dam failed in 1986 from piping of organics in the foundation contact. It was rebuilt to modern safety standards in 1991.

DMAD Dam Failure (1983)

DMAD Dam spillway failed in 1983, releasing 17,000-acre feet of water, flooding farmland, killing livestock, and flooding the town of Deseret. One person was killed trying to cross the flooding river on a suspended wire. The Gunnison Bend Dam was consequently breached proactively to keep it from overtopping.

Little Deer Creek Dam Failure (1963)

Little Deer Creek dam failed on its first filling on June 16, 1963, due to extensive foundation seepage caused by construction deficiencies. The catastrophic failure caused the drowning of a four-year-old child.

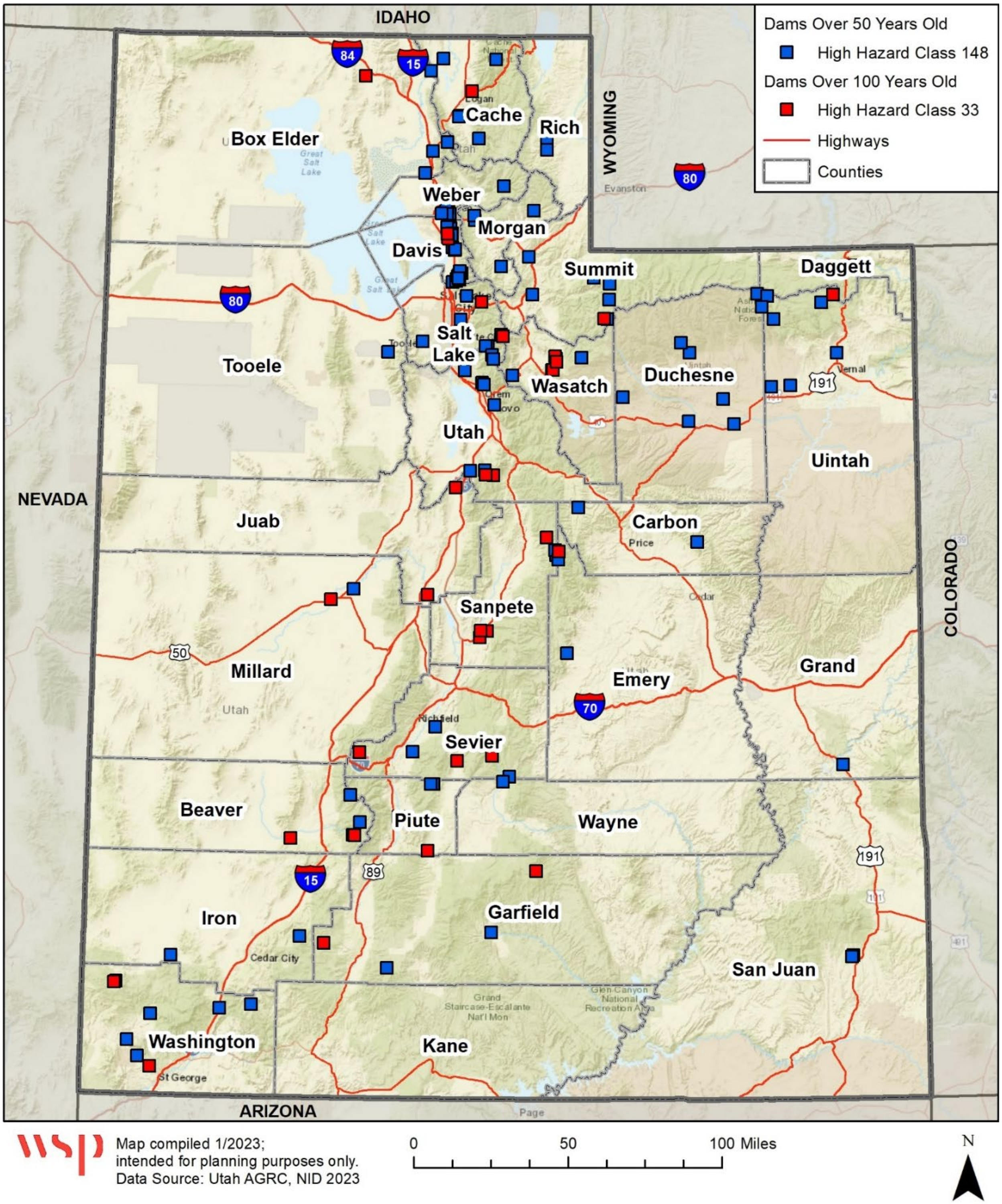
4.6.5 Probability

The probability of future dam failures has not been quantified, either by government agencies or otherwise. However, indicators exist that provide insight to the likelihood of future dam failure.

The first indicator is the frequency of incidents in the past. In recent decades, Utah has experienced roughly one notable incident per decade over the past 75 years (Section 4.6.4). This can provide a rough idea of the typical frequency of dam incidents in Utah.

The age of dams is a second indicator of future probability of failure. Dams deteriorate over time and have a designed life span. Simply stated, the probability of dam failure increases over time. At least 148 dams in Utah are classified as high hazard and are over 50 years old, 33 of which are 100 years old or older (Figure 4-31). By 2040 these numbers will balloon to 210 and 69 high-hazard dams at least 50 and 100 years old, respectively.

Figure 4-31 Utah Dams Over 50 and 100 Years Old



A third indicator of future dam failures is the dam safety condition rating assigned to dams. Based largely on dam inspections, the safety condition of dams is rated on a four-tier scale (Table 4-18).

Table 4-18 Dam Safety Condition Definitions

NID RATING	DEFINITION
Satisfactory	No existing or potential dam safety deficiencies are recognized.
Fair	No existing dam safety deficiencies are recognized for normal loading conditions. Rare or extreme hydrologic and/or seismic events may result in a dam safety deficiency.
Poor	A dam safety deficiency is recognized for loading conditions which may realistically occur. Remedial action is necessary. Poor may also be used when uncertainties exist as to critical analysis parameters which identify a potential dam safety deficiency. Further investigations and studies are necessary.
Unsatisfactory	A dam safety deficiency is recognized that requires immediate or emergency remedial action for problem resolution.

Source: National of Inventory Dams

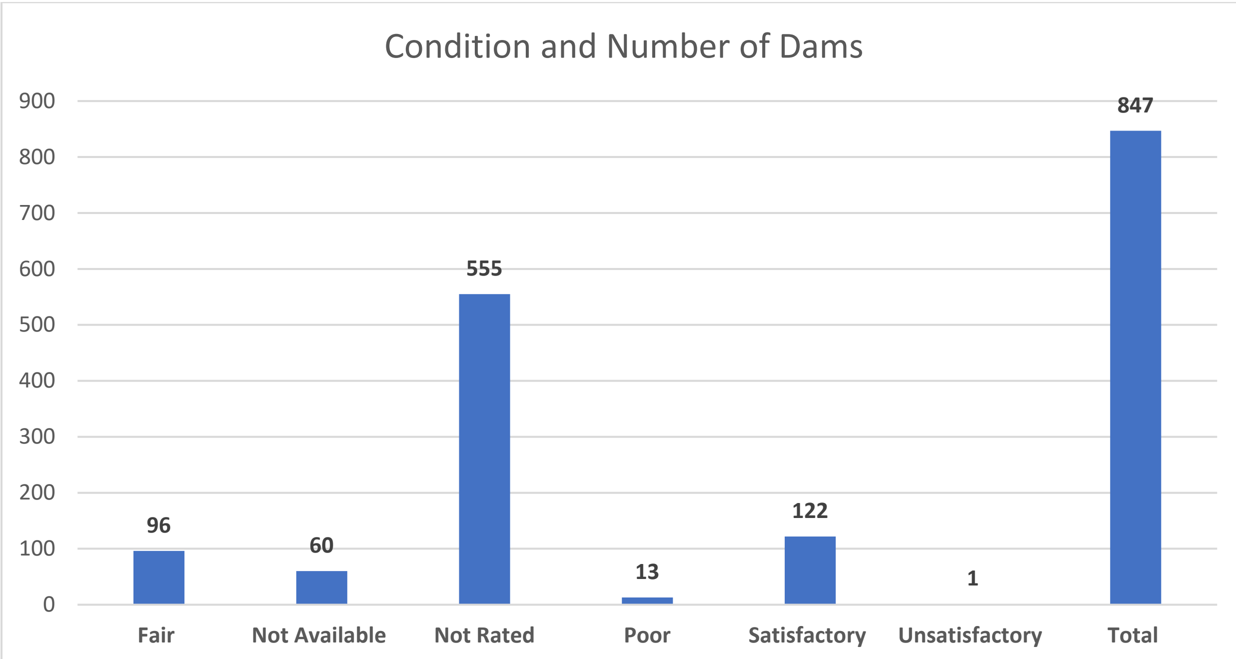
Many dams exist in Utah that do not have one of these safety condition ratings (Figure 4-32). Two-thirds of the dams in the Utah state database, 555 of 847, are classified as "significant" or "low" hazard dams and are listed as "not rated" for dam safety conditions. 73% of these dams (403 of 555) have been inspected and are typically inspected regularly. Nevertheless, these dams have been assigned a "not rated" safety condition classification. In addition, the safety condition rating of Federally managed dams typically exists but is not publicly available for analysis; 50 of 54 dams with a "not available" safety condition rating are under Federal jurisdiction.

What remains are the 232 dams in the Utah state database that have been assigned a safety condition rating. These dams include all non-Federally managed dams that are classified as high hazard, plus a small group of dams classified as significant and low hazard dams. All of these dams are inspected regularly, every year or two.

As stated at the beginning of this section, no probability of failure has been assigned to dams in Utah by any agency or other entity. Only one dam in Utah has a safety condition rating of unsatisfactory. This dam is fortunately classified as a low hazard dam and is therefore not of great concern for public safety. However, Utah has nine dams classified as high hazard (Section 4.6.3) with a safety condition rating of poor, which would have a higher likelihood of a dam incident. The location of these dams is shown in Figure 4-33. Eight of these dams fall under state of Utah jurisdiction and one is under federal jurisdiction.

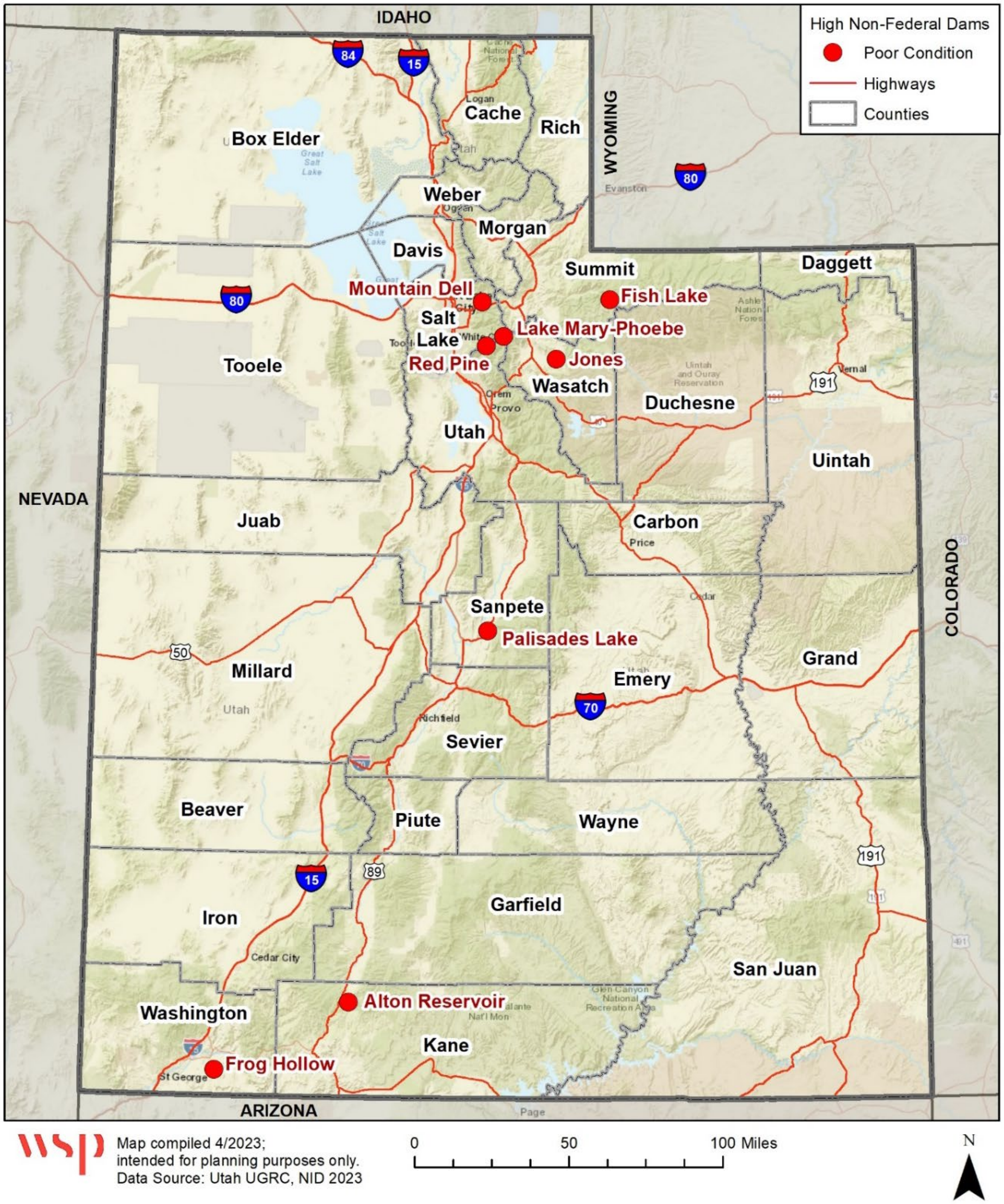
The effect of climate change on the probability of avalanche is discussed in Section 4.6.6, *Climate Change Considerations*. Discussion of the populations likely to be most severely impacted is provided in Section 4.6.8, *Potential Vulnerability of Jurisdictions*, specifically in the subsection titled *Population Impacts*.

Figure 4-32 Safety Condition Ratings of Utah's Dams



Source: National of Inventory Dams (2023)

Figure 4-33 Non-Federal, High Hazard Dams, with a safety rating of poor



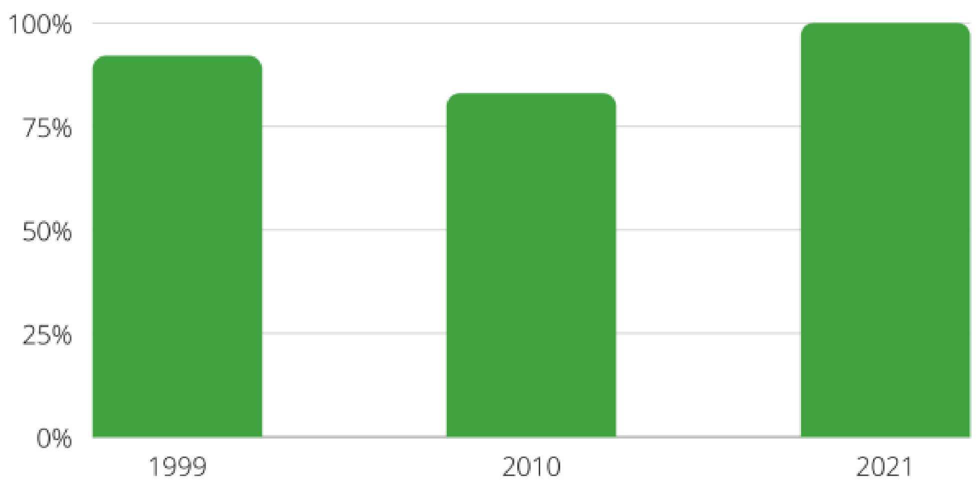
Dam Safety Inspection in Utah

Much of the previous discussion depends on the quality of the dam inspection program in Utah. Key issues are the mandate for dam inspection, how well dam inspection is funded, how well it is managed, and ultimately how reliably dams are inspected.

The Utah State Engineer has been charged with regulating non-federal dams in the State since 1919. Utah started its own Dam Safety Section in the 1970s within the State of Utah Engineers Office to administer all non-federal dams in response to the Federal Dam Safety Act. In 1990, the legislature directed the State Engineer to regulate all dams in the state, including federally owned dams, except those owned by the Bureau of Reclamation.

The frequency of dam inspection is designated based on hazard rating: The Utah Division of Water Rights inspects high-hazard dams annually, moderate hazard dams biannually, and low-hazard dams every five years. Figure 4-34 and Figure 4-35 show the efforts related to mitigating dam failure hazards throughout the state.

Figure 4-34 Percentage of State Regulated High-Hazard Potential Dam Inspections Completed



* Inspection percentages may vary above and below 100% for any given year based on a state's inspection frequency and scheduling.

Sources: Utah Division of Water Rights

Figure 4-35 Utah Dam Safety Performance Report – Utah Dam Safety Program Ratings

UT Weighted Percentage Detail	
LEGISLATION	82%
INSPECTION	84%
ENFORCEMENT	100%
EAP & RESPONSE	100%
PERMITTING	87%
EDUCATION/ TRAINING	72%
PUBLIC RELATIONS	8%
WEIGHTED %	**85%**

Overall Weighted Percentage	1989	1998	2010	2021
National Average	59%	66%	77%	80%
Utah	59%	94%	84%	85%

Sources: Utah Division of Water Rights

4.6.6 Climate Change Considerations

A recent and high-profile dam incident related to an unexpected high runoff event has raised serious concerns over the impact of climate change on dam safety. In 2017, an atmospheric river precipitation event in California dropped several inches of rain on a melting high-country snowpack that led to sudden and severe runoff. The resulting runoff nearly overtopped the Oroville Dam in northern California and did cause the spillway to fail. Concern for a catastrophic failure of the entire dam was sufficient to warrant an emergency evacuation of tens of thousands of people downstream. The 2017 Oroville Dam incident has led to increased scrutiny of the assumptions used in designing and building dams, especially in the western U.S.

More recently, evidence has mounted that climate change is making extreme weather events more frequent and more extreme. In 2022, researchers released the ARkStorm 2.0 severe storm and flood scenario (Huang and Swain, 2022). This was an update to a 2010 California statewide disaster scenario, developed using improved models and explicitly to evaluate runoff and flooding under future climate scenarios. The researchers found that climate change has already doubled the probability of an event sufficient to cause catastrophic flooding. In addition, the dynamics of a changing snow/rain regime could increase sudden runoff by another 200-400% in the future. To be clear, the ARkStorm scenario is for California, not Utah. However, the Oroville Dam and ARkStorm 2.0 developments serve to reveal a potential long-term vulnerability of dams to unexpectedly high sudden runoff caused by climatic conditions that did not exist when our dams were designed and constructed. As of 2023, no similar evaluation of future worst case scenario flooding has been conducted in the state of Utah.

The lessons of the 2017 Oroville dam incident and subsequent study of dam safety in the face of climate change amplifies the urgency for planners and other responsible officials to anticipate and mitigate the evolving risk posed by dams in a world affected by climate change. Unfortunately, this endeavor is limited by the lack of an 'ArcStorm-style' study in the state of Utah. Given the current state of understanding, the best that can be said is that climate change increases the dam incident risk in all areas. The highest-risk areas have a high concentration of both dams and people. Data provided in Figure 4-31 suggest Salt Lake, Wasatch, Cache, Weber, Morgan, and Davis counties are of elevated concern. A more nuanced view of poor-condition, high-hazard dams (Figure 4-33) in highly populated areas suggests Summit, Wasatch, and Salt Lake counties are of greatest concern.

4.6.7 Vulnerability of State Assets

Analysis of the vulnerability of state assets to dam incidents is also restricted by data availability. Ideally, the vulnerability of state assets to dam incidents would be based on the type, location, construction, height, and age of state assets as it relates to dam incident damage. These types of data are not available for state assets. In addition, data for dam incidents, specifically dam failure inundation zones, do not exist or are not available for many dams.

The 2024 plan takes a multi-tier approach to describing the vulnerability of state assets to dam incidents. First, this update provides an analysis to identify *exposure* of state assets to dam incident hazards. In essence, all state assets are identified that exist within delineated dam failure inundation zones. The first analysis does not estimate *vulnerability* of each asset or its *risk* of loss.

A second analysis provides data on recent losses from dam incidents as an indicator of the magnitude of typical loss due to this hazard. As stated above, the vulnerability of state assets to dam incidents is dependent on the type, location, construction, height, and age of state assets. However, if these qualities remain constant through time, vulnerability will also be stable[13] and recent loss will provide a measure vulnerability in the near future. This analysis is limited by the assumption that the vulnerability of state assets is slow to change and by not providing information on which specific assets are most at risk.

A third, albeit limited, analysis considers the consequence of losing state assets to a dam incident. Consequences can be difficult to predict and data to describe these consequences is commonly a problem. Nevertheless, this assessment is intended to help develop a sense of the scale and type of community-based impacts relating to dam incident.

These analyses are intended to provide key information to planners. As a starting point, these analyses serve to define the range of assets that could be lost and as an indicator of the magnitude of loss that commonly occurs from dam failure. In addition, these analyses provide information to help identify problem areas worthy of immediate attention. Finally, these analyses serve as a foundation for additional study to characterize which state assets are most vulnerable to actual loss. In particular, evaluating which insured assets accounted for the most damage would be a useful exercise, if those data are accessible.

The first analysis identified exposure of state assets to dam incidents. Updated State Facility Assets data were provided by Utah Division of Risk Management for the 2022-2023 update. Using GIS, the state facilities shapefile was overlaid with the Utah state dam failure inundation areas layer in order to determine vulnerable state-owned structures in each county. Statewide, 455 state facilities with $1.4 billion in value were found to be in dam failure inundation areas. Fully two-thirds of the exposed state-owned structure value is located within Salt Lake County. In contrast, seven counties have no state facilities in dam failure inundation areas: Beaver, Carbon, Daggett, Garfield, Kane, Morgan, Rich, San Juan, Sanpete, and Wayne counties. A key

13 It is acknowledged that vulnerability may remain stable while risk changes as exposure to hazards changes.

limitation of this analysis is the lack of delineated dam incident inundation areas for federally owned dams due to homeland security concerns, an issue discussed further in Section 4.6.8.

Table 4-19 State Owned Facilities in Dam Failure Inundation Areas for All Counties in Utah

COUNTY	COMMUNICATIONS	ENERGY	FOOD, WATER, SHELTER	HAZARDOUS MATERIAL	HEALTH AND MEDICAL	SAFETY AND SECURITY	TRANSPORTATION	TOTAL COUNT	TOTAL VALUE
Beaver	-	-	-	-	-	-	-	**0**	**$0**
Box Elder	-	-	-	-	-	5	-	**5**	**$1,552,309**
Cache	-	-	-	-	-	21	-	**21**	**$42,190,679**
Carbon	-	-	-	-	-	-	-	**0**	**$0**
Daggett	-	-	-	-	-	-	-	**0**	**$0**
Davis	-	-	-	-	-	15	-	**15**	**$112,746,986**
Duchesne	-	-	-	-	-	5	-	**5**	**$11,529,082**
Emery	-	-	-	-	-	6	-	**6**	**$2,444,000**
Garfield	-	-	-	-	-	-	-	**0**	**$0**
Grand	-	-	-	-	-	7	-	**7**	**$5,314,800**
Iron	-	-	-	-	-	35	-	**35**	**$24,071,749**
Juab	-	-	-	-	-	7	-	**7**	**$832,000**
Kane	-	-	-	-	-	-	-	**0**	**$0**
Millard	-	-	-	-	-	5	-	**5**	**$1,795,760**
Morgan	-	-	-	-	-	-	-	**0**	**$0**
Piute	-	-	-	-	-	9	-	**9**	**$1,132,074**
Rich	-	-	-	-	-	-	-	**0**	**$0**
Salt Lake	-	-	-	-	1	207	-	**208**	**$976,852,592**
San Juan	-	-	-	-	-	-	-	**0**	**$0**
Sanpete	-	-	-	-	-	-	-	**0**	**$0**
Sevier	-	-	-	-	-	39	-	**39**	**$111,605,452**
Summit	-	-	-	-	-	1	-	**1**	**$7,000,000**
Tooele	-	-	-	-	-	9	-	**9**	**$53,879,704**
Uintah	-	-	-	-	-	14	-	**14**	**$33,956,000**
Utah	-	-	-	-	3	42	-	**45**	**$28,257,425**
Wasatch	-	-	-	-	-	9	-	**9**	**$2,603,816**
Washington	-	-	-	-	-	14	-	**14**	**$27,799,542**
Wayne	-	-	-	-	-	-	-	**0**	**$0**
Weber	-	-	-	-	-	1	-	**1**	**$735,840**
Total	**0**	**0**	**0**	**0**	**4**	**451**	**0**	**455**	**$1,446,299,810**

Source: Utah, Risk Management, Utah Division of Water Rights, WSP Analysis

The State Assets were also broken out by Agency in Table 4-20. One striking vulnerability identified in Table 4-20 is that the University and Community Colleges of Utah have slightly more than half of their collective $1.4 billion in assets located within dam inundation zones. Another vulnerability in Table 4-20 is that 70 of 156 state-owned correctional facility assets are inside dam failure inundation zone. This is the second greatest value at risk to dam inundation of any agency. The State Asset Database developed for this ESHMP update contains additional information on each asset such as the address and building identifier and can be referenced with Utah DEM.

The potential consequence of losing assets related to the university system and the correctional system from a dam incident are very different. Immediate impacts to the university system are likely related to community safety and security. Additional impacts would likely cascade from a major dam incident, such as the loss of access to food, water, and shelter, and healthcare. Power, communications, and transportation infrastructure also may be impacted, especially on the university properties in the path of a dam incident.

Correctional facilities face a different set of consequences, especially to the Safety and Security lifeline. If advance warnings of a dam incident are provided, complex issues face evacuation of correctional facilities. Additionally, by design people are literally trapped and unable to move to safety during a dam incident. Administering aid to correctional facilities in the aftermath of a dam incident is similarly complex. Verifying specifically if incarceration facilities are at risk and if evacuation plans exist and are practiced is an information gap as of this ESHMP update.

The effect of climate change on state asset vulnerability deserves consideration. Recent experiences with climate-change driven atmospheric rivers and rain-on-snow events have created unprecedented rates of runoff. These factors triggered the Oroville dam incident and near-failure and prompted the state of California to investigate the effects of climate change on dam safety (see section 4.6.6 *Climate Change Considerations*). As yet, no similar evaluation of the effects of climate change on dam safety have been done in Utah. At best, a qualitative statement can be made that projected changes in rain on snow events and large precipitation events such as from atmospheric rivers likely increase the risk of dam incidents in coming decades by an unknown degree. This elevates the vulnerability of state assets accordingly.

Table 4-20 State Owned Facilities in Dam Failure Inundation Areas by Agency

AGENCY	COMMUNICATIONS	ENERGY	FOOD, WATER, SHELTER	HAZARDOUS MATERIAL	HEALTH AND MEDICAL	SAFETY AND SECURITY	TRANSPORTATION	TOTAL COUNT	TOTAL VALUE
Administrative Services – Facilities (DFCM)	-	-	-	-	-	28	-	**28**	**$204,097,223**
Alcoholic Beverage Control	-	-	-	-	-	1	-	**1**	**$31,105,000**
Corrections – Utah State Prison	-	-	-	-	-	69	-	**69**	**$264,446,478**
Corrections AP & P	-	-	-	-	-	1	-	**1**	**$11,964,600**
Courts	-	-	-	-	-	1	-	**1**	**$9,916,000**

AGENCY	COMMUNICATIONS	ENERGY	FOOD, WATER, SHELTER	HAZARDOUS MATERIAL	HEALTH AND MEDICAL	SAFETY AND SECURITY	TRANSPORTATION	TOTAL COUNT	TOTAL VALUE
Environmental Quality Department	-	-	-	-	-	4	-	**4**	**$224,000**
Health Department	-	-	-	-	-	1	-	**1**	**$90,000**
Human Services – Juvenile Justice Services	-	-	-	-	-	7	-	**7**	**$24,839,000**
Human Services – State Hospital	-	-	-	-	3	-	-	**3**	**$57,740**
Human Services Department	-	-	-	-	-	6	-	**6**	**$4,037,140**
National Guard	-	-	-	-	-	18	-	**18**	**$18,709,300**
Natural Resources – Forestry, Fire & State Lands	-	-	-	-	-	10	-	**10**	**$4,216,000**
Natural Resources – Parks & Recreation	-	-	-	-	-	80	-	**80**	**$15,000,373**
Natural Resources – Wildlife Resources	-	-	-	-	-	21	-	**21**	**$10,727,600**
Salt Lake Community College	-	-	-	-	-	12	-	**12**	**$199,570,000**
Snow College	-	-	-	-	-	4	-	**4**	**$76,126,000**
Southern Utah University	-	-	-	-	-	5	-	**5**	**$3,944,297**
Tooele Technical College	-	-	-	-	-	2	-	**2**	**$21,302,300**
Transportation (UDOT)	-	-	-	-	-	67	-	**67**	**$37,464,509**
Uintah Basin Technical College	-	-	-	-	-	5	-	**5**	**$29,151,000**
University Of Utah	-	-	-	-	-	88	-	**88**	**$381,468,677**
Utah State University	-	-	-	-	-	21	-	**21**	**$78,157,573**
Veterans Affairs	-	-	-	-	1	-	-	**1**	**$19,685,000**
Total	**0**	**0**	**0**	**0**	**4**	**451**	**0**	**455**	**$1,446,299,810**

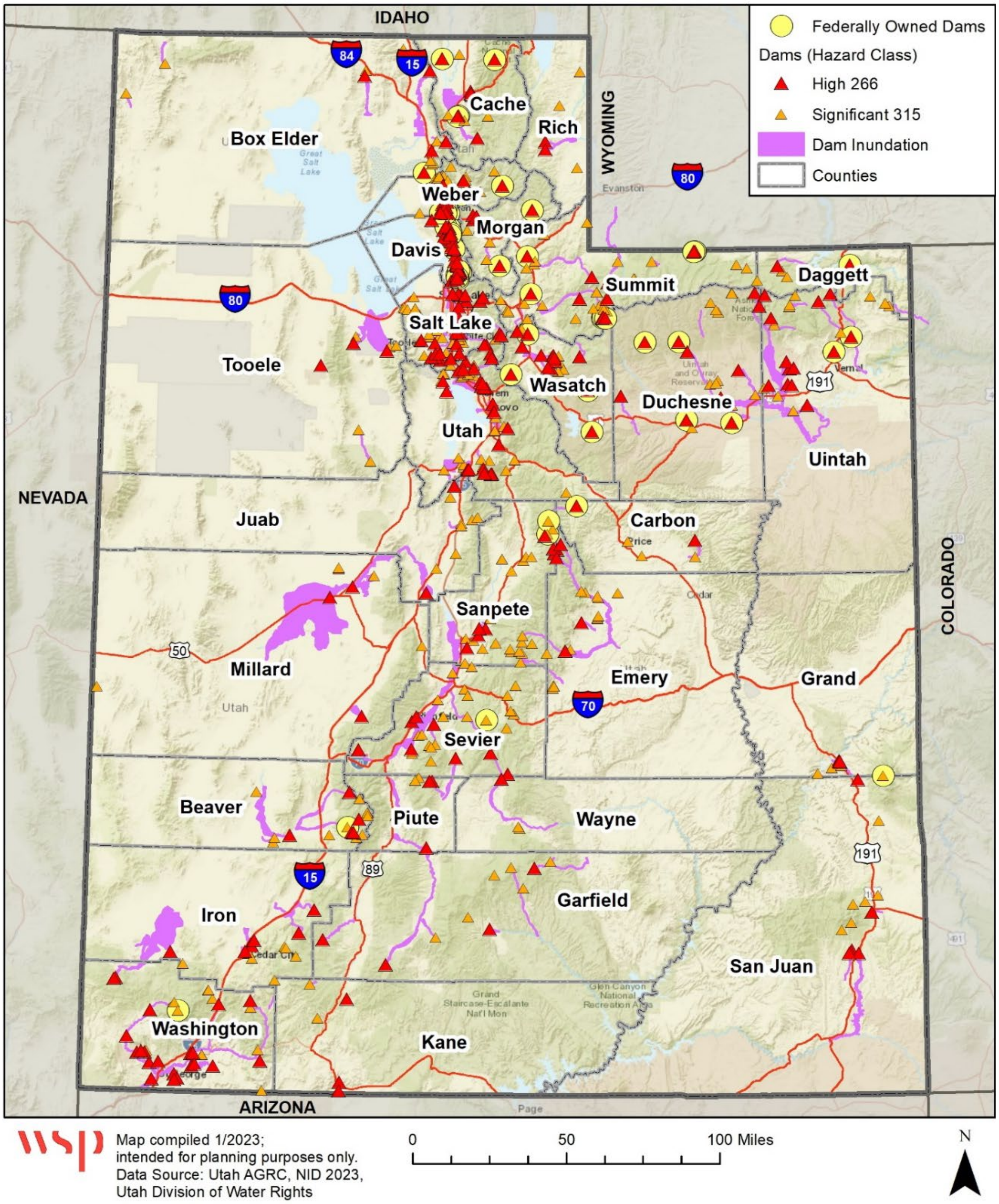
Source: Utah, Risk Management, Utah Division of Water Rights, WSP Analysis

4.6.8 Potential Vulnerability of Jurisdictions

Figure 4-36Figure 4-36 shows the locations of all high-hazard and significant-hazard dams in Utah and inundation areas, where available. Eighty-one Federally owned dams rated as having a high hazard or significant hazard potential are indicated in the figure with yellow circles.

Dam-failure inundation areas are indicated as pink areas and are relatively few compared to the number of dams on the map. This is because dam inundation areas often have not been delineated or, in the case of any Federally operated dam, are not readily available. Planners are often left to infer where high hazard areas exist. Where inundation areas have been delineated, the impacts have not, which is one of the data limitations. One approach to overcoming this limitation is increasing digital inundation modelling and mapping as methods become more automated and affordable. Therefore, the state of knowledge regarding dam failure inundation is the areas of exposure and *potential impact*. Individual EAPs often have better inundation information on a case-by-case basis.

Figure 4-36 Potential Dam Inundation Areas and Federally Owned Dams



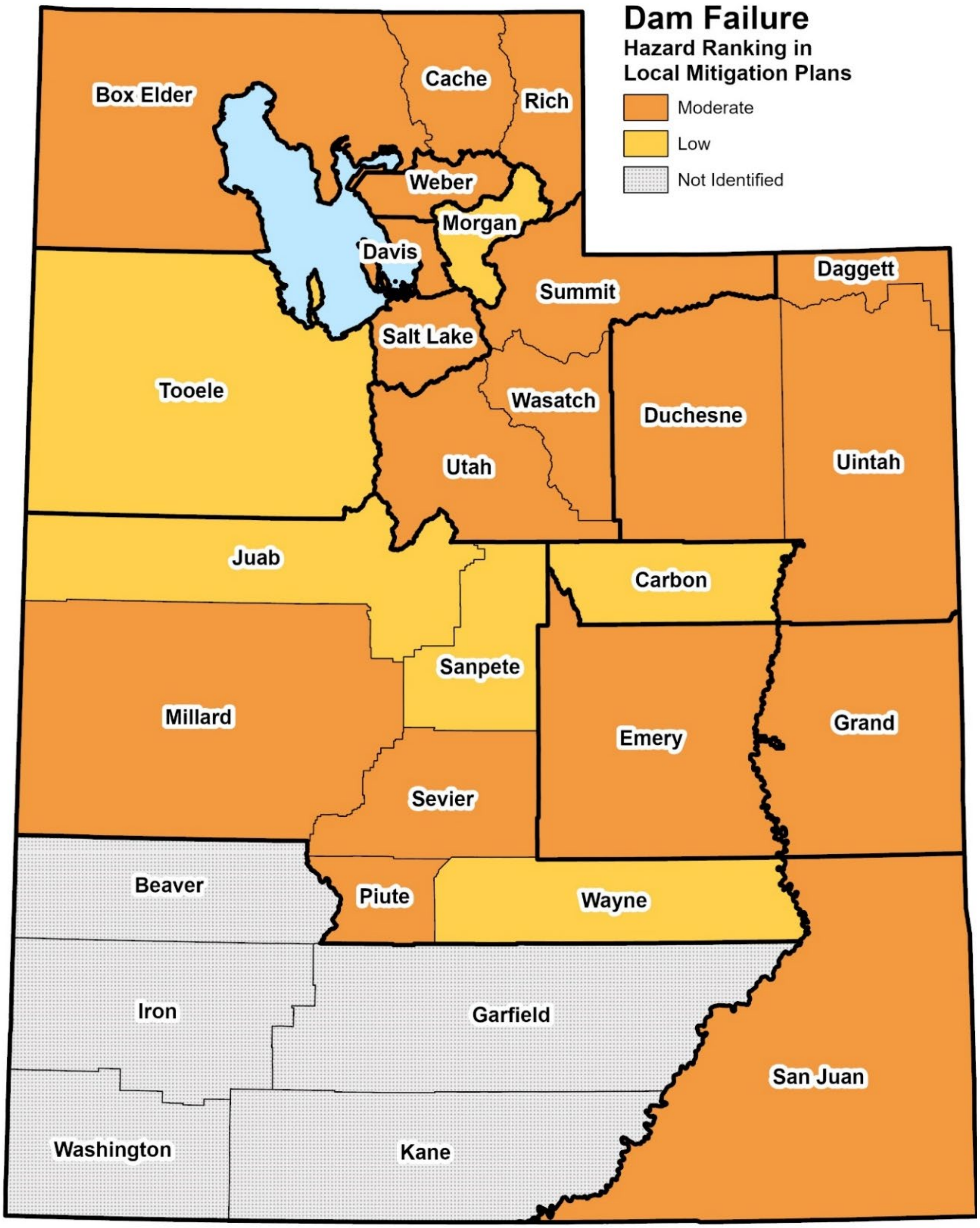
National Risk Index Assessment

The FEMA NRI does not address dam incidents.

Local Hazard Mitigation Plan Assessment

A map was created that shows the hazard ranking for dam failure regarding each county as reported in the LHMPs. The hazard ranking is calculated from low to moderate with counties in grey not having ranked dam failure in their previous LHMP. Based on the reporting in LHMPs, several counties in Utah reported dam failure as a moderate or low hazard risk. The counties in southwest Utah are shown as being "not identified". Figure 4-37 below shows the county ranking from the LHMP's regarding dam failure as a hazard.

Figure 4-37 Dam Failure Rankings from LHMPs



Source: Bear River AOG 2021, Carbon 2018, Davis 2022, Emery 2018, Five County AOG 2022, Grand 2018, Mountainland AOG 2022, Morgan 2022, San Juan 2018, Six County AOG 2021, Salt Lake 2020, Tooele 2022, Uintah Basin 2019, and Weber 2016.

Population Impacts

The impact of dam failure hazards on people in Utah is similar to riverine flooding, but the potential magnitude and sudden onset of flooding can be especially catastrophic. Impacts range from death and physical harm to displacement and property damage to inconvenience. Road closures, road congestion, and possible loss of services such as water supply and wastewater are possible.

Vulnerable populations will experience impacts more severely and tools such as Social Vulnerability Index have been developed to describe the characteristics and location of vulnerable persons (Section 3.5.1). Counties with elevated dam incident hazards (Figure 4-37Figure 4-37) and high social vulnerability (Figure 3.6, and 3.7) are most likely to experience impacts most severely. San Juan, Washington and Piute Counties are the greatest concern in this regard, while persons in Grand County are of marginally lower concern. Regardless of county, unhoused persons commonly take refuge in undeveloped floodplain areas. This puts this population at particularly high risk by being both more likely to be exposed and more vulnerable to impacts, as well as less likely to receive alerts and warning during an incident.

While evaluating state assets at risk to dam incident inundation, it also became apparent that substantial state correctional facility assets are exposed to the dam failure hazard; 70 of 156 state-owned correctional facility assets are inside dam failure inundation zones. It is unclear how many of these assets house inmates or how many more non-state-owned jail facilities may be exposed. The issue is worthy of additional consideration as a vulnerable population that may have limited or complex evacuation options.

Additional study at state and local levels will very likely enable better hazard mitigation for vulnerable populations. The state-level analysis in this section is useful to identify counties that are likely at increased risk from dam incidents. However, additional local analysis can provide far more actionable information, such as *why* these counties are at risk and *how* to mitigate those vulnerabilities. In addition, local analyses are able to evaluate much finer scales, such as which populations within the county are most vulnerable, and how to mitigate risk for those populations. As LHMPs evolve to be more inclusive of all-dam risks there could be more population and social vulnerability analysis to roll up into future ESHMP updates. Thus, the role of the state-level vulnerability analysis will expand to verifying that local level analyses appropriately evaluate vulnerabilities and possibly to facilitating such analysis.

Community Lifelines and Infrastructure/Risk to Dams

In the aftermath of a dam incident, such as a high-hazard dam failure, any and possibly all community lifelines will be impacted. The immediate concern is for safety and security of people in inundation areas. It is reasonable to expect that access to food, water, and shelter, as well as healthcare will be compromised for many people. Dam failures are notoriously destructive and impacts to above-ground power distribution, if not generation, can be expected. The same can be said for transportation, especially due to damaged roadways and railways. Cellular communications may fare better. Inundation zones are relatively narrow and elongated and unaffected transmission towers may be able to service inundated areas. The release of hazardous materials is an area of uncertainty. What does seem certain is widespread impact. Articulating precisely what these impacts mean and how to mitigate them is a difficult to fill knowledge gap.

A special concern of dam safety is not only the safety of dams to the community, but the safety of dams themselves to other hazards or to the failure of upstream dams. Floods, earthquake ground shaking, surface faulting, and landslides all pose a concern for causing a dam incident. A GIS overlay analysis of the 266 high hazard dams and these hazards was conducted during the update of this plan. Of note are 63 of the high hazard dams are within very strong/severe ground shaking hazards and 94 are within severe/violent ground shaking. Most of these dams are located in Davis, Salt Lake and Weber counties. A total of 39 high hazard dams are located with 1% annual chance flood hazard zones. Eleven (11) dams are within high severity landslide areas, and another 25 within moderate severity landslide hazard areas. Thirty-eight (38) were found to be within surface fault rupture hazard areas. The specific dams with risk details, including location by county and downstream city, can be found in Appendix F.

Over time, dams have been constructed with gradually improving safety standards and construction practices. Regulatory oversight and record keeping has improved over time. Older dams are also more likely to be nearing or exceeding their designed lifespan. Inventorying dams 50-years and 100-years in age provides a measure of vulnerability of dams to other hazards. Figure 4-31 identifies dams over 50 and 100 years old.

4.6.9 Changes in Development

Development affects the dam incident hazard in two ways. First, new dams are being designed and constructed. As of 2018, there are four high hazard dams and four moderate hazard dams in Utah being planned or designed: the Garley Canyon, Hurricane Cliffs, Toquer (Anderson Junction), and Warner Valley dams. Three of these high hazard dams are in Washington County, which is one of the most populous and fastest growing counties in Utah. The other high hazard dam being planned is in Carbon County. One moderate hazard dam is under construction as of 2018, the Northside Creek Dam in Morgan County. An analysis of development trends in LHMPs (see Section 3.7 Development Trends) did not yield much in the way of specific concerns with dam incidents, and this is potentially an area to expand upon further as LHMPs address all-dam risks in order to me High Hazard Potential Dam planning and grant requirements.

A second way development affects the dam incident hazard is indirect. Utah is one of the fastest growing states in the country. As the population grows and shifts, situations arise where development in areas downstream from dams causes the hazard potential for some dams to increase, for example from a significant hazard to high hazard. The numbers of high-hazard dams should be tracked over time to determine if this is a potential trend. The issue of development in dam inundation areas has not been well researched. This is possibly due to the lack of delineated inundation areas. As data availability improves this situation may improve in the future.