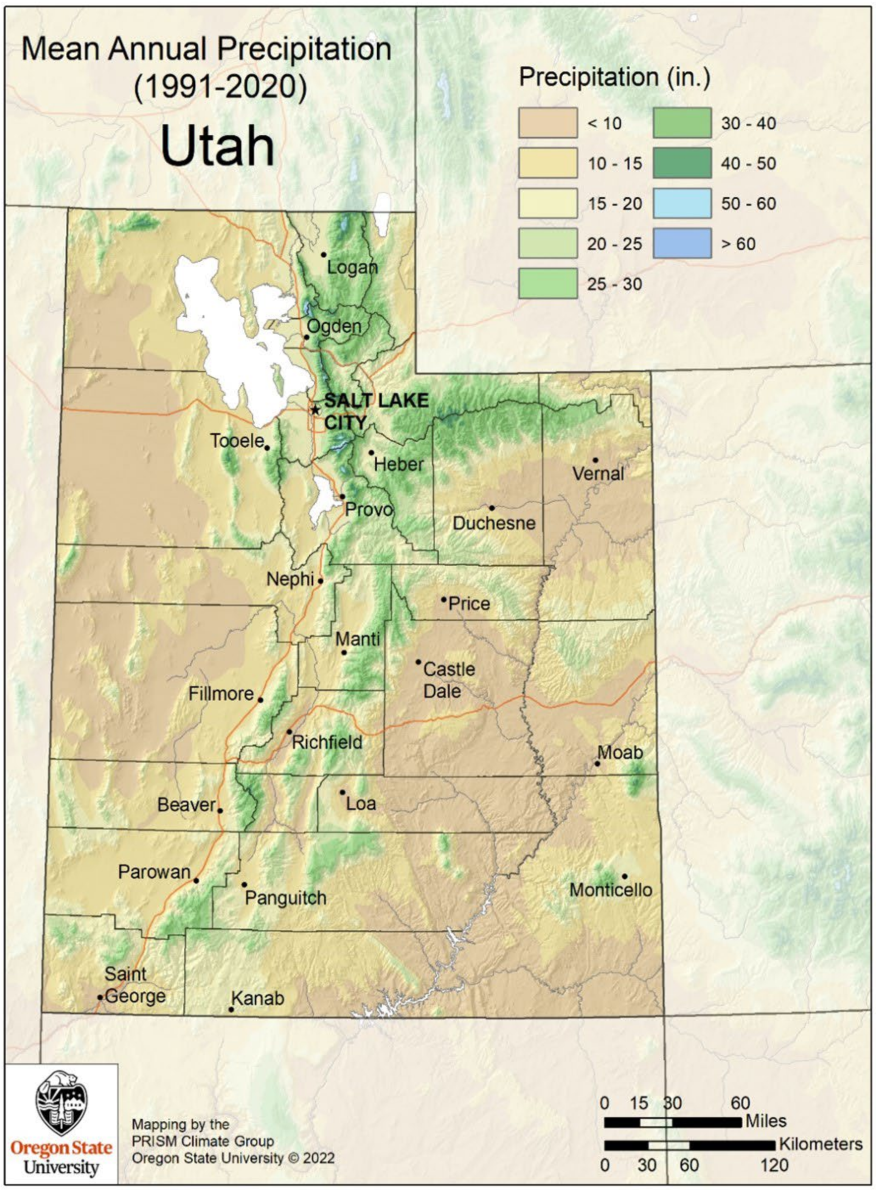
4.7 DROUGHT

4.7.1 Description

Utah is an arid climate with the average annual precipitation near or below 10 inches in the western and eastern sides of the state (Figure 4-38Figure 4-38). The majority of the precipitation falls at higher elevations. The net result is that life in most of Utah has developed either near the edge of what is possible with existing water supplies or has grown dependent on augmented water supplies in some fashion.

Figure 4-38 Average precipitation map of Utah



Source: Map created 8/1/2023, PRISM Climate Group, copyright © 2023, Oregon State University, https://prism.oregonstate.edu.

Aridity should not be confused with drought. Drought describes conditions that are *unusually* dry for an *unusual* length of time, relative to '*normal*.' However, when normal conditions barely support life as we know it, drought can have a particularly harsh impact.

Drought has financial costs. Costs can be direct, such as increasing the amount of water that must be purchased to irrigate crops and livestock. Costs can also be indirect, such as by increasing the extent of wildfire and exposing people to hazardous levels of smoke. Often, the indirect costs of drought can be far greater than direct costs.

Trends in drought and precipitation continue to be areas of intense research and general interest. Concerns range from short term drought conditions to the long-term decline in 'normal' precipitation caused by climate change. At the same time, Utah is one of the fastest growing states in the U.S. This has put strain on local water management and has increased the risk of drought.

All drought is caused by a deficiency of precipitation over an extended period of time. Defining what drought means depends largely on one's perspective. A farmer likely has a very different view of drought than a fisheries biologist, a reservoir manager or a recreational skier. In addition, the effects of a lack of precipitation evolve over time. Various definitions of drought have been developed that are sensitive to these various perspectives.

Meteorological drought describes a physical lack of moisture. It is characterized by a divergence of precipitation from the long-term average precipitation over a given length of time. The measurement of meteorological drought that include causation like evaporation are determined through indices such as the Standardized Precipitation Evapotranspiration Index (SPEI) and the Evaporative Demand Drought Index (EDDI).

Hydrologic drought describes how a meteorological drought affects the physical availability of water in streams, lakes, reservoirs, soils, snowpack, and groundwater. Hydrologic drought conditions are also expressed as the deviation from normal or long-term averages. This approach provides a more nuanced definition of drought and is arguably more useful for water managers in regions such as Utah that depend on winter snowpack and reservoir storage.

Agricultural drought describes how meteorological drought and hydrologic drought affect the agricultural sector. Soil water deficiency, which stresses crops and plants, is a key factor that determines agricultural drought. Dry farms can be especially vulnerable to agricultural drought, while impacts to irrigated farms can hopefully be limited to increased irrigation costs. Longer duration droughts have an increased impact on agriculture by affecting plant life cycles and vegetation health.

Socioeconomic drought occurs when a shortfall in water supply causes a shortage of an economic good. For example, if precipitation is low enough, reservoir levels may decline to a point where generation of hydropower is not possible. Snowpack being insufficient to support a good ski season is another example of a socioeconomic drought.

Drought Indices

Drought is typically quantified using indices that statistically compare present and recent conditions with a long-term average condition. These indices utilize various climatological, meteorological, and hydrological parameters to develop a relationship between instrumental measurements and drought. Drought indices are especially relevant to the Utah HMP, as they are used to trigger the state Drought Response Plan and also by the USDA to declare droughts as disasters and activate many Federal mitigation programs. The U.S. Drought Monitor regularly publishes notable and widely used drought severity maps that are curated by a team of drought professionals using all available information and severity ratings (Table 4-21). U.S. Drought Monitor ratings are based on a convergence of evidence, rather than on a defined set of variables, and the various ratings are defined in the table below.

Table 4-21 U.S. Drought Monitor drought classifications

Category	Description	Possible Impacts
D0	Abnormally Dry	Going into drought: • short-term dryness slowing planting, growth of crops or pastures Coming out of drought: • some lingering water deficits • pastures or crops not fully recovered
D1	Moderate Drought	• Some damage to crops, pastures • Streams, reservoirs, or wells low, some water shortages developing or imminent • Voluntary water-use restrictions requested
D2	Severe Drought	• Crop or pasture losses likely • Water shortages common • Water restrictions imposed
D3	Extreme Drought	• Major crop/pasture losses • Widespread water shortages or restrictions
D4	Exceptional Drought	• Exceptional and widespread crop/pasture losses • Shortages of water in reservoirs, streams, and wells creating water emergencies

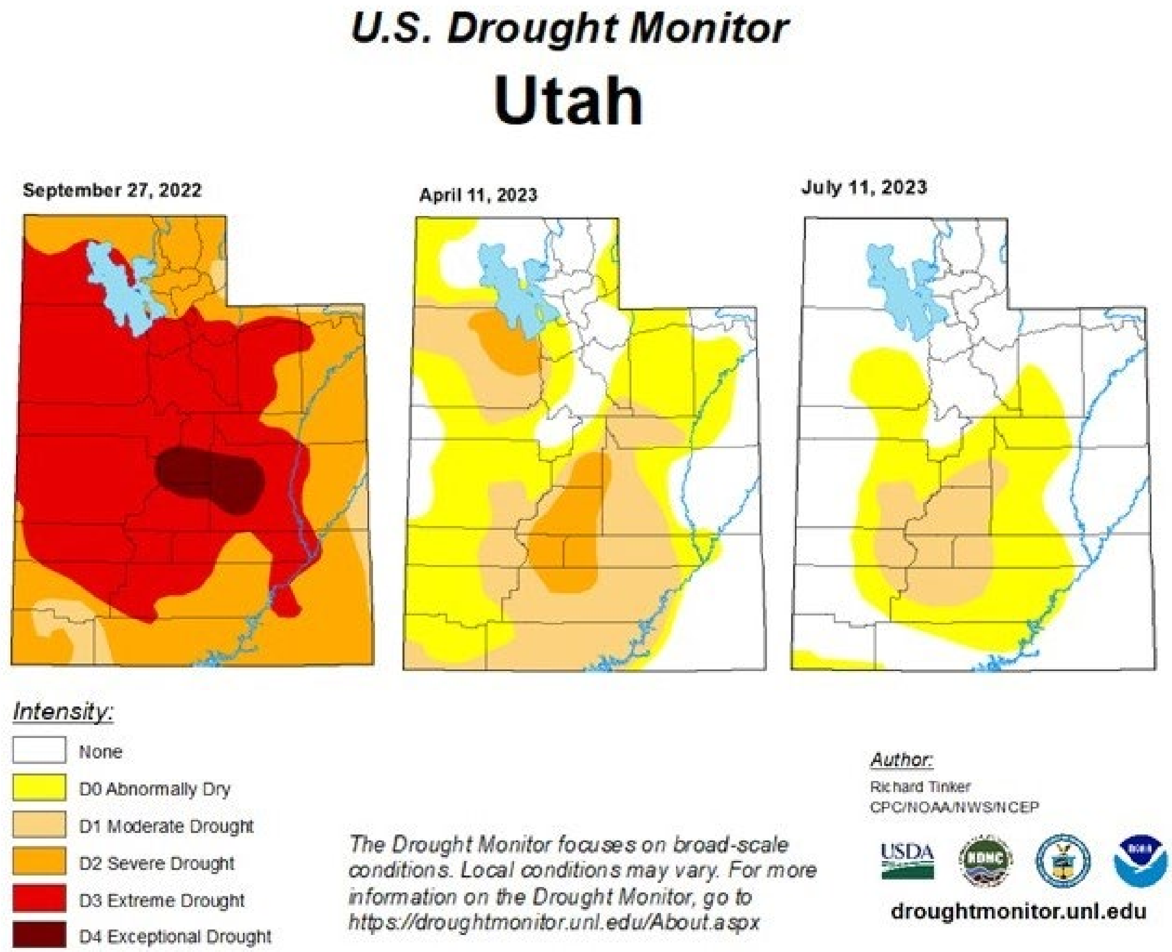
Source: Table modified from Northeast Regional Climate Center, https://www.nrcc.cornell.edu/services/blog/2018/06/28/index.html

4.7.2 Geographic Area

Over the long term, drought is experienced everywhere. Periods of unusually low precipitation, meteorological drought, will occur regardless of the location. All locations experience below average precipitation 50% of the time and the bottom decile of precipitation 10% of the time. In other words, a map of long-term drought frequency will tend to show homogenous drought conditions; it is not 'dryness' that defines drought, it is how *unusual* that dryness is for a particular location.

However, over short time scales, drought is often dramatically variable over an area the size of Utah. Likewise, any given location can experience dramatically different drought conditions over a relatively short number of months. Figure 4-39 shows drought conditions in Utah on specific dates and illustrates the potential for drought variability over space and time.

Figure 4-39. Drought Conditions in Utah, 2022-2023



4.7.3 Extent and Magnitude

Understanding the severity of drought and its impacts in Utah helps planners characterize the severity of the drought hazard. It also helps planners prioritize drought mitigation relative to mitigating other hazards and needs.

One of the best attributes of the U.S. Drought Monitor products is the connection between their ratings, D0-D4, and real-world impacts. Table 4-21 provides the U.S. Drought Monitor's official descriptions of drought categories. In lay-person terms, D4 Exceptional Drought serves as an apt description of what 'bad' means with regard to drought. The historical frequency of these drought categories in Utah is described below in the section titled, "Past Events, 1895 - present." Figure 4-39 shows drought conditions in Utah that range from D2 to D4 across the entire state as recently as 2022.

The National Drought Mitigation Center categorizes impacts related to drought and provides an additional description of drought impacts in various contexts. These categories are as follows:

- **Agriculture** - Drought effects associated with agriculture, farming, aquaculture, horticulture, forestry, or ranching. Examples of drought-induced agricultural impacts include damage to crop quality; income loss for farmers due to reduced crop yields; reduced productivity of cropland; insect infestation; plant disease; increased irrigation costs; cost of new or supplemental water resource development (wells, dams, pipelines) for agriculture; reduced productivity of rangeland; forced reduction of foundation stock; closure/limitation of public lands to grazing; high cost or unavailability of water for livestock, Christmas tree farms, forestry, raising domesticated horses, bees, fish, shellfish or horticulture.

- **Business & Industry** - This category tracks drought's effects on non-agriculture and non-tourism businesses, such as lawn care, recreational vehicles or gear dealers, and plant nurseries. Typical impacts include reduction or loss of demand for goods or services, reduction in employment, variation in number of calls for service, late opening or early closure for the season, bankruptcy, permanent store closure, and other economic impacts.
- **Energy** - This category concerns drought's effects on power production, rates, and revenue. Examples include production changes for both hydropower and non-hydropower providers, changes in electricity rates, revenue shortfalls and/or windfall profits, and purchase of electricity when hydropower generation is down.
- **Fire** - Drought often contributes to forest, range, rural, or urban fires, fire danger, and burning restrictions. Specific impacts include enacting or easing burning restrictions, fireworks bans, increased fire risk, occurrence of fire (number of acres burned, number of wildland fires compared to average, people displaced, etc.), state of emergency during periods of high fire danger, closure of roads or land due to fire occurrence or risk, and expenses to state and county governments of paying firefighters overtime and paying equipment (helicopter) costs.
- **Plants & Wildlife** - Drought effects associated with unmanaged plants and wildlife, both aquatic and terrestrial, include loss of biodiversity of plants or wildlife; loss of trees from rural or urban landscapes, shelterbelts, or wooded conservation areas; reduction and degradation of fish and wildlife habitat; lack of feed and drinking water; greater mortality due to increased contact with agricultural producers, as animals seek food from farms and producers are less tolerant of the intrusion; disease; increased vulnerability to predation (from species concentrated near water); migration and concentration (loss of wildlife in some areas and too much wildlife in others); increased stress on endangered species; salinity levels affecting wildlife; wildlife encroaching into urban areas; and loss of wetlands.
- **Society & Public Health** - Drought effects associated with human, public and social health include health-related problems related to reduced water quantity and/or quality, such as increased concentration of contaminants; loss of human life (e.g. from heat stress, suicide); increased respiratory ailments; increased disease caused by wildland fire concentrations; increased human disease caused by changes in insect carrier populations; population migration (rural to urban areas, migrants into the United States); loss of aesthetic values; change in daily activities (non-recreational, like putting a bucket in the shower to catch water); elevated stress levels; meetings to discuss drought; communities creating drought plans; lawmakers altering penalties for violation of water restrictions; demand for higher water rates; cultural/historical discoveries form low water levels; prayer meetings; cancellations of fundraising events; cancellation/alteration of festivals or holiday traditions; stockpiling water; public service announcements and drought information websites; protests; and conflicts within the community due to competition for water.
- **Tourism & Recreation** - Drought effects associated with recreational activities and tourism include closure of state hiking trails and hunting areas due to fire danger; water access or navigation problems for recreation; bans on recreational activities; reduced license, permit, or ticket sales (e.g. hunting, fishing, ski lifts, etc.); losses related to curtailed activities (e.g. bird

watching, hunting and fishing, boating, rafting, etc.); reduced park visitation; and cancellation or postponement of sporting events.

- **Water Supply & Quality** - Drought effects associated with water supply and water quality include dry wells, voluntary and mandatory water restrictions, changes in water rates, easing of water restrictions, increases in requests for new well permits, changes in water use due to water restrictions, greater water demand, decreases in water allocation or allotments, installation or alteration of water pumps or water intakes, changes to allowable water contaminants, water line damage or repairs due to drought stress, drinking water turbidity, change in water color or odor, declaration of drought watches or warnings, and mitigation activities.

4.7.4 Past Occurrences

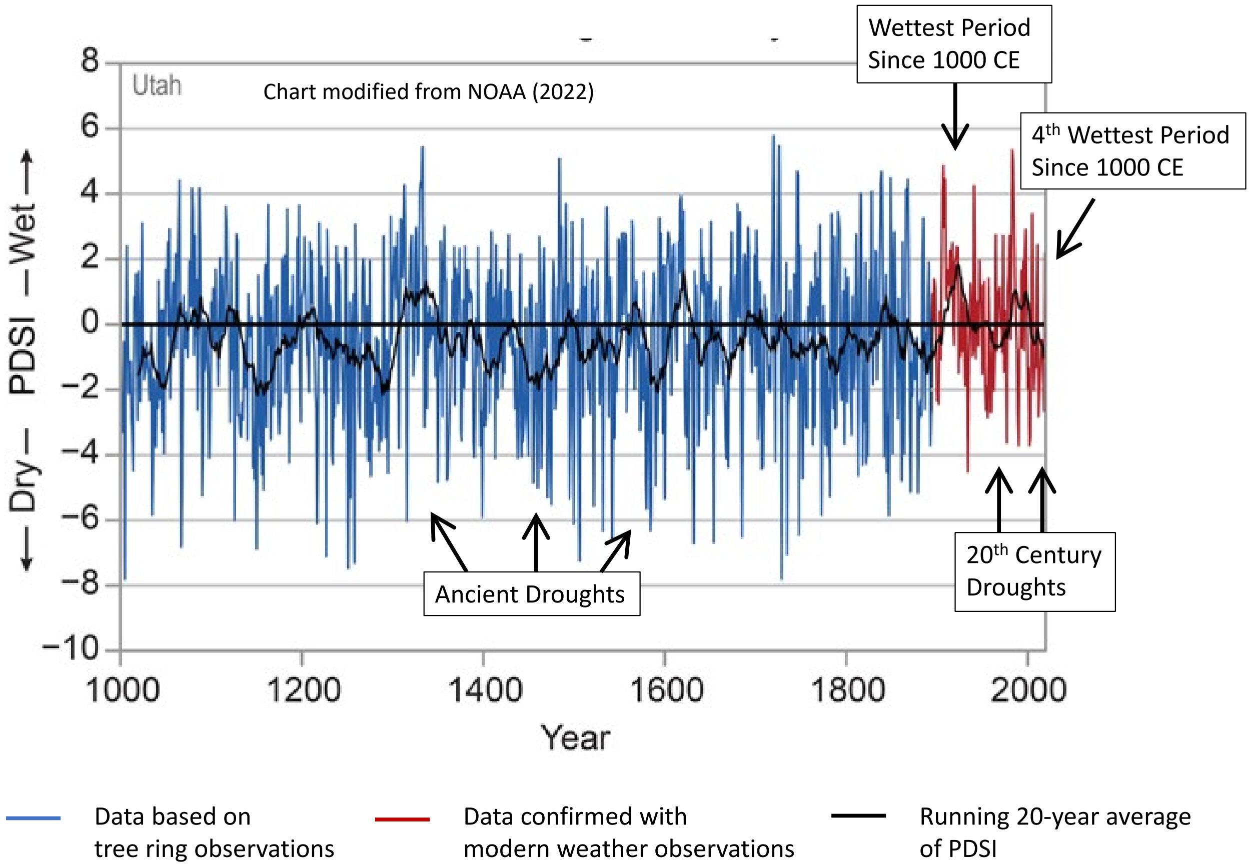
Evaluating past occurrences of drought helps build an appreciation for how drought has affected Utah in modern times and places our modern experience into context with the full historical variability of the drought hazard. This exercise is useful to develop a sense of what the future drought hazard may be and how it may affect Utah. This analysis also provides planners with a basis for designing and implementing drought mitigating strategies. To this end, we divide our analysis into pre-settlement times and the past 100-125 years for which formal weather records are available. All of this comes with the important caveat that climate change is a phenomenon that expands the drought hazard beyond past occurrences, this is addressed in Section 4.7.6, "Climate Change Considerations."

Past Events, 1000 CE - 1895

Well-cited academic studies using tree-ring analysis to evaluate pre-historic hydrologic conditions in northern Utah provide an ominous view of the potential severity for drought. Allen et al. (2013) reconstructed Logan River conditions from 1605 to present and found streamflow was more variable in ancient times, before instrumented records began in 1921. A follow-up study by the same research group confirmed the existence of more severe droughts and wet periods occurring in ancient times for the Weber River (Bekker et al., 2014).

These researchers extended their analysis to the past 1,200 years for the Bear River of northern Utah (DeRose et al., 2015) and NOAA's 2022 State Climate Summary for Utah summarizes state-wide drought conditions since 1,000 CE (Figure 4-40; NOAA, 2022). The last half of the 20th century was the second wettest period in the analysis and that a 70-year drought occurred in the mid-1200s CE. Taken together, these and other studies suggest the natural variability of the hydrologic system may be much greater than planners have accounted for in the past.

Figure 4-40. Historical Drought in Utah, 1,000 CE to Present



Past Events, 1895 - present

The past 100-125 years of weather record-keeping has enabled us to develop a relatively detailed understanding of drought patterns over this time. For example, an analysis of drought conditions since 1895 was completed for Utah's seven climate divisions (Figure 4-41) and is provided in Figure 4-42. The shaded areas in Figure 4-42 signify the existence of multi-year droughts, defined as two consecutive years of annual average PDSI values less than or equal to -1.0; and second, a drought was considered to have ended with two consecutive years of near or above normal conditions (annual average PDSI value greater than -0.5).

At times, drought may affect the entire state of Utah to varying degrees. Figure 4-43 shows the severity and extent of drought as a proportion of the total area of Utah since 2000. Table 4-22 documents multi-year, state-wide droughts in Utah since 1898 and describes their impacts.

Figure 4-41. Climate divisions in Utah

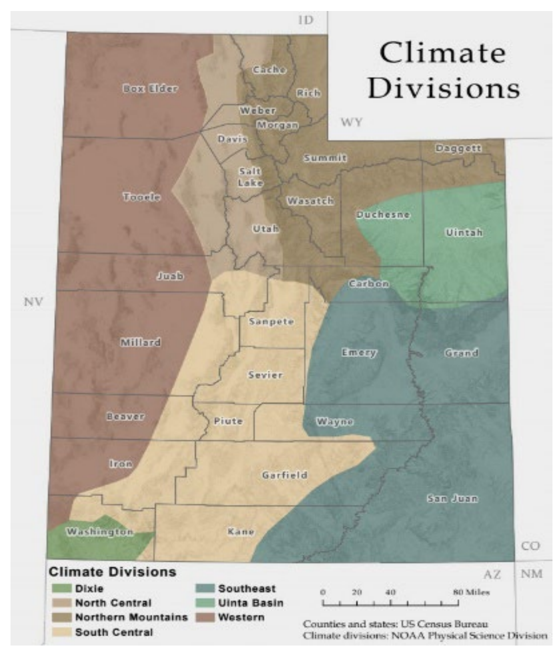
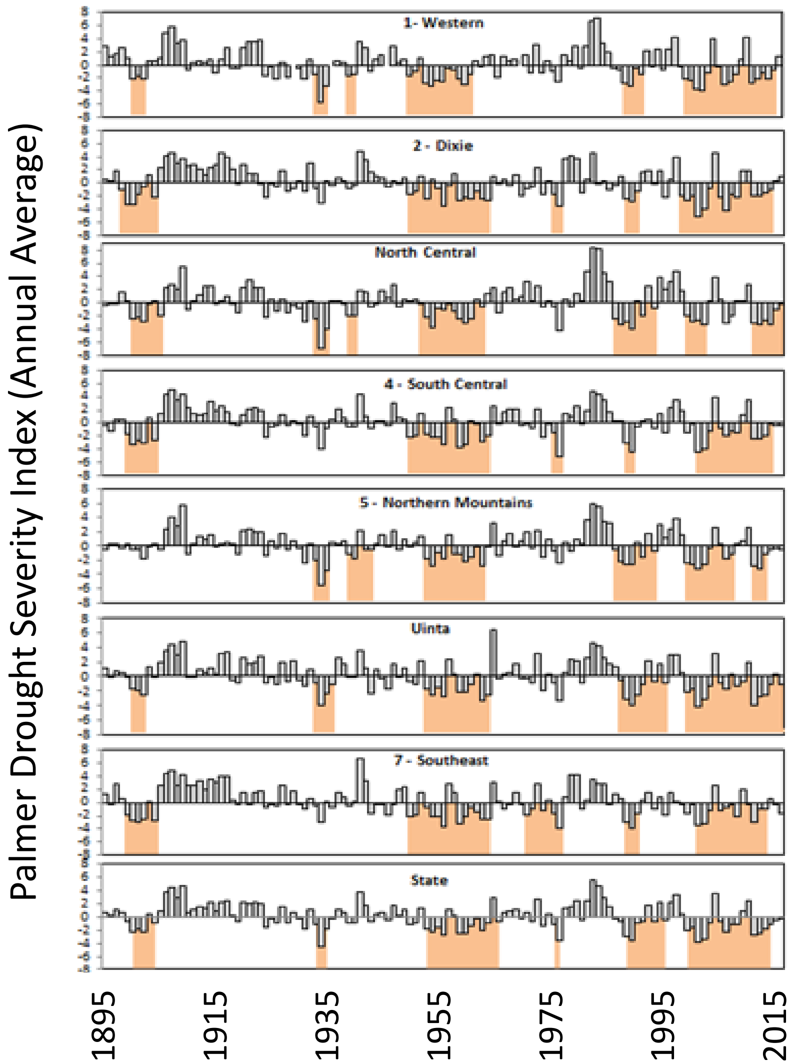


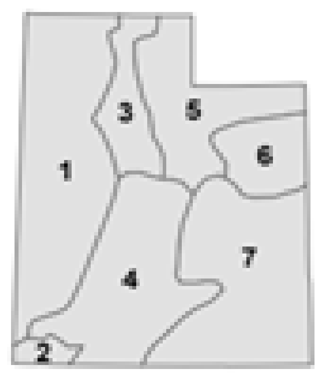
Image modified from Rangeland Resources of Utah – 2009 Revision

Figure 4-42 Drought Severity by Climate Division, 1895-2017



Shaded areas denote multi-year droughts

Climate Divisions: Numbers correspond with graphs at left.



Also see Figure 4.

Figure 4-43 Percent of Utah in Drought, 1/2000 – 1/2023

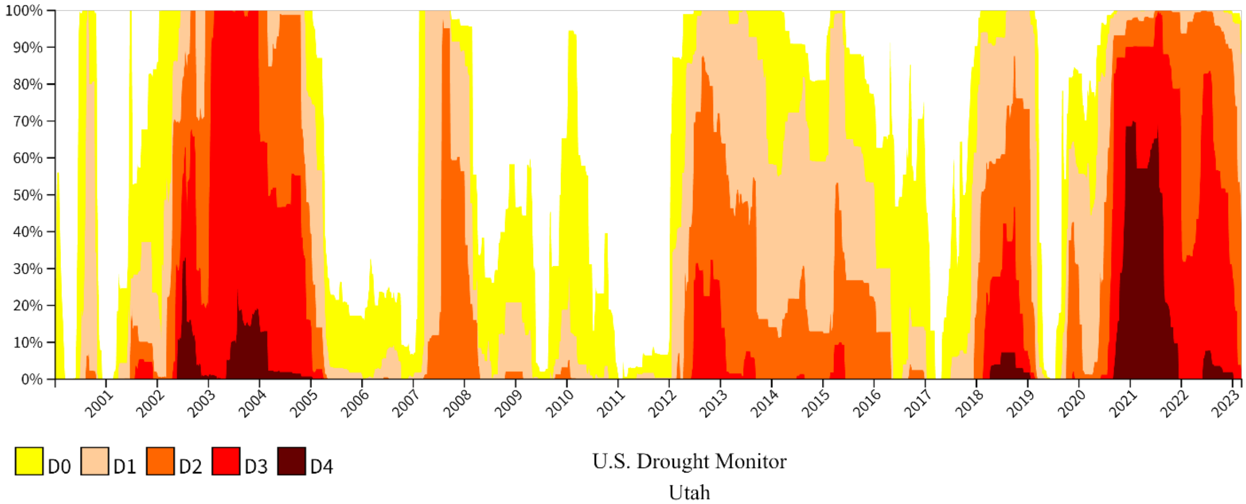


Table 4-22. Multi-year droughts in Utah, 1898-2023.

1898 – 1905: Large cattle operations folded, leaving small operations to fight over what was left of adequate grazing lands. The drought forced settlers to uproot their families as lands were drying up and water rights were inadequate.

1933 – 1943: The "Dust Bowl Years" affected approximately 75% of Utah. Agriculture productivity decreased to almost half of prior years' production and the number of farms significantly decreased.

1950 – 1966: Multiple areas within Utah were declared disaster areas. Statewide, impacts were lessened due to steps taken to enhance the water supply.

1971 – 1977: Conditions in seven of Utah's counties prompted the Governor to request Federal Disaster Declarations for these counties. By the end of 1977, the State lost $41 million ($70 million in 2023 dollars) due to the drought impacts.

1988 – 1993: This drought produced some of the hottest years and driest years on record. Statewide reservoir capacity plunged below 50% at times and farmers and ranchers struggled to continue operations.

1999 – 2006: The longest duration of drought in Utah lasted 288 weeks beginning on April 3, 2001, and ending on October 3, 2006.

2012 – 2016: Persistent hot and dry conditions led to low snowpacks and allowed for moderate to severe drought to persist, resulting in years ranked in the top third driest for the state. Utah's drought conditions reached a threshold that triggered the State's statutory responsibility to convene Utah's Drought Review and Reporting Committee.

2019 – 2023: Utah experiences a statewide record for dryness and warmth. The driest year on record was 2020, and by the end of the year, 90% of the state was in extreme or exceptional drought. Dry conditions since 2000 have resulted in record-low water levels in the Great Salt Lake. The most intense period of drought since 2000 occurred the week of January 26, 2021, where D4 affected 69.99% of Utah land.

4.7.5 Probability

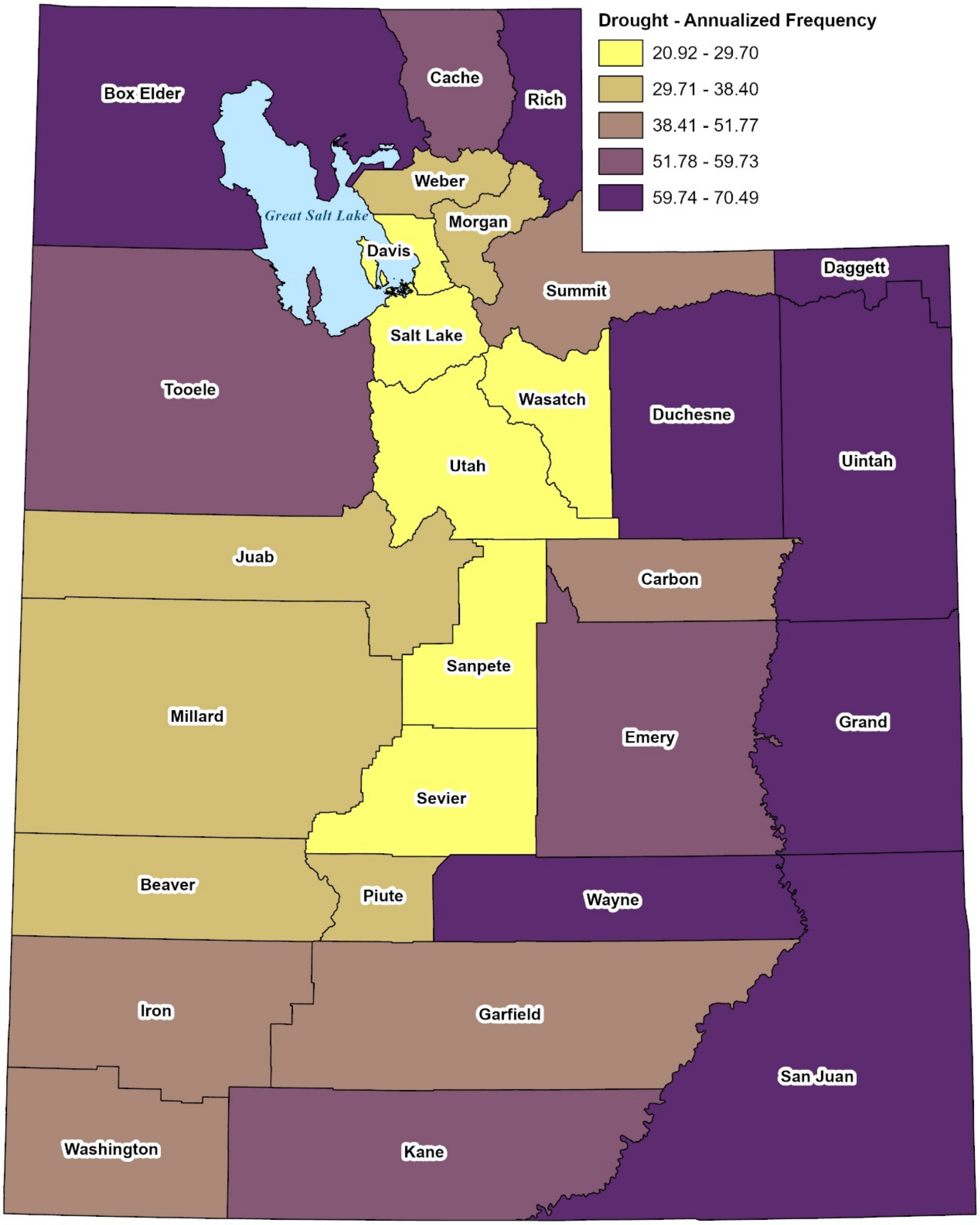
Drought conditions in Utah have become more frequent and severe in recent decades relative to the past 100-125 years (Figure 4-42 and Figure 4-43). Two lines of evidence suggest the future frequency and severity of drought will continue to increase. First, as disruptive as drought in Utah has been in recent years, we are likely enjoying a relatively wet period in comparison to what has existed since 1,000 CE (DeRose et al., 2015; NOAA, 2022; Figure 4-40). From a statistical perspective, conditions can reasonably be expected to be more drought prone as time passes and Utah regresses toward the mean of its natural climate. Second, academic studies have documented trends in worsening drought in Utah and have developed a theoretical basis to explain why such a trend exists. Notable works include Zhang et al. (2018), Gillies et al. (2012) and Scalzitti et al. (2016), in addition to those discussed in the following section on Climate Change Considerations.

Taken together, available evidence suggests that drought will become increasingly frequent and severe. This is without considering the effects of climate change. Forecasting the frequency and severity of drought in Utah over the next half-century remains an important research gap and will likely depend largely on the severity of climate change, discussed in the next section.

Annualized frequency is scoped by the National Risk Index (NRI), defined in Section 4.7.8, the expected frequency or probability of a hazard occurrence per year. The map below presents a picture of frequency by county.

The effect of climate change on the probability of drought is discussed in Section 4.7.6, Climate Change Considerations. Discussion of the populations likely to be most severely impacted is provided in Section 4.7.8, Potential Vulnerability of Jurisdictions, specifically in the subsection titled *Population Impacts*.

Figure 4-44 NRI Annualized Drought Frequency



Source: FEMA NRI November 2021

4.7.6 Climate Change Considerations

The initial effects of climate change on drought in Utah are already evident. Average air temperature has increased by about 2°F since 1950, outpacing the national increase by a healthy margin (Utah DWR, 2021). This change in temperature has caused an increase of evapotranspiration, which has proven to be much more significant to drought than any changes attributed to changing precipitation patterns.

For example, higher temperatures, which have been widely attributed to climate change, are commonly cited as increasing the effects of drought (NOAA, 2022; Gonzalez et al., 2018). A NOAA taskforce report explaining the causes of the 2020-2023 drought found the drought was largely a result of high temperatures and unfortunate, but apparently natural, variation in precipitation (Makin et al., 2021). Another study (Lehner et al., 2018) states it this way, "while warming [observed in recent decades] is largely due to greenhouse gas forcing, the drying [observed decrease in precipitation] is mostly due to internal climate variability."

Estimates of additional temperature change through the year 2100 vary, depending to a large extent on global emissions of greenhouse gasses (Figure 4-45). What is nearly certain, however, is that the climate-change related increase in temperature and its associated amplification of drought will continue.

Figure 4-45. Observed and Projected Mean Temperature for the State of Utah, 1900-2100. Modified from NOAA (2022).

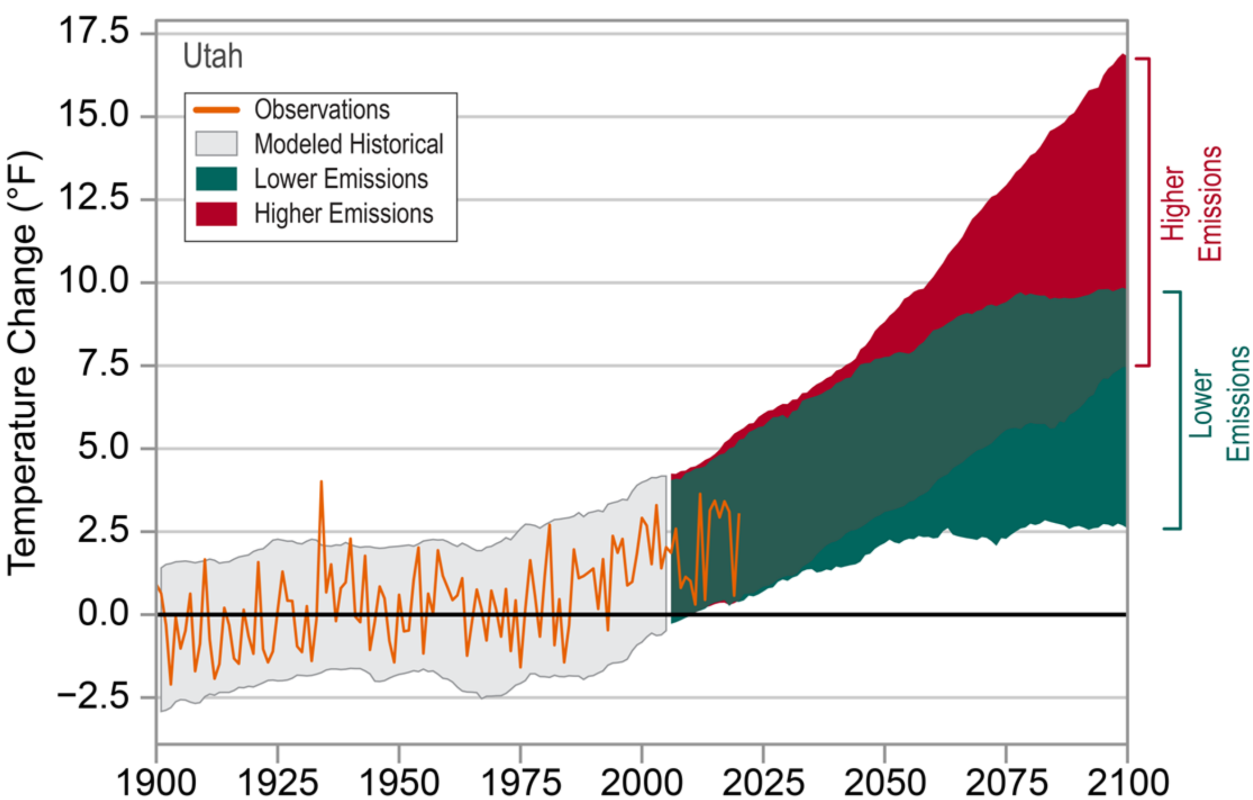
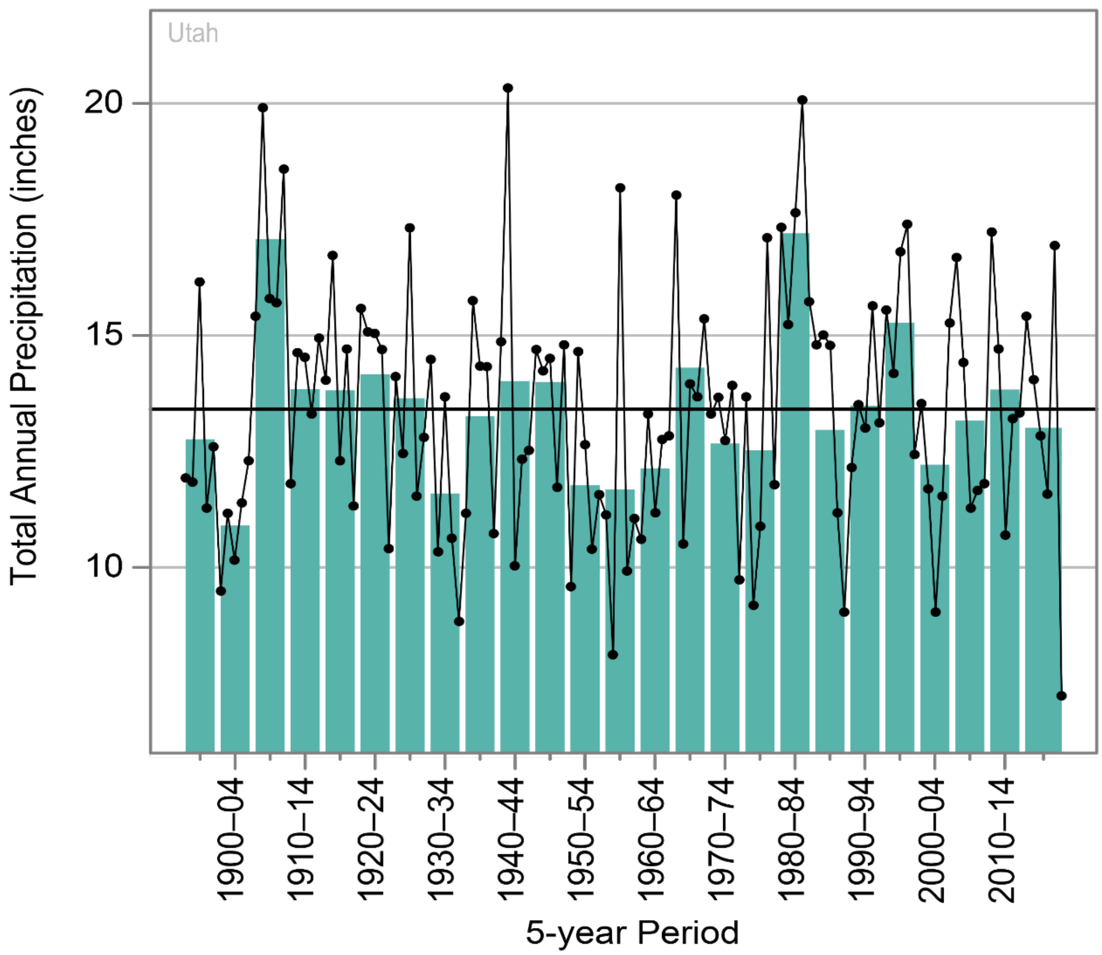


Figure 4-46. Observed Annual Precipitation, 1895-2020



Bars show 5-year averages, last bar is a 6-year average, dots show annual values. Horizontal black line shows long-term average annual precipitation, 13.4 inches. Modified from NOAA (2022).

The effect of climate change on precipitation is more nuanced. Total statewide precipitation has changed very little since 1895 (Figure 4-46; Khatri & Strong, 2020). With respect to drought, any changes in statewide total precipitation are insignificant relative to changes in air temperature. Available information on future changes to precipitation in a climate-change affected Utah remains uncertain.

Though state-wide total *precipitation* has been stable in recent history (Figure 4-46), *snowpack* has decreased (Figure 4-47). Since 1955, the snowpack has peaked earlier and has had a reduced season length. These trends are also expected to continue into the foreseeable future. Due primarily to increasing air temperature, the proportion of precipitation that falls as snow will continue to decline. Warmer conditions are simply less likely to produce snow. Also, warmer conditions cause the snow line, the lowest elevation at which snow falls, to recede. As the snowline moves upward, the area receiving snowfall is reduced.

What a reduced snowpack means to Utah's water supply and ability to cope with drought is unclear. Winter precipitation that falls as rain is not lost; it merely joins the hydrologic system differently than snowfall. Rainfall is more vulnerable to evapotranspiration loss than snowfall, while snowfall can have a high loss to sublimation. The snowpack melts in the spring, largely flows quickly to streams, and is responsible for the high spring and early summer streamflow we are accustomed to experiencing. Rainwater that avoids evapotranspiration largely flows as groundwater and will eventually discharge to a downgradient stream or lake. The timing of groundwater flow to streams and lakes is different and far more variable than that of melted snowpack. Groundwater is responsible for what hydrologists describe as baseflow. Baseflow is critical for stream habitat, especially during the low-flow periods of late summer through winter. How a shift in winter precipitation from snow to rain will play out in the future is a clear research gap. It is apparent that future streamflow in Utah will be different than what we have experienced in the past. If these changes will prove to be 'good' or 'bad' for water management and ecosystems is uncertain.

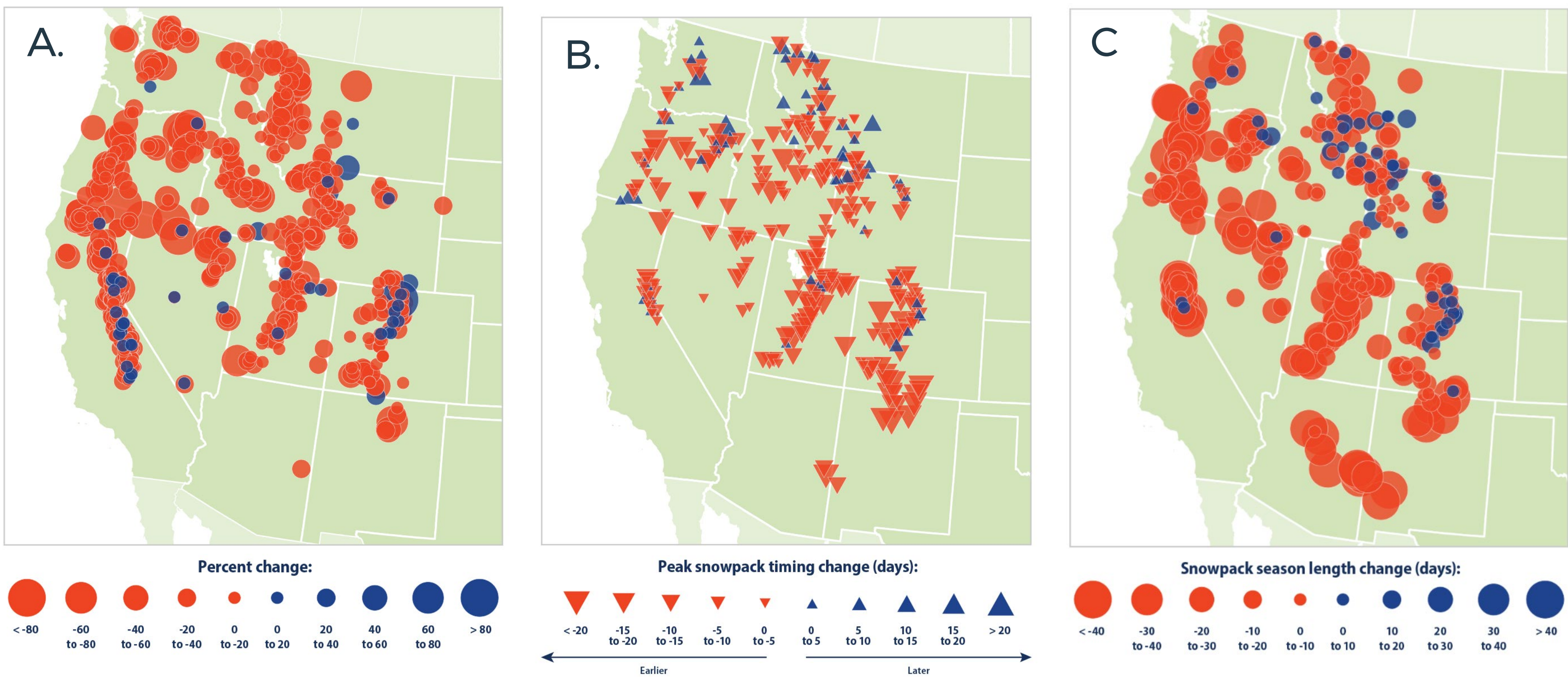
Climate change-induced changes in evapotranspiration further complicate the issue of drought. As temperature and evapotranspiration increase, even a historically normal winter precipitation and snowpack may move through the hydrologic system differently. Evapotranspiration effectively intercepts water that would normally recharge groundwater and be available to agriculture, ecosystems, and water managers and returns it to the atmosphere. As water available to these uses declines, hydrologic, agricultural, and even socioeconomic drought can exist, even if precipitation were to remain normal.

Figure 4-47 Snowpack trends in Western USA. Modified from US EPA (2022)

Trend in April Snowpack Snow-Water Equivalent, SWE 1955-2022

Change in Peak Snowpack Timing 1982-2021

Change in Snowpack Season Length 1982-2021



For more information and to access indicator customization tools, visit U.S. EPA's "Climate Change Indicators in the United States" at www.epa.gov/climate-indicators.

Desiccation of the Great Salt Lake

The Great Salt Lake has lost over half its volume since the 1980s. Vast areas of lakebed have become exposed and now contribute to severe dust storms and reduced air quality that impact human health in nearby cities. A greatly reduced lake area also reduces habitat for wildlife. Another impact of reduced lake area is to reduce lake-effect snow, which further reduces water supply to the Great Salt Lake basin and impacts wintertime tourism and recreation. These and other issues have caused considerable alarm among many.

Decreased Great Salt Lake water levels cause negative economic consequences for state and local governments, as well as to individuals. Economic impacts (Section 4.7.8) result from health impacts, reduced snowpack in areas dependent on wintertime tourism, and likely from managing a limited water supply that is further reduced by decreased lake-effect snow.

Although overall water supply from nearby mountains shows no long-term trend, inflow to the lake is clearly decreasing. This decrease reflects greater depletion at lower elevations due to water diversion and consumptive use and possibly increased evapotranspiration due to higher temperatures in the watershed. Given these conditions, when drought occurs, the decrease of inflows can be dramatic and lead to the lake level declines seen in recent decades. Stated another way, variation in precipitation and drought cause substantial fluctuations in water level, but fluctuations that tend to even out over time. In contrast water diversions for consumptive use such as agriculture starve the lake of incoming water, are not balanced over time, and result in a long-term decline in lake levels.

Recent academic research has quantified the impact of climate change, water diversion and consumptive use, and drought on Great Salt Lake water levels. Wine et al. (2019) found that some portion of the drought loss can be attributed to climate change, but the amount is relatively trivial relative to naturally occurring droughts and especially consumptive use. Wurtsbaugh and Sima (2022) found that roughly one-third of recent water loss in the Great Salt Lake is due to the effects of drought and two-thirds to consumptive water use in the basin. In concept, the decline in lake levels from drought should be reversed when precipitation and inflow increase above the long-term average, but the decline from consumptive uses will persist.

Wildfire

Another health concern related to drought is the recent increase in wildfire. The rate of wildfire loss is accelerating across the western U.S., causing dangerous smoke exposure to tens of millions of people, vast loss of property, and loss of life on the scale of entire towns in some cases. Burned areas can have profound impacts on water quality. Sedimentation and flooding below burn scars have become a chronic problem in many areas, occasionally filling reservoirs with sediment and leading to floods that cause additional loss of property and life.

As much as one half of the burned forest area in the western U.S. in recent decades is a result of climate change, driven by increased drought caused by air temperature increases. Many recent studies project a marked increase in wildfire for the U.S. southwest, due largely to climate-change induced drought. The impacts of drought-induced wildfire will grow in the state of Utah. For example, by 2050, increased healthcare costs in Utah related to wildfire-smoke related asthma is projected to be approximately $25 million annually (Stowell et al., 2022). Quantifying future impacts specific to Utah from wildfire is a gap in current research. See also the discussion in the Wildfire section.

4.7.7 Vulnerability of State Assets

Very few state assets are directly at risk from drought, particularly compared to the vulnerability of the agricultural industry. Common vulnerabilities of state assets cited in nearby western states are increased costs of managing structures, such as landscaping irrigation costs. These costs are practically insignificant relative to the state budget or even to impacts from other hazards.

Indirect costs to state assets are related to decreased revenue from lower visitation at State parks during drought, or reduced hunting, fishing, and boating license sales due to drought impacts on wildlife and water resources. For example, South Dakota claimed a $1 million loss in revenue during a drought in 2005 due to reduced pheasant hunting license sales. No similar studies for Utah exist to link drought with lost state revenue from license sales.

Indirect costs to the State are likely far greater than direct costs but are still small. Reduced tax revenue related to drought-related drops in tourism and recreation are unquantified, but likely small but significant, particularly during a poor snowpack year that could impact winter recreation.

The upcoming 2034 Winter Olympics in Utah may present a potential vulnerability of state assets, driven at least in part by climate change. It remains unknown if special measures will be taken to assure sufficient snowpack for the 2034 Games, but recent history provides a cautionary tale. The 2010 Winter Games in Vancouver were marred by unseasonably warm temperatures that caused fog and slushy snow that forced postponement of snow-dependent events. Helicopters were used to ferry snow to a snowboarding course on an emergency basis. Organizers of the 2014 Olympics in Sochi took extraordinary measures to ensure sufficient snowpack. These organizers installed a network of many hundreds of snow-making guns and built an enormous reserve of a half-million cubic meters of snow in 2013 in large mounds that were insulated to reduce melting through the summer to provide an emergency source of snow in the very possible event of insufficient snowfall for the 2014 Winter Games. Fully 100% of the snow used at the 2022 Beijing Winter Olympics was artificially made. Utah has an advantage over these recent Olympic venues of having more reliable winter conditions, but with winter snowpack reliability becoming less certain in the face of climate change, mitigating a potential snow drought could be a financial burden for Utah's 2034 Winter Olympics.

4.7.8 Vulnerability of Jurisdictions

Due to the diversity of drought impacts and their tendency to exacerbate other hazards, it is difficult to provide loss estimate values at the jurisdictional level. Simply stated, drought can be expensive without damaging a lot of possessions or structures. For example, the economic cost of a snow-drought related disruption of the 2034 Olympics may be a worthy issue to study further, but such a study has not been done as of this ESHMP update. In addition, issues such as increasing mental healthcare costs due to drought go largely unmeasured. Drought losses also exist that are not covered by insurance. For example, if a well runs dry, the cost of drilling a deeper well is typically not an insured loss. Formal statistics of drought damages are often limited to the agriculture and tourism sectors.

Current water management practices also complicate evaluations of drought vulnerability. For example, life as we know it in Utah is largely dependent on moving water from water-rich mountainous areas to desert-like, low-lying areas (Figure 4-38). Drought occurring in the desert areas is relatively unimportant; our water management practices already mitigate the hazard. However, low-lying, dry areas are potentially vulnerable to drought in water-rich mountainous areas used as the source for their water supply.

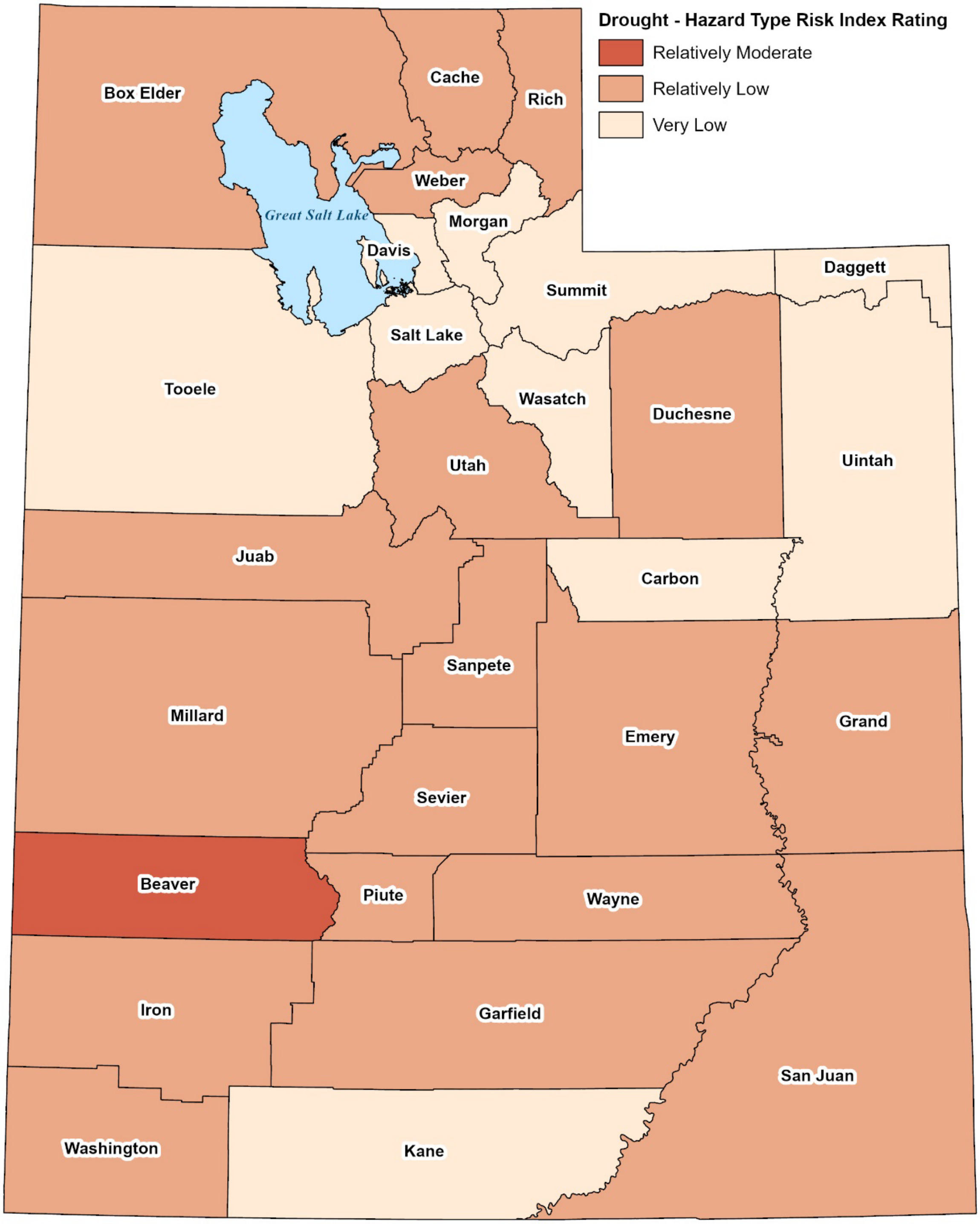
Further complicating the drought-vulnerability discussion, the water management system in Utah and the West depends in part on a system of many dams that are especially useful for capturing excess water in wet years for use in dry years. Because of this, short-term drought is not a large problem for water supply. It is long-term, multi-year drought that can limit water available for use in dry areas.

The following sections describe ways of understanding the magnitude of vulnerability jurisdictions have to drought. In short, no concise, or even complete, assessment exists. Taken together, quantifying the impact of drought on jurisdictions is a knowledge gap. Even a high-level state-wide assessment to identify problem areas would be useful from a planning perspective. However, in-depth study of this local-impact issue is suitable for being addressed as needed in local-HMPs or other local-focused studies.

National Risk Index Assessment

The National Risk Index (NRI) provides a range of ratings for drought occurrence, exposure, loss, and risk in Utah. However, the methods used for calculating drought in NRI data only reflect exposure of crops to drought (Zuzak et al., 2023). This nuance in NRI computations limits the utility of NRI drought products to planning in the Utah context. For example, drought in mountainous areas affects Utah's tourism sector and water supply but is not captured in the NRI. The NRI risk ratings by county for drought are shown in the figure below, but generally reflect risk related to the agricultural sector.

Figure 4-48 NRI Drought Risk Rating

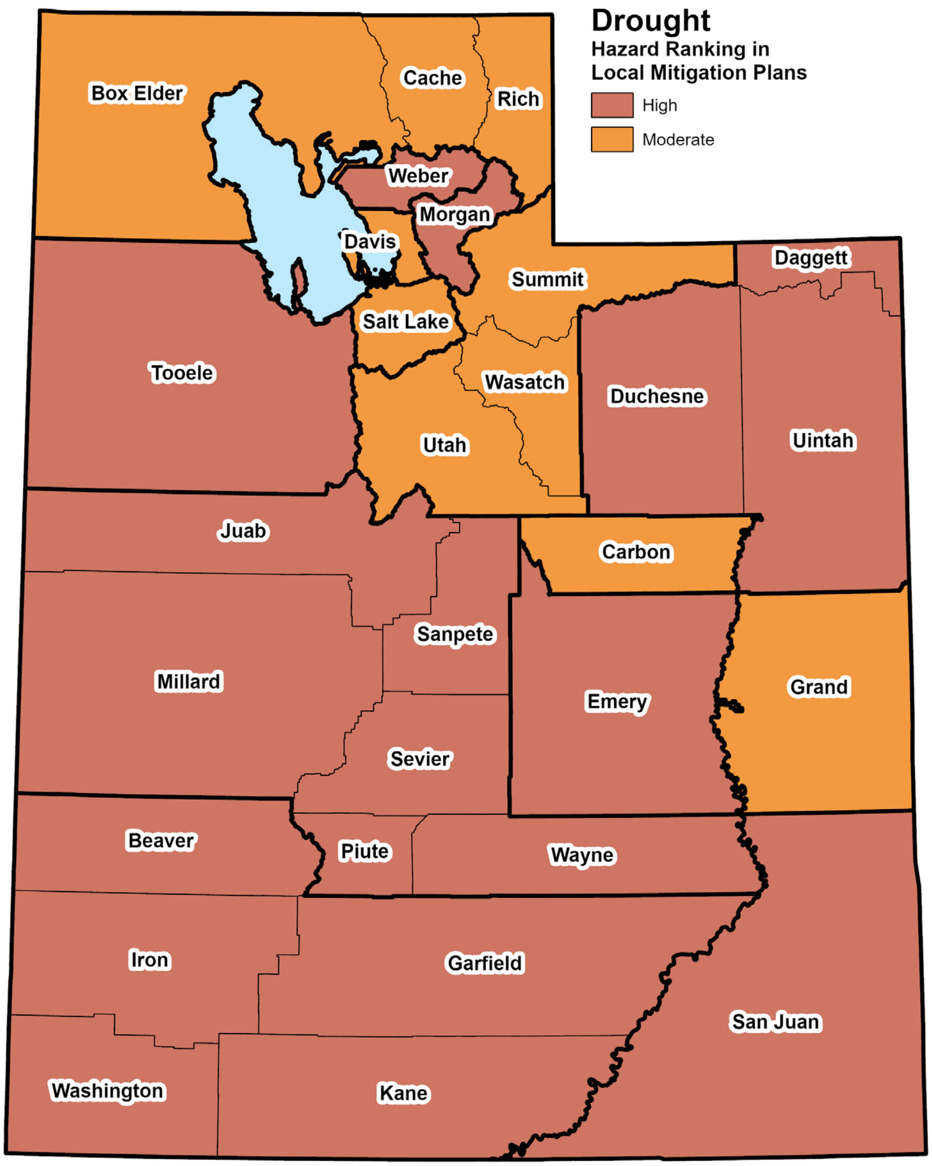


Source: FEMA NRI November 2021

In addition, the NRI does not account for the vulnerability of source water from potentially distant locations or the mitigating effects of water management practices. As discussed above, desert areas are potentially vulnerable to multi-year drought occurring in mountainous areas to a far greater extent than they are vulnerable to drought occurring locally and for shorter duration. For all of these reasons, the risk assessments in local planning documents may provide a more accurate indication of drought risk throughout Utah (Figure 4-49).

Local Hazard Mitigation Plan Assessment

Figure 4-49 Ranking of drought concern in local mitigation plans.



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.

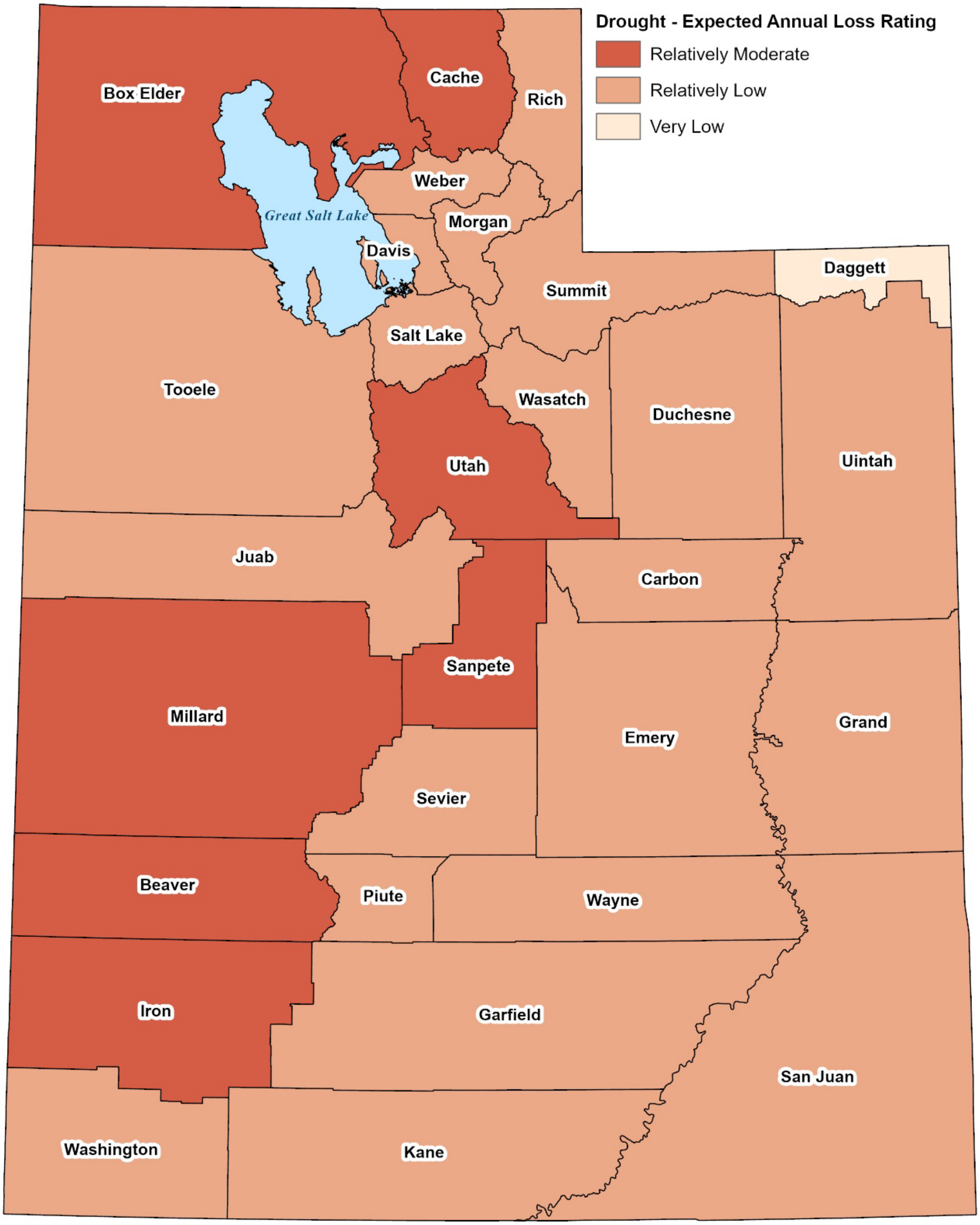
Agriculture Sector

The agriculture accounts for more than 70% of the state's water use – much of it going to grow feed for livestock (Barlow, et.al, 2021). Developing countries, expanding global markets, and changing consumer food purchasing behaviors keep Utah's agriculture industry evolving and in demand. The value of agricultural sector production totaled $2.25 billion in 2021 (USDA, 2022). For context, this represents 0.9% of Utah's $225.34 billion GDP in 2021 (U.S. Bureau of Economic

Analysis, 2023). The farm, forestry, fishing, and related activities sectors provided 25,148 jobs earning a total of $320.3 million (Hargraves, 2021). This represents approximately 1.5% of all jobs in the state of Utah (US Bureau of Labor Statistics, 2023).

The agricultural sector in Utah and the individuals dependent on agriculture and agricultural products are vulnerable to drought. However, the vulnerable are not spread evenly across the state. Figure 4-50 shows the relative value of crops in Utah counties, as defined by the National Drought Index Expected Annual Loss rating. Table 4-23 provides relevant agriculture statistics for Utah's counties from the *2017 Agriculture Census*. The 2022 Agriculture Census will update these values but has not been published as of July 2023.

Figure 4-50 Distribution of the value of crops in Utah counties.



Source: FEMA NRI November 2021

Table 4-23. 2017 Agriculture Statistics for Utah's Counties

COUNTY	FARMS	TOTAL ACRES	MARKET VALUE OF PRODUCTS SOLD ($1,000)
Beaver	272	157,030	$258,008
Box Elder	1,187	1,220,773	$134,068
Cache	1,397	276,273	$162,737
Carbon	309	230,942	$6,459
Daggett	52	17,671	$2,403
Davis	528	51,793	$23,798
Duchesne	1,063	1,057,413	$57,892
Emery	504	133,699	$15,354
Garfield	286	82,637	$21,786
Grand	102	231,361	$7,170
Iron	486	512,940	$133,512
Juab	292	264,644	$53,679
Kane	182	128,697	$6,267
Millard	654	481,539	$179,959
Morgan	372	242,666	$17,129
Piute	104	54,445	$40,605
Rich	160	374,947	$22,074
Salt Lake	592	61,965	$19,901
San Juan	823	1,657,212	$16,776
Sanpete	1,003	301,691	$171,757
Sevier	691	108,992	$88,546
Summit	626	295,588	$25,540
Tooele	540	348,934	$40,753
Uintah	1,114	1,824,700	$42,268
Utah	2,589	303,795	$202,580
Wasatch	475	97,098	$8,802
Washington	537	155,047	$16,458
Wayne	209	42,751	$12,885
Weber	1,260	94,361	$49,443
Total	18,409	10,811,604	$1,838,610

Source: U.S. Department of Agriculture 2012 Census.

While drought, as a physical hazard, strikes all locations sooner or later, considerable disparity exists between counties in losses related to drought. This is reflected by the number of USDA disaster declarations due to drought between 2012 and 2021 (Table 4-24). Between 2012 and 2021, San Juan and Box Elder counties had the highest number of declarations, with 65 and 42 declarations respectively, followed by Kane, Millard, Tooele, and Washington Counties, all with 39 declarations.

Table 4-24 USDA Drought Disaster Declarations by Year, 2012 – 2021

COUNTY	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	GRAND TOTAL
Beaver County	7	4	8	4	1	0	2	3	5	3	**37**
Box Elder County	5	5	10	4	1	1	4	2	3	7	**42**
Cache County	4	3	6	2	1	0	2	1	1	6	**26**

COUNTY	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	GRAND TOTAL
Carbon County	2	2	6	4	2	1	2	3	4	2	**28**
Daggett County	3	4	2	2	1	0	5	2	4	4	**27**
Davis County	2	1	4	3	1	0	4	1	3	4	**23**
Duchesne County	3	2	8	5	2	1	4	2	5	3	**35**
Emery County	3	2	6	5	2	0	5	3	6	2	**34**
Garfield County	5	3	6	3	0	0	3	3	4	2	**29**
Grand County	4	3	8	3	0	1	7	3	6	2	**37**
Iron County	7	4	8	3	0	0	4	3	5	2	**36**
Juab County	3	3	6	4	3	1	3	2	2	3	**30**
Kane County	6	4	10	2	0	0	5	5	5	2	**39**
Millard County	5	5	6	6	3	1	3	3	4	3	**39**
Morgan County	2	2	4	3	1	0	3	0	3	5	**23**
Piute County	5	3	6	2	0	0	3	2	2	2	**25**
Rich County	4	5	6	2	1	0	3	0	4	8	**33**
Salt Lake County	3	2	6	5	2	1	4	1	5	5	**34**
San Juan County	7	7	18	6	0	2	8	6	7	4	**65**
Sanpete County	2	2	4	5	2	1	2	2	3	2	**25**
Sevier County	5	3	4	5	2	0	3	2	4	3	**31**
Summit County	4	4	4	4	2	0	7	0	6	6	**37**
Tooele County	3	3	8	5	2	1	6	2	4	5	**39**
Uintah County	3	3	2	2	1	0	7	4	6	3	**31**
Utah County	4	2	8	6	3	1	3	2	5	3	**37**
Wasatch County	3	2	8	4	2	1	4	0	4	4	**32**
Washington County	7	5	10	3	0	0	4	3	4	3	**39**
Wayne County	4	2	6	3	0	0	4	3	4	2	**28**
Weber County	2	2	4	2	1	0	4	1	2	5	**23**

The Governor's Office of Planning and Budget (GOPB) compiled drought loss numbers from 2002 for the *2003 Economic Report to the Governor*. The Economic Report to the Governor suggested that the 2002 drought reduced employment by 0.4%. Job change in 2002 was reported at –1.0%; suggesting that without the drought, job change might have been –0.6%, 0.4% lower than what actually occurred.

During the 2002 drought it is estimated that the agricultural sector experienced losses of $150 million ($250 million in 2023 dollars). Ranchers were forced to sell their livestock for very low prices, and many were unable to make a profit from their sales. In addition, it is reported that this drought led to increased unemployment with the loss of 6,110 jobs and $120 million in income (King, 2007). It is expected that future droughts will similarly impact the agricultural sector, possibly creating even greater losses in the severity and extent of the drought if it increases in magnitude.

Tourism and Recreation Sector

For the 2017-2018 ski season, snowfall was down 26% across the Rocky Mountain region as Utah experienced higher than average temperatures. Utah ski visits were down 9.6% year-over-year and ski/snowboard spending fell an estimated $109 million year-over-year (Drought Review and Reporting Committee, 2018). As temperatures continue to rise, similar decreases in snowfall and ski/snowboard spending can be expected.

According to a 2023 report led by researchers at Brigham Young University, Utah's Great Salt Lake is facing a dire situation and is projected to disappear within five years if immediate and drastic measures are not taken to reduce water consumption (Abbott et al.). The lake has already lost a significant amount of its former volume due to unsustainable water usage, reducing it to just 37 percent of its previous size. The current megadrought in the western region, exacerbated by climate change, has further accelerated the lake's decline at a rate much faster than anticipated by scientists.

The report highlights that existing conservation efforts are insufficient to replace the 40 billion gallons of water lost by the lake annually since 2020. To save the Great Salt Lake from irreversible collapse, the report calls for nearby states to reduce their water consumption by 33 to 50 percent, thereby allowing 2.5 million acre-feet of water to flow from streams and rivers into the lake over the next couple of years. In addition to destroying the economic value of the Great Salt Lake (Table 4-25), the vanishing of the Great Salt Lake would have significant ecological implications and expose millions of people to toxic dust emanating from the drying lakebed.

Table 4-25. Direct Economic Value of the Great Salt Lake

	Millions USD / Year			Number
Sector	**Economic Output**	**Labor Income**	**Total Economic Value**	**Jobs**
Industry	1,549	434	1,973	5,400
Recreation	186	63	249	1,800
Ski Industry	110	53	163	1,000
Aquaculture	78	28	106	600
Total	**1,923**	**568**	**2,491**	**8,800**

Source: Abbott et al., 2023

Population Impacts

Drought can lead to air quality issues, including increased propensity for dust storms. This, in turn, can lead to health impacts, especially to people experiencing respiratory health problems. As described above, desiccation of the Great Salt Lake leads to especially hazardous dust hazards. In the future, drought could plausibly lead to problems with drinking water availability and quality. This would present a public health concern for waterborne disease and water access issues.

These impacts are not likely to be experienced evenly across the population. Vulnerable populations will experience impacts more severely (Section 3.5.1). Counties with elevated drought hazards and high social vulnerability (Figure 3-6 and Figure 3-7) are most likely to experience impacts most severely. Lower income persons with respiratory issues that may not be able to afford health insurance could be more susceptible to air quality impacts from drought. San Juan and Piute Counties are the greatest concern in this regard, in addition to persons in Washington, Garfield, and Kane Counties. Residents near the Great Salt Lake in Davis, Weber, Salt Lake, Box Elder and Toole counties are likely to experience more severe health impacts, but counties in this area in general have lower social vulnerability according to SoVI

(Figure 3-6 and Figure 3-7). Indirectly, economic impacts of drought affect some groups more than others. Farmers, and those dependent on the farming industry, are likely to experience impacts disproportionately.

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 drought. However 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. In the case of drought, reducing the vulnerability of the socio-economically disadvantaged and people experiencing chronic respiratory health problems can be addressed more effectively in the local plans of counties throughout the state. In future ESHMP updates, 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

Damage to infrastructure can and often does occur from drought. This impact of drought is often overlooked, perhaps because the damage is usually sporadic and may become increasingly evident over time, as opposed to instantaneous damage from a flood or earthquake. Damage to underground pipelines and above ground infrastructure can occur due to the shrink/swell cycles associated with periods of drought when soils dry out and shrink and wet periods when soils expand. This is especially problematic in areas with high concentrations of clay in the soil.

Drought can also directly impact water storage and distribution systems. Decreased pore water pressure from low water levels can increase the potential for structural damage to earthen dams. As reservoir water levels decline shoreline areas are exposed and susceptible to erosion, leading to increased sedimentation. Damage to water distribution and treatment systems can be caused by high sediment loads when pulling water from the bottom of low reservoirs. In severe cases this can cause damage to outlet structures and water treatment facilities. In general, increased maintenance and oversight are required for these structures during drought. Increased silting and sedimentation in reservoirs as a result of drought and fire damaged watersheds can ultimately require a need for expensive dredging operations. Water supply ditches that remain dry for extended periods of time can be prone to animal damage such as burrowing and plant overgrowth.

Decrease in surface water during drought periods may lead to increases in well pumping. This in turn puts stress on well pump equipment and can fatigue the equipment sooner. Equipment may not be taken offline for scheduled maintenance during drought periods thus exacerbating the potential for equipment break down.

While water treatment systems see an increase in demand during drought, wastewater systems can experience the opposite: decreased flow. This can cause challenges both at the plant and in the collection system. Decreased flow is often more concentrated which can affect outflows and downstream ecosystems.

Drought and dust storms can cause issues with power line infrastructure. When dust and other contaminants coat insulators on power lines and get damp, they can conduct electricity and cause failures resulting in blackouts. Wildfires associated with drought also can also damage power line infrastructure. Hydropower plants, by their very nature, are susceptible to drought (Planning and Drought PAS Report 574, APA 2013).

4.7.9 Changes in Development

Utah is presently the fastest growing state in the U.S. and one of the most arid. These fundamental facts form a 'grand challenge' to manage water resources to provide an opportunity for continued growth, while minimizing environmental and social impacts. Critical questions exist. How will water availability affect development costs moving forward? Will climate change further affect water availability and therefore increase development costs? Would higher development costs restrict development? Would economic growth be affected by slower development? With particular relevance to the present discussion, drought will amplify these issues. Clean energy development, including the federal push for hydrogen production, may cause additional pressures for water resources in the future.

Water conservation may reduce the impacts of development on competition for limited water resources related to drought. Agriculture is the largest water user. Additionally, agricultural water use is 65%-70% consumptive, meaning that most water used for agriculture evaporates rather than being returned to the local hydrologic system in liquid form. Much can be gained from conserving water in agriculture. For example, drip irrigation effectively irrigates many crops more efficiently than spray or furrow irrigation. Despite this, sprinkler irrigation is steadily increasing since at least 1950 and drip irrigation is relatively rare in comparison.

To be sure, complex legal, social, and pragmatic issues exist related to changing crops from water-intensive varieties such as alfalfa and other hay crops or even dry land farming. Nevertheless, shifting away from water-intensive crops provides an opportunity to reduce water use in agriculture. Recent research has found over 80% of irrigated agricultural land in Utah produces alfalfa, pasture, and hay crops[14].

Beyond conservation, land use changes have tremendous potential to reduce water use. For example, taking land out of irrigated farming or water-intensive industrial uses altogether frees a substantial amount of water that can be used to satisfy development. In many cases, the products that are no longer produced can be imported from other locations where water is more plentiful, a concept known as virtual water[15].

Reducing irrigation in urban areas also provides an opportunity to blunt the impact of development on water resources, especially in times of drought. In Utah, 60% of residential water use goes towards outdoor irrigation, especially for water-intensive lawns. As with agriculture, outdoor irrigation is a consumptive use of water, in contrast to indoor water use that, once treated, remains available for downstream water users. To encourage the use of more water-efficient plants and landscape principles, the state has incentivized the replacement of lawn with waterwise landscaping through Utah Water Savers program.[16]

The Division of Water Resources has partnered with Central Utah, Jordan Valley, Washington County and Weber Basin Water Conservancy Districts to increase awareness and funding for the Utah Water Savers program. This program is operated to reduce landscaping irrigation, largely through financial incentive programs for removing highly water-intensive landscaping such as Kentucky Bluegrass with more water-friendly xeriscaping.[17] Program partners operate the

14 Barker, Burdette, Matt Yost, and Cody Zesiger. "Agricultural Irrigated Land and Irrigation Water Use in Utah." Utah State University Agriculture Extension (2023). https://digitalcommons.usu.edu/extension_curall/2311/
15 Allan, John A. "Virtual water: a strategic resource." Ground water 36, no. 4 (1998): 545-547.
16 See the Utah Water Savers program webpage at: https://utahwatersavers.com/
17 See the statewide landscape incentive program webpage at: https://conservewater.utah.gov/landscape-rebates/ and a fact sheet outlining the program at https://conservewater.utah.gov/wp-content/uploads/2023/05/UWS-Grass-Replacement-042823.pdf.

landscape incentive program within their service areas and the Division of Water Resources operates the program throughout the rest of the state.

Infrastructure plays a role in the resilience of Utah to past and future drought. Water storage, such as in reservoirs, allows the collection of water other in times of excess for use in times of shortage. A large network dams already exist in Utah for this purpose and this approach has largely allowed agriculture to develop as it has. Storage capacity and distribution infrastructure largely dictate the potential for using dams for mitigating drought. Expansion of the current network of dams remains possible, but also faces regulatory obstacles and introduces an additional burden of maintaining and monitoring more infrastructure. Constructing or expanding dams also creates new hazards associated with dam failure, described in Section 4.7.

Ultimately, the question remains where water will run out first. The answer is not clear, and agencies and municipalities have water management tools at their disposal to avoid such a situation and, in fact, are proactively managing water to avoid widespread water shortage. An analysis of development trends in LHMPs (see Section 3.7 Development Trends) noted some specific concerns with drought including Salt Lake County where increased population density and development will put further stress on limited water resources.

4.8 FLOOD

4.8.1 Description

Flooding is generally a temporary inundation of water onto normally dry land areas by overflow of water, an unusual rapid accumulation, mudflows, or runoff of surface waters from any source. Flooding is the most commonly occurring hazard in Utah despite the state being one of the driest parts of America. It occurs in Utah in many ways. It can be sudden or slow. It can affect mountain streams or slot canyons many miles from any rainstorm. It can even occur far from any river or other water body. Understanding the many forms of flooding in Utah is helpful to guide mitigation measures. Notably, floods in Utah are not only the most common but also the most expensive hazard. Of all the natural disasters occurring in Utah, floods consistently carry the highest price tag year after year. This underscores the critical importance of comprehensive flood preparedness and mitigation strategies to safeguard both the state's residents and its economic interests.

Additionally, Utah's unique geographical features contribute to its vulnerability to flooding. The state's varied topography, including steep canyons and arid plateaus, can lead to rapid runoff during intense rainfall. Urban areas, with their impervious surfaces, can exacerbate flooding, creating challenges for drainage systems. Moreover, the proximity of many communities to rivers and streams further amplifies flood risks. As climate patterns evolve, understanding and addressing these localized vulnerabilities will become even more crucial for effective flood risk management in Utah.