

03

Chapter

Water Supply

Chapter Highlights

- Accurate measurement is essential when determining water supply.
- The water supply is limited by three constraints: mechanical, hydrologic, and legal.
- Quantifying the current reliable water supply is valuable in determining what will be needed in the future.
- The Division developed and uses a Water Budget model to estimate the state's overall water supply and use.
- The Division uses geospatial technology to assess land use transitions, which is important when assessing water supply and use.
- Cloud seeding increases Utah's water supply.
- Climate change and drought impact available water supplies and make estimating future reliable supplies difficult.

Water Supply

Introduction

Meeting Utah's future water supply needs depends on reliable data, modeling, collaborative planning, and data-driven actions. To plan for more people, it's vital to understand the importance of water use efficiency, location of remaining available water resources, and where additional supply is needed. The highest quality and most readily available water sources for the municipal and industrial (M&I) and agricultural sectors have already been developed. As a result, water conservation is essential as Utah continues to grow. New projects to divert, store, or augment the water supply are becoming increasingly complex and expensive, but are necessary to meet future water needs (see Chapter 6).

Measuring the Water Supply

Accurate measurement is essential when determining water supply. Measuring supply includes collecting streamflow data, diversions, withdrawals from wells and springs, and inflow and outflow from reservoirs. Understanding how water data is obtained and its limitations are critical to using and interpreting it correctly. Measurements continue to improve as technologies evolve – which leads to more reliable data.

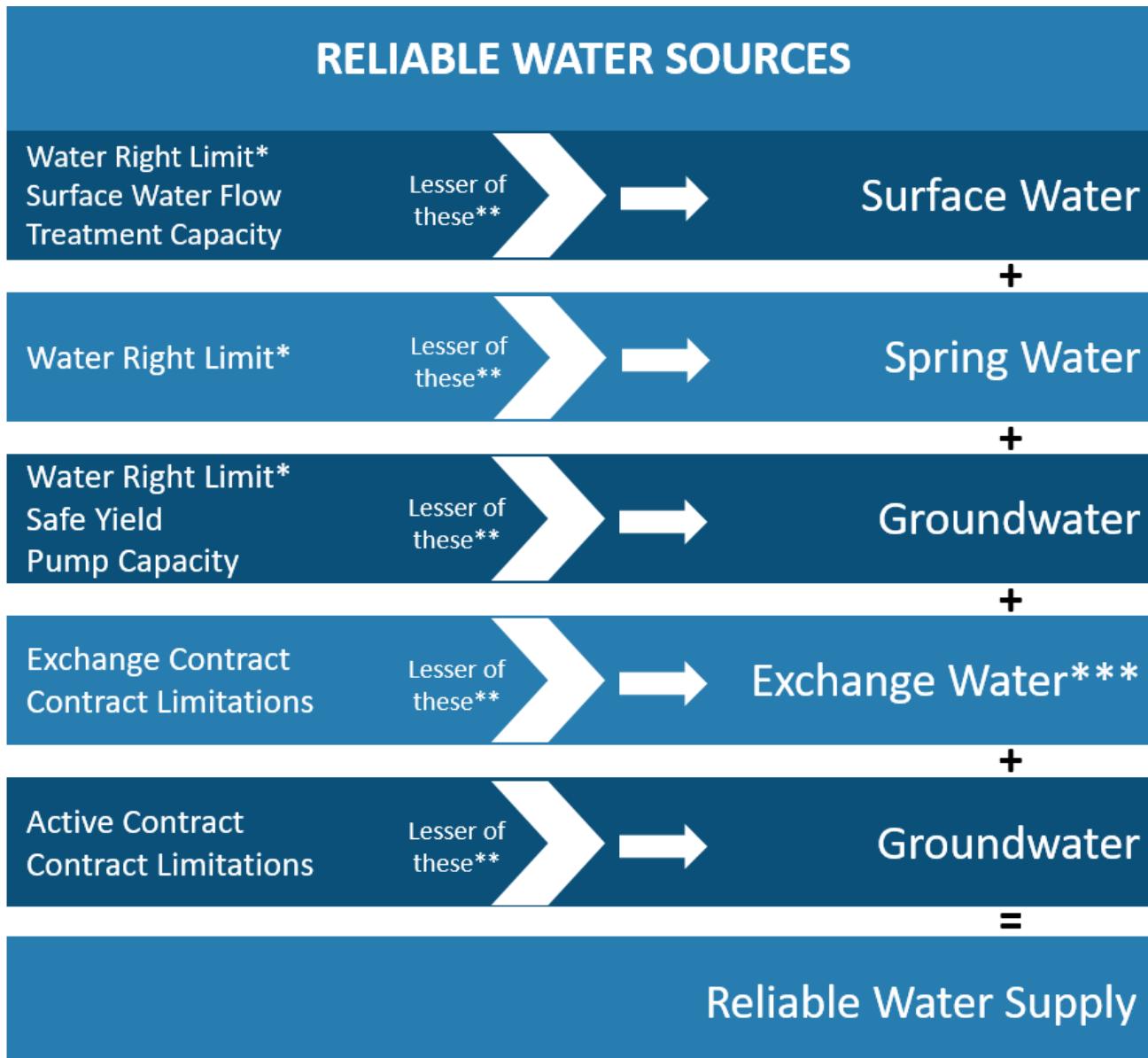
A water supplier's maximum developed water supply is limited by three constraints:

- Mechanical constraints (such as pump capacity)
- Hydrologic constraint (such as reliable streamflow or safe groundwater yield)
- Legal constraint (such as water right or legal contract)



Tibble Fork Reservoir, American Fork Canyon
PC: Shelby Erickson

Graphic 3-1 Water Supply Constraints



* The water right limit is roughly estimated by the Division and may not always reflect the actual limit that is determined through a more detailed evaluation.

** Each of the elements listed is compared to the other elements and only the lesser value is used to determine the total reliable supply for the system.

*** Water from a seasonal source traded or exchanged for water from a reliable source. Trade is formalized by contractual agreement.

Due to fluctuating water sources, not all the maximum developed water supply is available for use to meet water needs.

Annual reliable potable supplies are determined using various sources of average annual water supply. The Utah Division of Water Resources (Division) analyzes reliable

supply for public water systems to determine how much water is, and will be, available via sources like wells, springs, and reservoirs.

Graphic 3-1 shows how the reliable water supply is estimated for public water suppliers who have not conducted their own analysis.



Bridal Veil Falls, Provo Canyon
PC: Rob Hall

Existing Reliable Supply

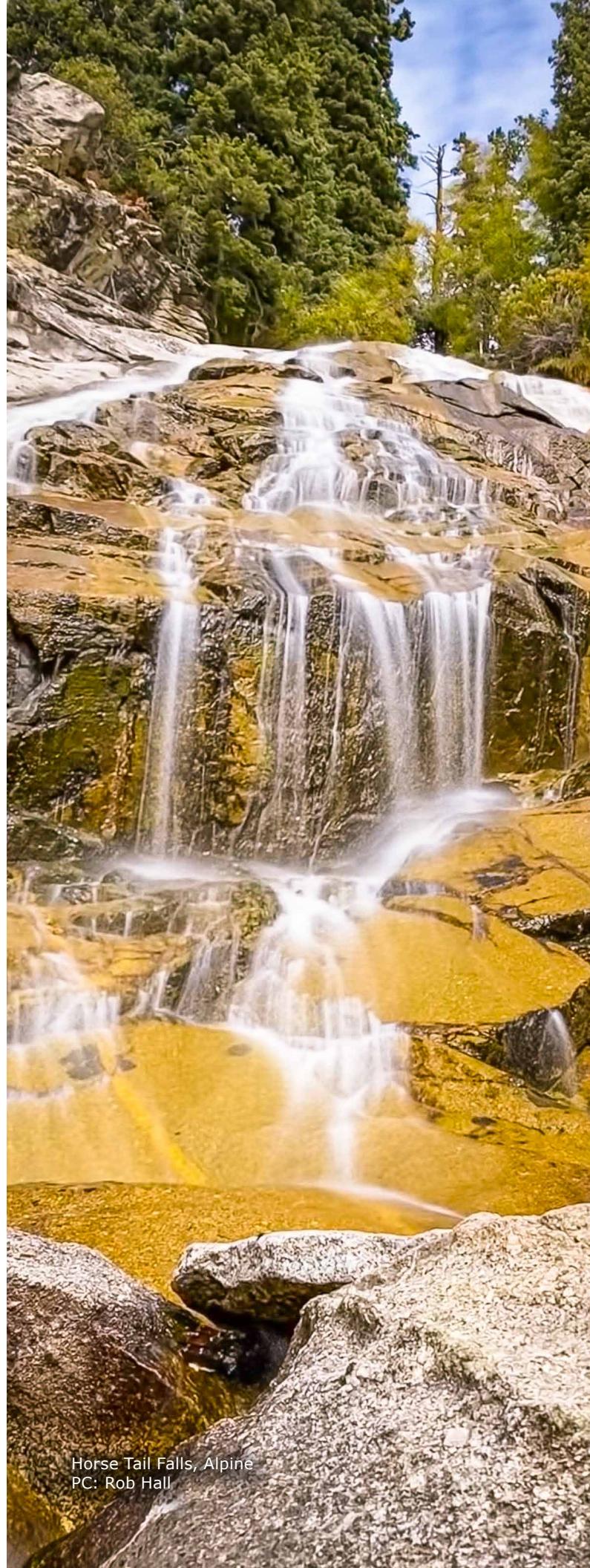
Supply source and water use records obtained from the Utah Division of Water Rights (Water Rights) provide the basis for the Division estimates of reliable M&I supplies. Interviews with water system operators are conducted to gain more information. Reliable supply values provided by the water supplier are preferred when possible. Every five years, the Division uses Water Right's data, estimates secondary uses, and reports M&I water suppliers' reliable supply. The reliable supply data in this report is from the year 2015. The process of collecting, reviewing, validating, and analyzing data takes about two years from the time data is submitted to Water Rights until it is publicly available. The 2020 data is expected in late summer 2021 and will be published in an M&I water use report in 2022.

Water suppliers evaluate their current supply capacity to understand when more water will be needed. An audit report recommended, and the Division agrees, that water suppliers need to determine the reliable supply for their water system (OLAG 2015). When a reliable supply is not provided by a water supplier, the Division estimates a reliable supply by examining the limiting factors that include a combination of water rights, surface supplies, water system treatment capacity, groundwater supplies, and supplier delivery capacity. The limiting factors among these areas help define the

Division's estimate for a supplier's reliable supply. For example, system treatment capacity, rather than the physical availability of water, could be the factor limiting the Division's estimate of reliable supply. Water data can be found on the Division's [Open Water Data](#) website.

When secondary water is used within water suppliers' boundaries, the estimated use is accepted as part of the reliable supply. Historically, secondary water use has been unmetered by water suppliers and underestimated by the Division. In recent years, many systems have started metering pressurized secondary water use, which has improved water use data and water efficiency. The Division combines readings from metered secondary water with improved estimates of unmetered use to quantify secondary water used within M&I system boundaries. It is assumed that the secondary supply is at least equal to the secondary use. This assumed secondary water supply and the potable reliable supply are added together and represent the total reliable supply (secondary water supply estimate + reliable potable water supply = total reliable supply).

Table 3-1 shows total reliable supplies by basin for the year 2015. Additional details are contained in Appendix G. For a general discussion of how these reliable supplies are used to help identify when and where additional water supplies may be needed, see Chapter 6.



Horse Tail Falls, Alpine
PC: Rob Hall

Table 3-1 Total Reliable Supply by Basin (2015)

Basin	Potable Supply (ac-ft)				Secondary Use (ac-ft)	Total Reliable Supply (ac-ft)
	Wells	Springs	Surface	Total		
Bear River	59,200	46,800	34,000	140,000	14,800	154,800
Cedar/Beaver	21,100	3,600	-	24,700	4,500	29,200
Jordan River	99,000	6,500	179,400	284,900	30,700	315,600
Kanab Creek/Virgin River	30,200	8,500	27,400	66,100	13,000	79,100
Sevier River	21,100	22,400	-	43,500	11,900	55,400
Southeast Colorado River	5,900	2,900	4,100	12,900	1,500	14,400
Uintah	4,900	9,700	37,500	52,100	4,600	56,700
Utah Lake	152,900	57,800	49,000	259,700	60,500	320,200
Weber River	99,100	9,200	87,500	195,800	92,500	288,300
West Colorado River	1,700	9,100	15,600	26,400	8,400	34,800
West Desert	22,700	5,000	-	27,700	4,000	31,700
State Total	517,800	181,300	434,500	1,133,600	246,500	1,380,100

Data source: 2015 Municipal and Industrial Water Use Data Report version3. 2020. Table A-3, A-4
Reliable Potable Supply by Basin.

Diversion vs. Depletion

The amount of water diverted (moved from its original location to another location) for a particular use does not always match the amount of water depleted or taken out of the watershed. When discussing water use, it is necessary to differentiate between diverted water and depleted water. For example, as water is used for agricultural purposes, some water returns to streams or recharges the groundwater in the watershed. The diverted water that returns to the watershed is not depleted (removed/exhausted from

the system). Depletion typically is caused by evaporation and transpiration through crops and land cover.

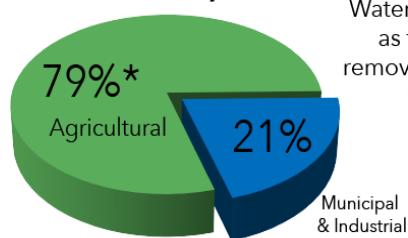
Diverted water used for M&I irrigation (lawn and garden) also partially returns to the system. Most of the M&I water diverted for indoor use (e.g. washing and food preparation) is not depleted. It returns to the watershed after being treated at a wastewater treatment plant. Water that reenters the watershed can then be diverted downstream for another use. Graphic 3-2 describes the difference between diversions and depletions.

Graphic 3-2 Diversion vs. Depletion

What's the difference between water diversions and depletions?

On average, Utahns divert 4,751,000 acre-feet of water per year, of which 2,957,000 acre-feet are depleted/consumed

Water Diverted By Sector

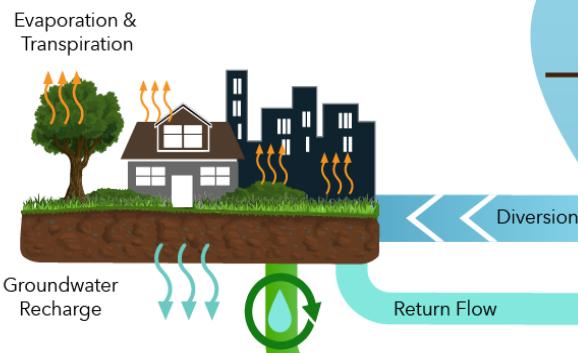


Water diversions are defined as the quantity of water removed from natural sources for beneficial use.

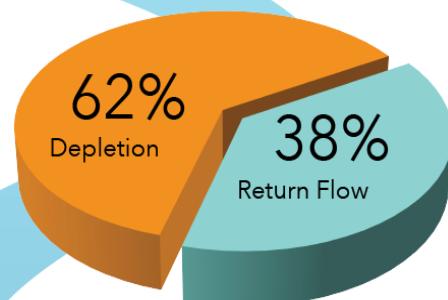


Water depletions are the quantity of water consumed from a diversion, also known as consumptive use. Depleted water is consumed in the growth of plants and animals, evaporation, and transmission away from the basin it was drawn from.

A proportion of diverted water returns to surface and groundwater sources via process like runoff and seepage. In Municipal and Industrial systems, water may also return from secondary water treatment systems for reuse.

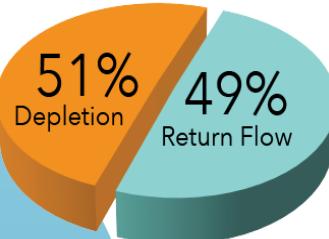


Average Depletion Proportion of all diversions - municipal, industrial and agricultural water use



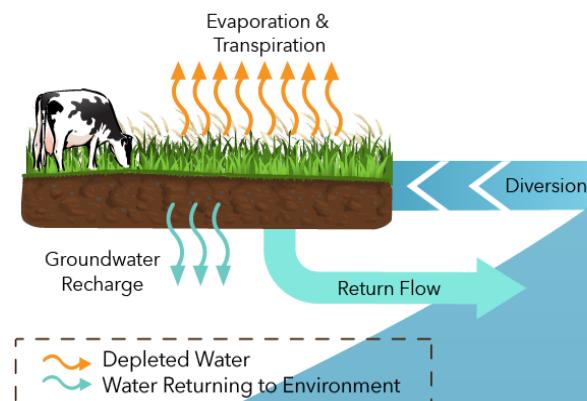
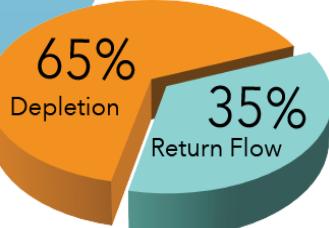
Municipal & Industrial Water Use

990,000 acre-feet of water diverted annually



Agricultural Water Use

3,761,000 acre-feet of water diverted annually



Source: Utah Division of Water Resources; Water Budget State Averages (1989-2018)

*data from the last five years (2013-2018) indicates about 75% of diversions are from agriculture

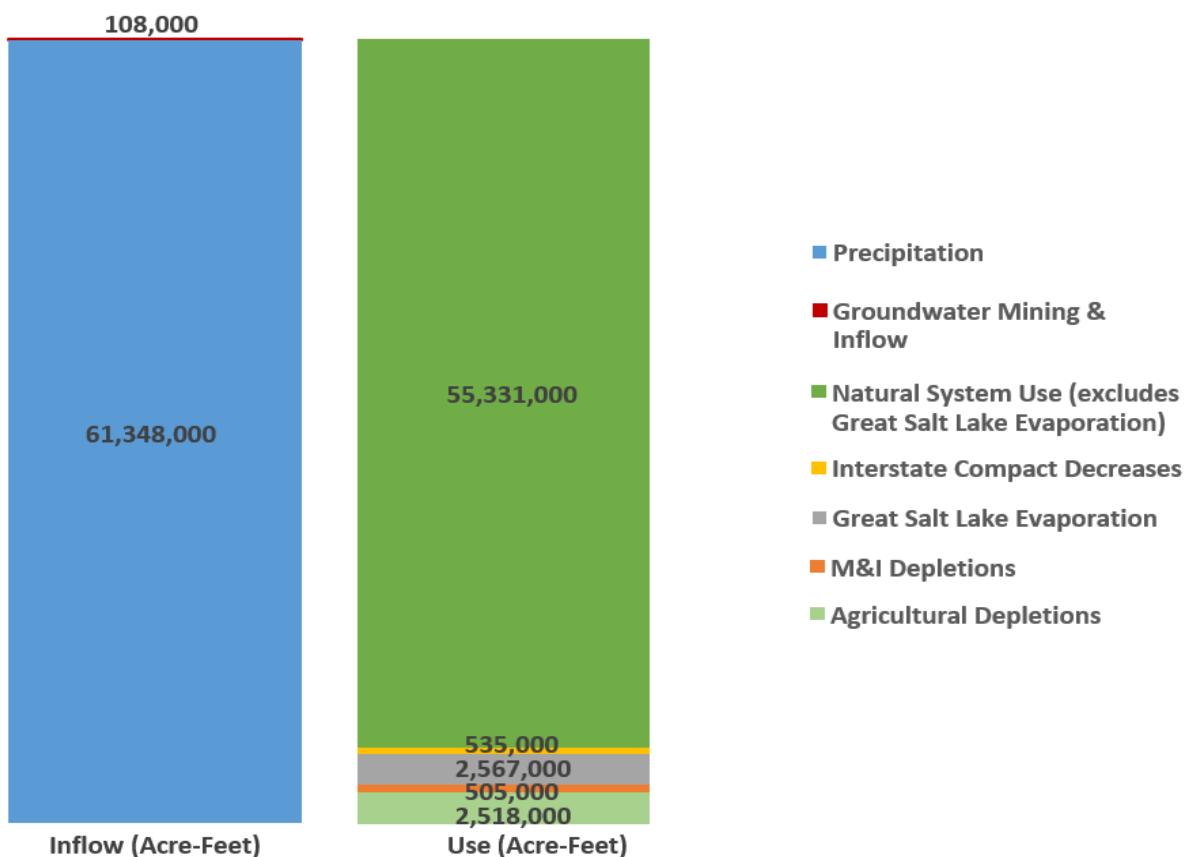
Water Budget

The Division has spent many years developing and refining a Water Budget model to estimate total water use in the state. Output from this model is available on the Division's [Open Water Data](#) website. The Water Budget is primarily focused on agriculture, but incorporates all uses. Graphic 3-3 shows the state's estimate of the overall water supply and use. The Water Budget takes into account the available water supply, including precipitation, groundwater, and reservoir storage (Graphic 3-4). It also estimates water diverted and depleted, including riparian, evaporation, agricultural (crop types), and M&I uses. The model provides a general summary due to the broad scope and geographic area. It's useful for understanding the big picture for

statewide water planning and illustrates the continuity from one hydrologic basin to another. However, not all of this water can be captured and put to use.

Precipitation data for the state is estimated by the PRISM Climate Group at Oregon State University. PRISM data shows Utah as one of the driest states in the nation. Utah's average annual precipitation is about 13 inches and ranks Utah among the top five driest states, depending on the water year. The average annual precipitation estimates across the state vary dramatically, with the highest over 60 inches occurring near Willard Peak and the lowest below 5 inches falling near Wendover, Utah. Predictably, the highest precipitation areas are the mountain ranges, where much of the precipitation falls as snow.

Graphic 3-3 Estimated Statewide Water Supply and Use



Graphic 3-4 Water Supply Data Sources



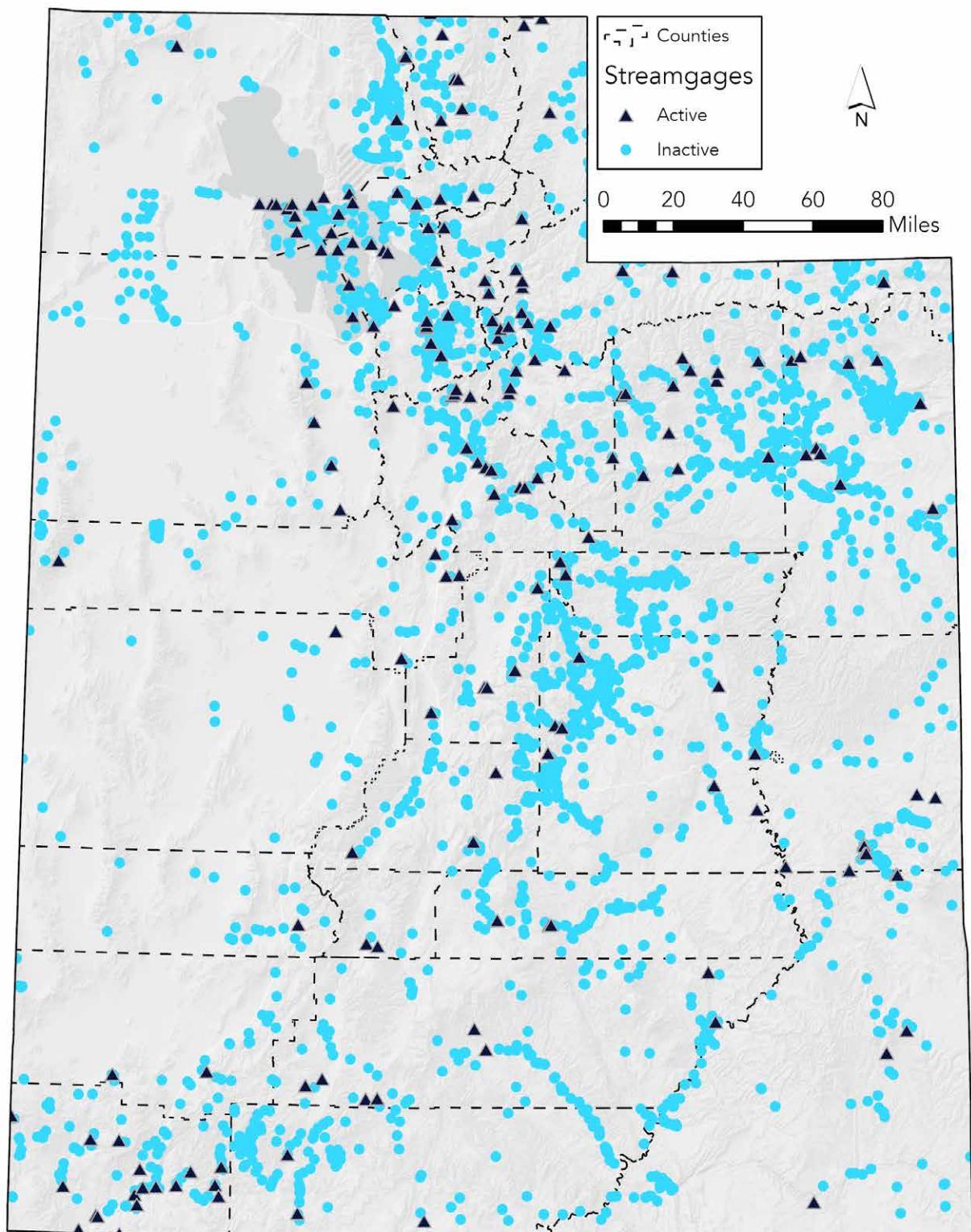
Although snowfall is included in PRISM's total precipitation data, snowfall data is sometimes separated from rainfall for modeling and water supply projections. The Natural Resources Conservation Service (NRCS) operates a data collection network called SNOTEL (short for Snow Telemetry). SNOTEL stations, located in high-mountain watersheds, collect snowpack and related climate data. This data is used to forecast yearly water supplies, predict floods, and conduct general climate research.

The U.S. Geological Survey (USGS) is the primary source for streamflow data. If a USGS streamgauge is no longer active, its historical flow is correlated with flows of nearby active streamgauges to estimate flows. Data from streamgauges maintained by irrigation companies, water systems, and other local sources is also used where available.



Spanish Fork River
PC: Rob Hall

Map 3-1 USGS Streamgage Locations



Data Sources: Streamgages - USGS. Base Layer - Esri, HERE, Garmin, FAO, NOAA, USGS, © OpenStreetMap contributors, and the GIS User Community

The Division plans to analyze existing streamgage networks and identify where additional monitoring is needed.

Water Budget Changes

Over the last 30 years, the Water Budget model has changed and improved with new data, models, and technology. Land use data (houses, golf courses, crops, or pastures) comes from the Division's Water-Related Land Use Survey. Originally, land use across the state was identified and categorized visually by Division staff over a six-year cycle. In 2017, the model started using aerial imagery to identify fields and the U.S. Department of Agriculture Cropland Data Layer to produce an annual land use dataset (Graphic 3-5). Details of the Water-Related Land Use program are available on the Division's [Open Water Data](#) website.

Water Budget Results

Utah receives an average of 61.3 million acre-feet of water from precipitation each year. Approximately 8.7 million acre-feet per year of water flows into the state through interstate streams. Much of the interstate stream water in the Colorado River Basin cannot be used within Utah because it's required to be delivered to the Lower Colorado River Basin states. Utah's use of Colorado River water is managed and protected by compacts, which allocate all system users a legal appropriation. (See Chapter 8).

Natural systems consume the vast majority of precipitation that Utah receives. Natural systems include forests, rangelands, riparian habitat, wetlands, lakes, and other water bodies, as well as groundwater aquifers. The remainder of the water is used for agriculture or municipal and industrial

Graphic 3-5 Water-Related Land Use Data Collection Evolution

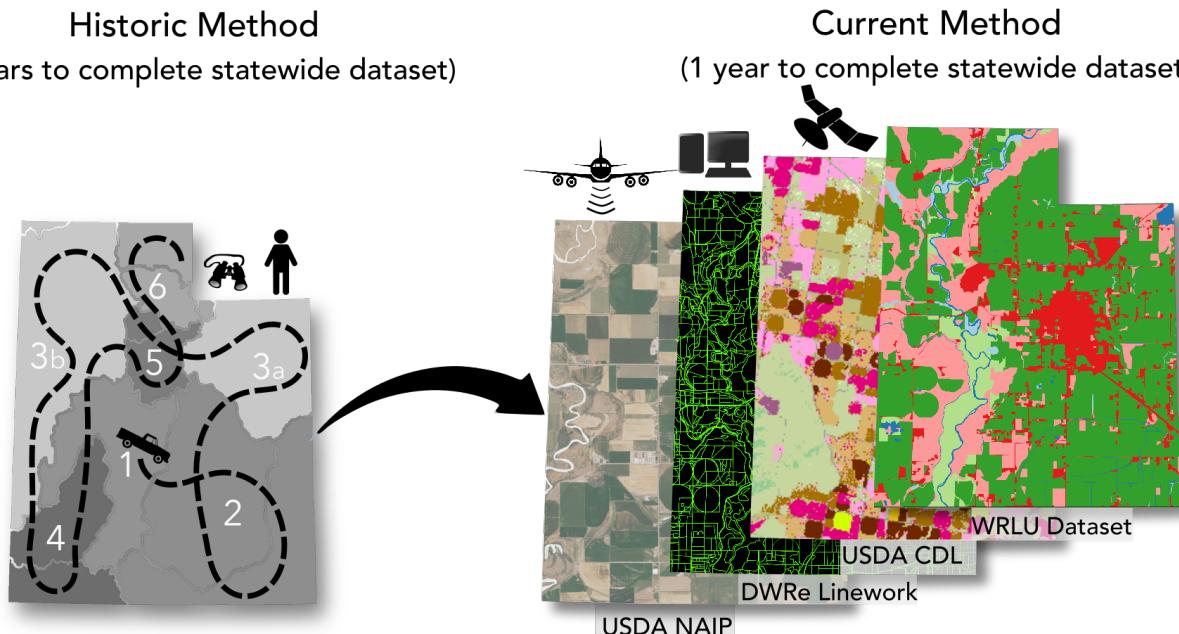


Figure 3-1 Water Diversions in Utah River Basins

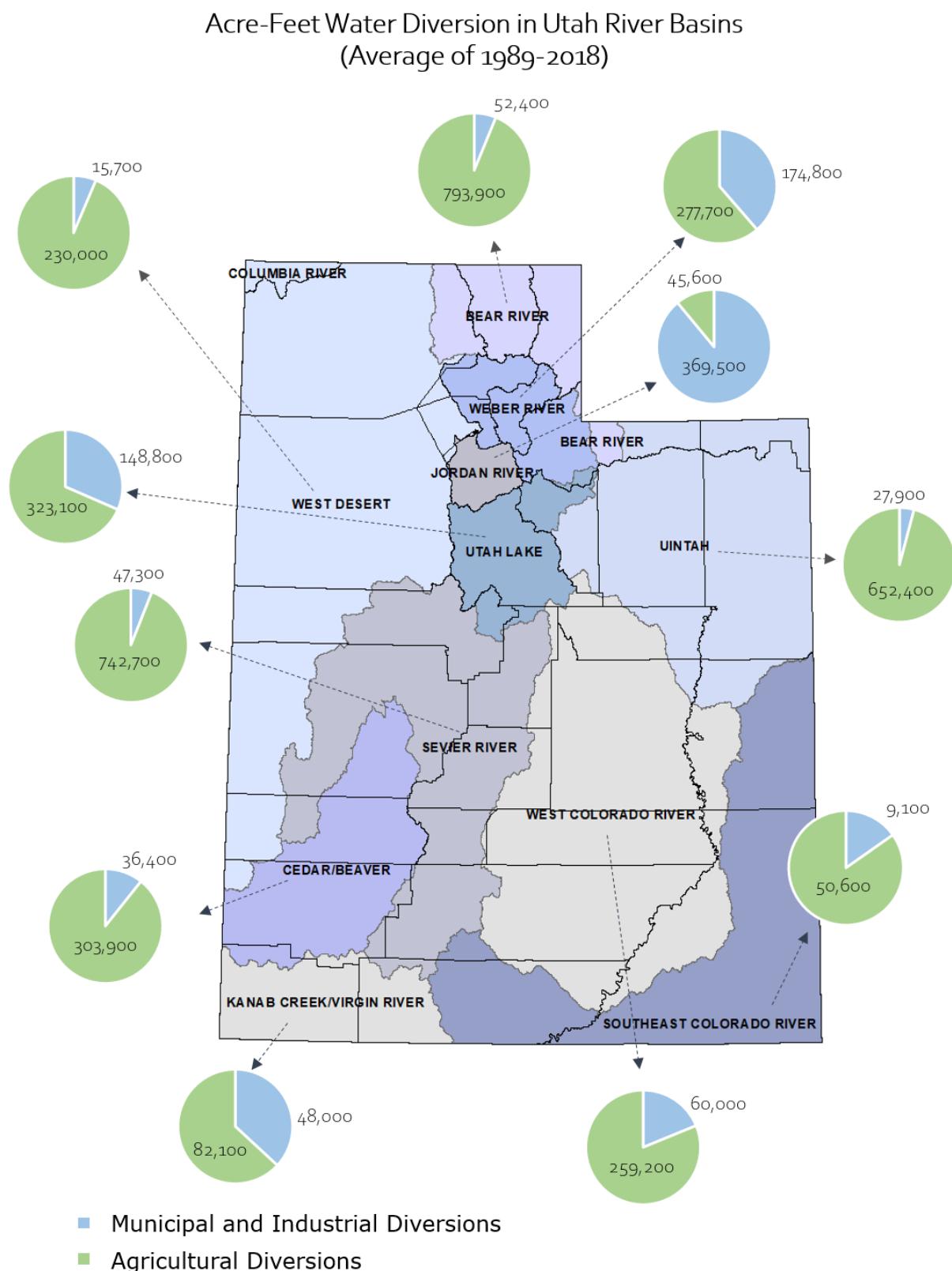
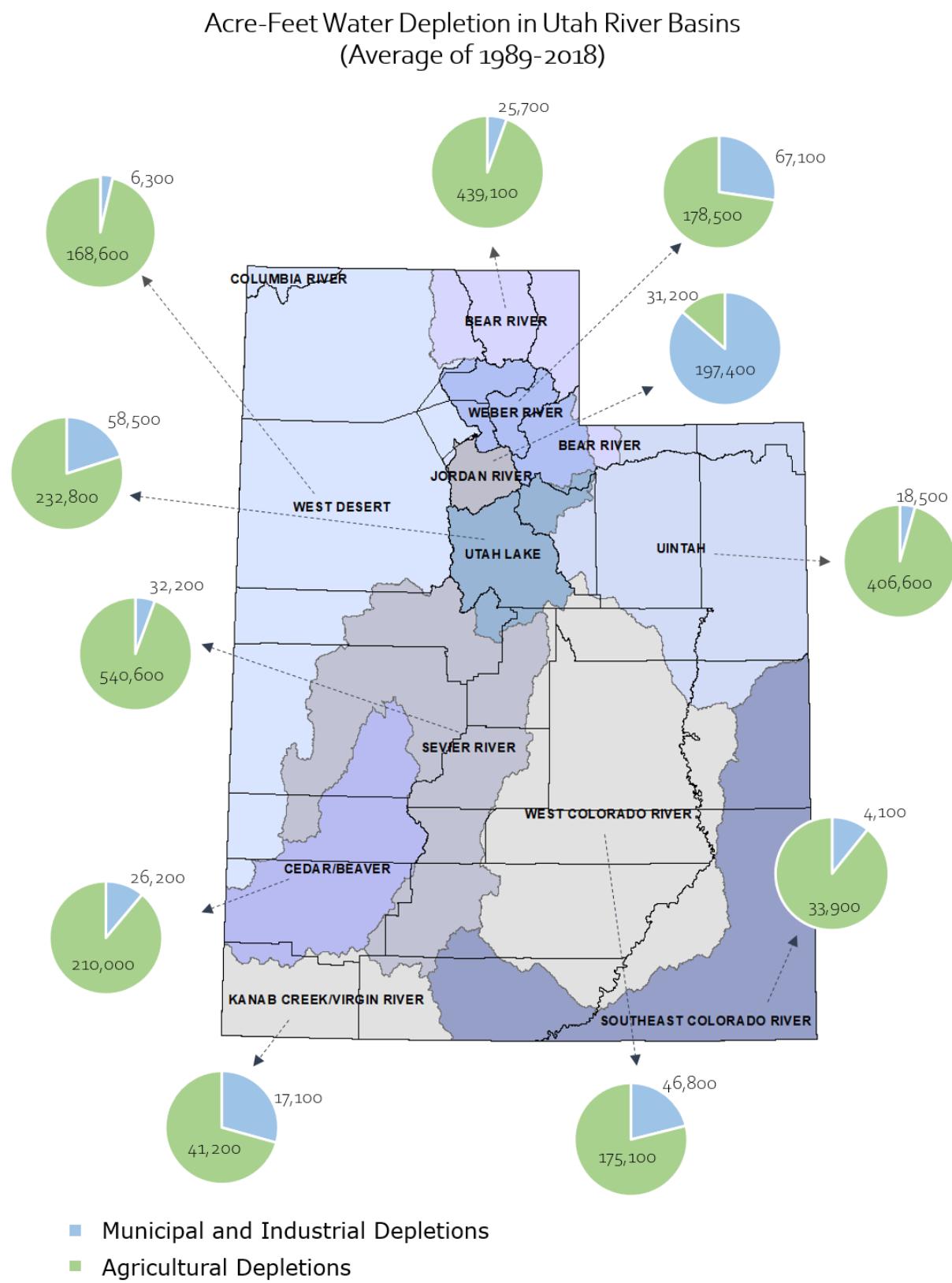


Figure 3-2 Water Depletions in Utah River Basins





Lower Kanarra Creek Falls
PC: Todd Stonely

uses as shown in figures 3-1 and 3-2. The figures show 10 of the 11 basins divert water mostly for agricultural use rather than M&I use. As discussed previously, more water is diverted than depleted. Water Budget data is presented in tabular form in Appendix D.

Evaporation & Evapotranspiration

Evaporation takes a significant amount of Utah's water and is included in the Water Budget model. This is especially significant in a semi-arid state like Utah. The model estimates that evaporation on Great Salt Lake is about 2.6 million acre-feet per year. The model also estimates that evaporation from all storage reservoirs in the state is approximately 1.0 million acre-feet per year. Additional evaporation occurs on lakes, natural and constructed wetlands, and other open bodies of water located throughout the state.

Evapotranspiration (ET), the amount of water used by plants and the water that evaporates from the soil, is an important factor in how much water is depleted. To estimate evapotranspiration, the Water Budget model uses Penman's method, which is endorsed by the American Society of Civil Engineers. This method allows for more crop types to be used, and results for each crop are recorded monthly rather than yearly.

Cloud Seeding – Increasing Water Supply

Weather modification, or cloud seeding, is a process that augments existing water supplies. Wintertime cloud seeding helps

produce precipitation at targeted times and places. Utah's first cloud seeding project began in 1951. In 1973, the Utah Legislature passed the Modification of Weather Act ([Utah Code 73-15](#)), authorizing the Division to manage the program. The Utah Board of Water Resources shares the cost of cloud seeding projects with local sponsors and other interested parties. Currently, the cost-share amount is up to 50% until the annual budget is met. Utah will continue to expand its cloud seeding program and adopt new technologies as budgets allow.



Cloud seeding generator | PC North American Weather Modification Council



How Cloud Seeding Works

In mountainous regions like Utah, clouds form as moist air rises and cools during its passage up and over mountain ranges. Many of these clouds retain more than 90% of their moisture. Typically, silver iodide is released into the air from ground generators to produce artificial nuclei. The nuclei help ice crystals to form from the moisture in

the surrounding air, forming particles large enough to fall to the ground as snow. Graphic 3-6 shows the cloud seeding process. Cloud seeding only takes place in the winter when the optimum conditions exist, primarily super-cooled moisture and prevailing winds. There are currently seven active cloud seeding projects in the state and more than 170 generators, as shown in Map 3-2.

Graphic 3-6 Cloud Seeding Process

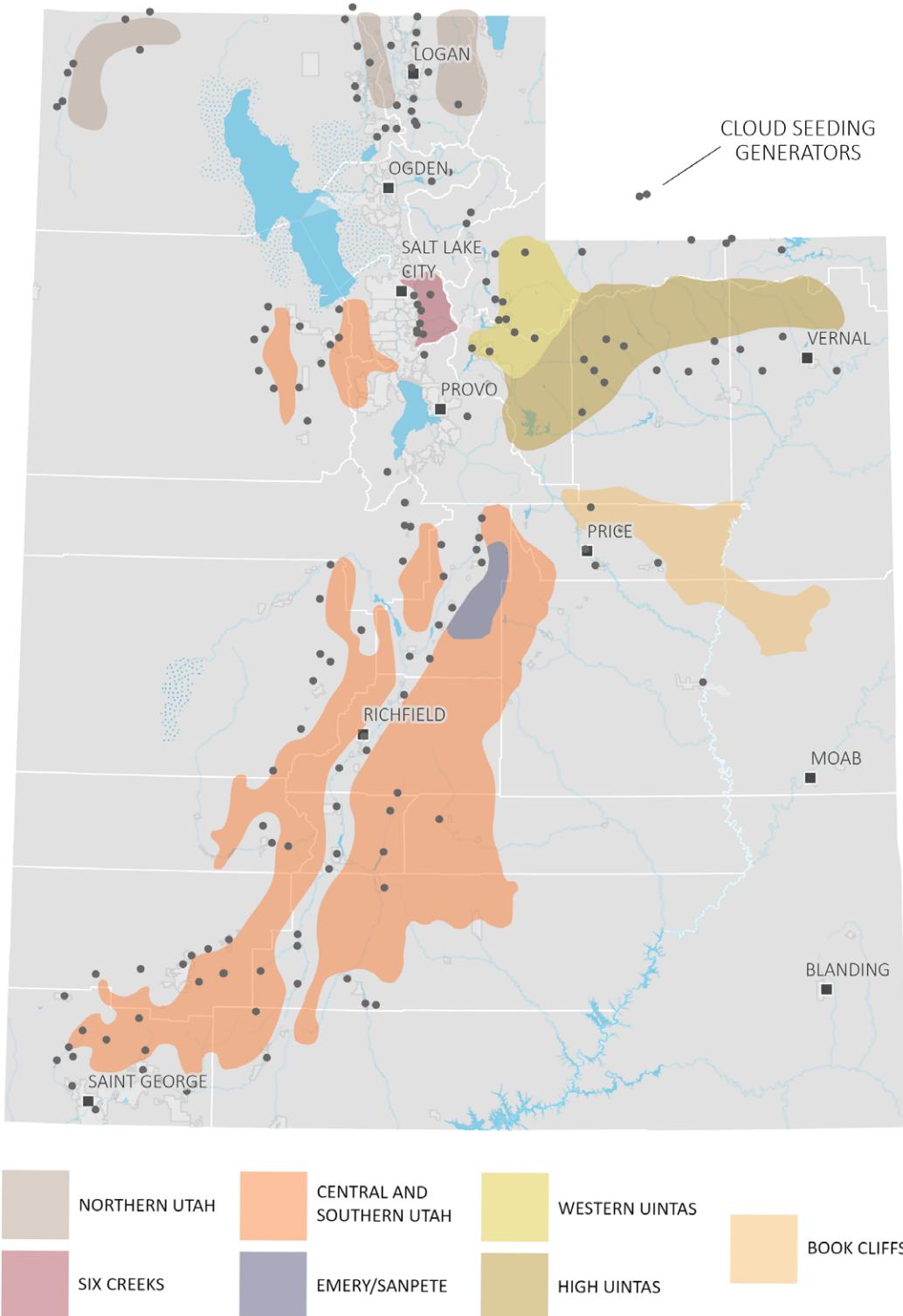
Weather Modification: Cloud Seeding Snowpack/Water Enhancement

- 1.** Moist air rises as it flows over the mountains, cooling and creating clouds composed of supercooled water droplets.
- 2.** Minute amounts of silver iodide in solution are sprayed across a propane flame or released from an aircraft-mounted flare. The air flow up the mountain barrier carries the particles into the clouds.

- ▲ Super-cooled water
- Silver-iodide crystal
- ✳ Ice crystal



Map 3-2 Cloud Seeding Project Areas



Cloud Seeding Cost

In 2015, the Division completed a study that indicated an increase of 3-17% Snow Water Equivalent (SWE) in cloud seeding areas. This resulted in an average annual increase in runoff of nearly 186,700 acre-feet at a cost of about \$2.20 per acre-foot. Cloud seeding is a valuable program that augments the water supply at low-cost per acre-foot.

Table 3-2 lists the estimated 2015 increase in runoff, the cost of operation, and the resulting cost per acre-foot.

Table 3-2 Estimated Increased Runoff and Costs of Cloud Seeding Projects (2015)

Project	Estimated Increased Runoff (ac-ft)	Project Cost	Unit Cost (\$/ac-ft)
Northern Utah	50,698	\$81,929	\$1.62
Central & So Ut	83,654	\$169,359	\$2.02
Western Uintas	22,364	\$69,753	\$3.12
High Uinta	29,947	\$86,758	\$2.90
Total	186,663	\$407,798	\$2.18*

*Indicates average unit cost rather than total.



New snowfall, Brighton Resort, 2019
PC: Dallin McCartney

Water Storage

Groundwater and reservoirs provide valuable storage for the water supply. Both groundwater and reservoir levels are influenced by precipitation, streamflow, and snowpack. Within the Water Budget model, groundwater withdrawals are estimated based on M&I use, agricultural and riparian demand, and [USGS Groundwater Reports](#). Reservoir data is obtained from the [U.S. Bureau of Reclamation](#) and other local reservoir operators. Current reservoir conditions are available on the [Bureau of Reclamation's](#) website.

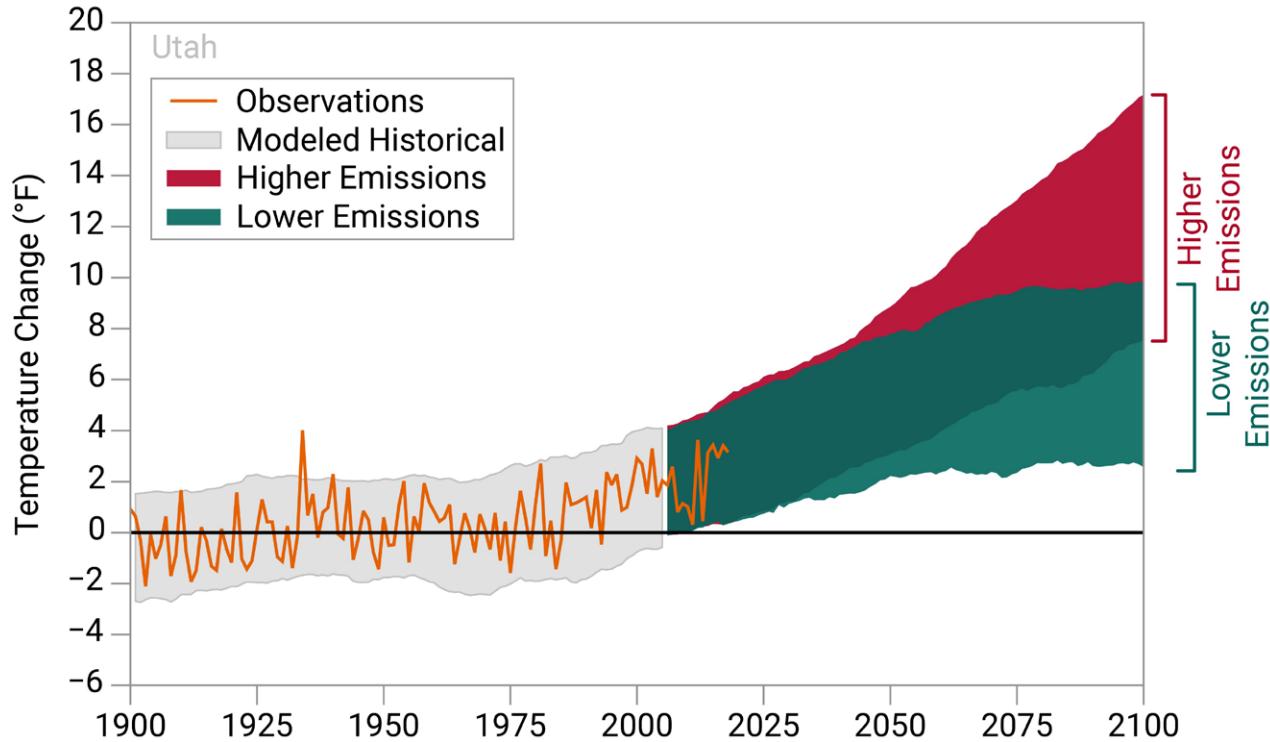
Water Supply Challenges Climate Change

Utah's climate is highly variable and strongly influenced by topographic and land-surface

contrasts, prevailing weather patterns, and proximity to the Pacific Ocean, Gulf of California, and Gulf of Mexico. Utah's historical temperature records from 1950 to 2017 show average temperatures in the state warmed by about 2°F. This rate of change is similar to the average warming of the western United States but higher than the national values of 1.3-1.9°F. The climate-warming rate in Utah in recent decades (2000 to 2017) is higher compared to records from 1950 to 2000. Figure 3-3 illustrates the change in warming rates. Most of the global and regional climate model projections indicate that annual average temperatures across Utah are likely to increase from 5°F to 7°F by the end of the 21st century (Khatri, K 2020).

The same kind of changes are not evident in historically observed precipitation records as they are for temperature. Precipitation

Figure 3-3 Temperature Change Projections



Source: Khatri, K 2020.

varies substantially across Utah depending on exposure to the typical seasonal weather patterns and elevation. Utah's precipitation increases in the winter and decreases in the summer. The majority of the regional future climate studies indicate decreases in snow accumulation and earlier snowmelt in the future. It is also predicted that changes in the frequency, duration, and magnitude of extreme weather events will be some of the consequences of a changing climate.

Changes in climatic variables, including temperature and precipitation, will affect snow hydrology, surface water, reservoir storage, and groundwater in multiple ways. Among the most significant of these anticipated effects are changes in snowpack accumulation and snowmelt, changes in runoff timing and quantity, and additional risks associated with extreme drought and runoff events. Changing climate will alter the hydrologic cycle, simultaneously affecting both water demand and water supply.

Planning for adaptation and mitigation measures to manage and respond to climate change is widely accepted in water planning circles today. Climate change estimates are used to review the suitability of current and planned water resources practices, policies, and infrastructure. The Division is working to evaluate and analyze how, where, and when climate risks will impact Utah's water resources. To plan for adaptation and mitigate the potential changes, climate change is accounted for in water models. The Division is currently using an 11% net increase in evapotranspiration by 2070 in the water demand model (see Chapter 4) and a possible reduction of 10% in future reliable supplies (see Chapter 6).

Drought

Water cannot be counted on to fall where, when, or in the amount we expect. Intense and prolonged drought have prompted research and action to help mitigate impacts. Tree ring studies show that prolonged periods of drought have occurred historically and are expected to occur in the future. Drought can affect many aspects of life in Utah, including agriculture, recreation, environment, tourism, the economy, and even residential landscaping resulting from water restrictions.

The 2018 water year (October 1, 2017, through September 30, 2018) consisted of record-low snowpack and an associated record-low spring runoff. This, combined with one of the warmest summers ever recorded, resulted in the governor declaring a statewide drought emergency. The effects of the drought were offset by high water levels in many reservoirs from a wet 2017 water year. Water reserves are critical to help areas cope with dry years. While most areas can manage one severely dry year, providing an adequate water supply over several years of drought is more challenging. The 2019 water year saw both extremes with high winter precipitation and an extremely dry summer in some areas. St. George set a new record with 155 days in a row with no measurable precipitation.

The 2020 water year had record dry weather and was the eighth-warmest calendar year on record. Soil moisture was also the driest since monitoring began in 2006, which reduces the effect of snowmelt as it's absorbed by dry soils rather than filling streams, rivers, and reservoirs.



The 2021 water year did not provide much relief. The intensity of the drought was extreme or exceptional (the worst two ratings) for most of Utah throughout the year. On March 17, 2021, Gov. Cox declared a state of emergency due to drought, and the state took unprecedented actions to help reduce water use and mitigate impacts of ongoing drought.

Utah Drought Planning

Utah has a State Drought Response Plan. The purpose of this plan is to provide an effective and systematic way for the state to respond to emergency drought circumstances. As there is no universally accepted definition of drought, the Surface Water Supply Index (SWSI) is currently used to objectively quantify a drought that triggers specific state actions. The plan outlines itemized drought response actions and identifies which SWSI values will initiate the described actions.

Within each of the actions, tasks are assigned to different task forces. The task forces gather water availability and drought impact information and provide this information to state government leadership and response agencies. The 2013 State [Drought Response Plan](#) can be found on the Division's website. The Division is working with the Division of Emergency Management to update the plan to include lessons learned from the recent drought as well as new drought measurement methods.

The Evaporative Demand Drought Index estimates the changing evaporative demand and is a new method for measuring drought. The National Oceanic and Atmospheric Administration (NOAA) defines evaporative demand as the “thirst of the atmosphere for any water – on the surface of lakes, rivers, in soils, or in plants.” The index accurately signaled the onset of a 2015 drought in Wyoming as well as a 2017 drought in South Dakota’s Black Hills and the southeastern

United States (NOAA 2017). Currently, the widely accepted U.S. Drought Monitor is the tool of choice, although the Evaporative Demand Drought Index is gaining support.

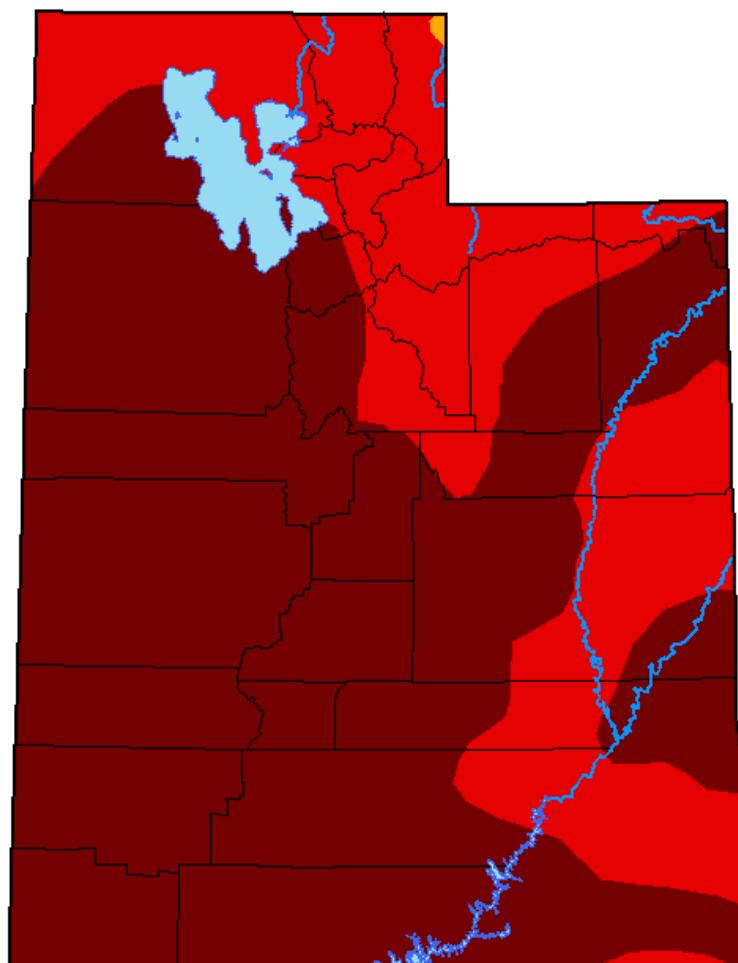
The U.S. Drought Monitor Map is updated weekly by the National Drought Mitigation Center. The [U.S. Drought Monitor](#) website houses current and historical maps. To populate the map, the Drought Monitor authors use multiple weather indicators as well as information from the state on its current water situation. Since rainfall and weather data are more sparse in many rural areas, the Division, the Utah Department of Agriculture and Food, and the Utah Climate Center host monthly webinars with state

and federal partners to provide feedback to the Drought Monitor authors. The goal of these webinars is to gather and share information, which helps create maps that more accurately represent the statewide drought situation.

Drought Mitigation

While Utah has a Drought Response Plan, drought mitigation plans are best prepared on a local level. A mitigation plan includes advance preparation for potential drought conditions, rather than a response once a drought hits. Mitigation plans prepare for droughts locally, creating capital

Graphic 3-7 U.S. Drought Monitor Map for Utah (Sample)



July 20, 2021

(Released Thursday, Jul. 22, 2021)

Valid 8 a.m. EDT

Intensity:

- [White square] None
- [Yellow square] D0 Abnormally Dry
- [Light orange square] D1 Moderate Drought
- [Orange square] D2 Severe Drought
- [Red square] D3 Extreme Drought
- [Dark red square] D4 Exceptional Drought

The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. For more information on the Drought Monitor, go to <https://droughtmonitor.unl.edu/About.aspx>

Author:

Brad Rippey
U.S. Department of Agriculture



droughtmonitor.unl.edu

improvement plans, water use reductions, and vulnerability assessments for water systems.

Recommendations

The Division will work with cooperating partners to implement the following recommendations:

- Evaluate and advance a standard methodology used to determine depletion.
- Analyze existing streamgage and weather station networks within the state and identify where additional resources are needed.
- Investigate ways to improve the Water Budget and supply measurements.
- Identify new cloud seeding areas, implement new technology as it's available, and continue to fund cloud seeding projects to augment Utah's water supply.
- Continue to incorporate climate change in planning models.
- Update and revise the Drought Response Plan.

Chapter 3 Links

Open Water Data Website - dwre-utahdnr.opendata.arcgis.com

PRISM - <http://prism.oregonstate.edu/>

SNOTEL - <https://www.wcc.nrcs.usda.gov/snow/about.html>

Streamgages - <https://waterdata.usgs.gov/nwis/rt>

USGS Groundwater Reports - <https://ut.water.usgs.gov/publications/pubsgw.html>

U.S. Bureau of Reclamation - <https://www.usbr.gov/uc/water/index.html>

Tea-cup Diagrams of Current Reservoir Conditions - <https://www.usbr.gov/uc/water/basin/index.html>

Cloud Seeding to Increase Precipitation Act (Utah Code 73-15) - <https://le.utah.gov/xcode>Title73/Chapter15/73-15.html>

Cloud Seeding Study - <https://water.utah.gov/wp-content/uploads/2019/CloudSeeding/Cloudseeding2015Final.pdf>

Division Drought Website - <https://water.utah.gov/water-data/drought/>

Division Website - <https://water.utah.gov/>

U.S. Drought Monitor - <https://droughtmonitor.unl.edu/>

Drought Mitigation Plans - <https://drought.unl.edu/Planning/DroughtPlans.aspx>

Statewide Water Infrastructure Plan - <http://prepare60.com/Content/SWIP.pdf>

Prepare 60 Website - <http://prepare60.com>

Division of Drinking Water System Sizing and Capacity Evaluation - <https://deq.utah.gov/drinking-water/system-sizing-and-capacity-evaluation>

Citations

Khatri, K. and Courtney Strong, 2020. *Climate Change, Water Resources, and Potential Adaptation Strategies in Utah*. Salt Lake City, Utah. (https://water.utah.gov/wp-content/uploads/2020/11/Finaldraft_ClimateChangeUtah_March2020.pdf)

OLAG 2015. Office of the Legislative Auditor General, *A Performance Audit of Projections of Utah's Water Needs*, 2015.

NOAA 2017. National Oceanic and Atmospheric Administration, "New NOAA tool is helping to predict U.S. droughts, global famine," November 30, 2017. (<https://research.noaa.gov/article/ArtMID/587/ArticleID/12/A-new-NOAA-tool-is-helping-to-predict-US-droughts-global-famine>)