August 2025

Great Salt Lake Basin
Integrated Plan

Municipal and Industrial

WATER CONSERVATION OPPORTUNITIES

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Prepared for:

Utah DNR Water Resources

STATE OF UTAH
DEPARTMENT OF NATURAL RESOURCES

DIVISION OF WATER RESOURCES

MUNICIPAL AND INDUSTRIAL WATER CONSERVATION OPPORTUNITIES

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BACKGROUND

Water conservation has been a priority for Utah state water agencies and water suppliers for decades. Over time, efforts to conserve water in Utah have evolved, expanded, and succeeded; state agencies continually evaluate progress and seek new opportunities.

The 1998 Water Conservation Plan Act aimed to have water suppliers develop strategies to reduce water use (Utah Code § 73-10-32, 2024). The following year, water districts and state agencies launched "Slow the Flow, Save H2O," a campaign to educate the public on strategies to conserve water (Slow the Flow, n.d.). The programs were effective in reducing water demands and marked the beginning of more in-depth studies and conservation efforts.

In 2013, Governor Gary Herbert established the "25 by 2025" goal for municipal and industrial (M&I) water conservation: reduce per-capita water usage by 25% by 2025 based on a 2000 baseline. By 2015, per capita water usage had decreased by at least 18%, prompting the need to update the goal. In 2019, the Division of Water Resources (DWRe) established regional water conservation goals to replace the statewide goal (HAL & BC&A, 2019). The project was based on a 2015 legislative audit, which also recommended improved measurement of water use and the development of statewide tools for reporting (DWRe, 2015). Another study prompted state agencies to improve the water use data collection program, especially for secondary water (BC&A & HAL, 2018). The study also solidified the need for water conservation goals that account for region-specific challenges and opportunities. Many communities are already achieving the goals as water use practices continue to change.

As water conservation efforts continue in Utah, challenges related to Great Salt Lake (GSL) have accelerated the need to be more deliberate and strategic about future actions:

> *Although natural fluctuations in rainfall and streamflow cause Great Salt Lake to rise and fall over annual and decadal periods, there has been no significant long-term change in precipitation or streamflow from mountain tributaries that could have driven this change since pioneers arrived in 1847. By contrast, water development and river diversions since 1847 have produced a persistent reduction of flow into the lake, approaching 40% in recent years. Much of the diverted water is lost via evaporation from agricultural fields, urban landscaping, and industrial activity* (Wurtsbaugh et al., 2017).

Great Salt Lake reached its lowest recorded level in 2022 and needs major changes to recover. Restoring the water level and maintaining it is essential for sustaining the region's economy, health, and ecology. As noted in the Great Salt Lake Strike Team 2025 report:

- *Economic benefits – The Great Salt Lake benefits the Utah economy through industrial activity, aquaculture, and recreation. Low water levels put these benefits at risk.*
- *Health risks from dust – Dust plumes from over 800 square miles of exposed lakebed pose a health and property value risk to Utahns and can increase snowmelt rates in nearby mountains.*
- *Ecological contributions – Great Salt Lake wetlands provide vital habitat for as many as 12 million migratory birds and their food web. The lake's health requires Utah's*

environmental stewardship and will be a focal point leading up to the 2034 Winter Olympic and Paralympic Games (Great Salt Lake Strike Team, 2025).

In response to increasing concerns over the lake, the 2022 Utah legislature appropriated nearly $1 billion for water conservation and infrastructure and passed H.B. 429, which directed DWRe to develop the Great Salt Lake Watershed Integrated Water Assessment (IWA). That same year, DWRe was awarded a WaterSmart Grant by the U.S. Bureau of Reclamation to develop a Great Salt Lake Basin Study. With the shared goals of ensuring a resilient water supply for GSL and its watershed—and supporting the long-term water strategy of the Office of the Great Salt Lake Commissioner—the two efforts were merged into the Great Salt Lake Basin Integrated Plan (GSLBIP).

The GSLBIP is a coordinated set of projects designed to improve understanding of the complex water supply and demand dynamics in the GSL basin (inflows also include trans-basin diversions from the Colorado River Basin). It consists of two phases: Phase One, the Work Plan, and Phase Two, the Integrated Plan. Completed in 2024, the Work Plan “synthesizes information, literature and data across the watershed related to water quantity and quality, water use, water demand, surface and groundwater diversions, depletions and return flows” (DWRe & BOR, 2024). In short, it established the strategic foundation for the knowledge gaps, issues, and actions to be further explored in the Integrated Plan.

One of the knowledge gaps identified in the Work Plan was the need to better understand M&I water demands and their impacts on the Great Salt Lake (DWRe & BOR, 2024). As a part of the Integrated Plan, Hansen, Allen & Luce (HAL) and Jacobs were tasked with identifying M&I water conservation opportunities that could benefit the lake. This report presents findings from analyses of historical M&I water use and depletion and proposes conservation strategies aimed at reducing anthropogenic impact on GSL while continuing to support M&I water needs. An unexpected finding from this effort is the possibility to balance the water supply between a growing population, while conserving agriculture and the environment, by continuing conservation and limiting future depletion through regional collaboration. The scope of this study focuses on M&I associated with public water systems (self-supplied industrial water for mineral extraction, power generation, and others were not considered in this study).

WATER DEMAND AND DEPLETION

An in-depth investigation of M&I water demand and depletion across the GSL basin is essential for developing water management solutions for the future. Several key terms are used when discussing water conservation across the GSL basin:

> **Water demand (diversion)** is the water that is withdrawn from a source. It includes water that is delivered to the end user, depleted, and returned to the hydrologic system.
>
> **Water use** is a portion of water demand that is measured at the user's connection. After use, some of this water returns to the hydrologic system or is depleted.
>
> **Water depletion** is a portion of water demand and use that does not return to the hydrologic system. Usually this means evaporation and transpiration, collectively called evapotranspiration.
>
> **Return flow** is the portion of water that returns to the hydrologic system after use and is available to meet other water demands, including the water supply for GSL.
>
> A **water budget** is a tool that balances water sources and water use (demands) within a basin. A water budget is used to create a better understanding of the amount of surface water and groundwater that is diverted and depleted by major sectors (e.g., municipal and agriculture), which is fundamental to water planning.

The relationship between water diversion and water depletion is critical when evaluating the effectiveness of water conservation programs. While reductions in water use are valuable in water conservation efforts, focusing on reducing water *depletion*—the portion of diverted water that does not return to rivers, streams, or groundwater (hydrologic system)—has direct impacts on GSL water levels. By decreasing water depletion across the GSL basin, more water can remain in the system and ultimately make its way to the lake.

Future water conservation efforts in the M&I sector should seek to reduce *depletion*. This represents a paradigm shift relative to planning efforts up to this point, which have focused on reducing water diversions, not necessarily depletion. **Only reductions in depletion will help minimize human impact on GSL.** Additionally, water rights mechanisms are necessary to ensure that saved water is delivered to GSL (see later sections). **M&I demands offer opportunities for conservation because they are concentrated in urban and industrial centers** where high population density and centralized infrastructure allow for coordinated policy implementation, efficient retrofitting of systems, and public outreach. These concentrated areas also make monitoring and enforcement of water conservation initiatives more feasible and cost-effective.

Aside from GSL itself, depletion from M&I water use is the second-largest sector (after agriculture) for depletion in the GSL basin (Great Salt Lake Strike Team, 2025). Methods to measure depletion have evolved with improved data availability, particularly through inflow and outflow metering, as well as better technology to measure evapotranspiration. The widespread adoption of universal metering has also provided better insight into depletion estimates. Historical depletion estimates have changed and will continue to change. However, not all secondary systems are metered, requiring serval assumptions for outdoor depletion measurement. For this reason, historical depletion estimates should be examined with care.

Depletion from M&I water use has been relatively constant since 1994, only slightly increasing from an average depletion of 320,000 ac-ft/yr (1994–1998) to 347,0000 ac-ft/yr (2019–2023) (Great Salt Lake Strike Team, 2025, Appendix A). However, depletion measurements before 2019 include self-supplied industrial water usage, which may increase depletion measurements. Additional data provided by DWRe indicates that municipal outdoor water usage has increased over time (Appendix A).

Trends indicate that depletion per capita has not substantially grown, regardless of potential uncertainties in past depletion estimates. Over that same period, the population nearly doubled, while depletion has not increased at the same rate. **Nevertheless, future conservation efforts should continue to reduce depletion associated with municipal growth. Responsible development that focuses on long term sustainability is necessary to preserve GSL levels.**

A separate analysis was completed to determine the average M&I water demand and depletion from 2019 to 2023 (Appendix A). It can be reasonably assumed that indoor and outdoor water demands have depletion rates of 5% and 80%, respectively (Figure 1). The average annual demand was approximately 281,000 ac-ft for indoor use, with 14,000 ac-ft depleted. The average annual demand for outdoor is 417,000 ac-ft, with 333,000 ac-ft depleted.

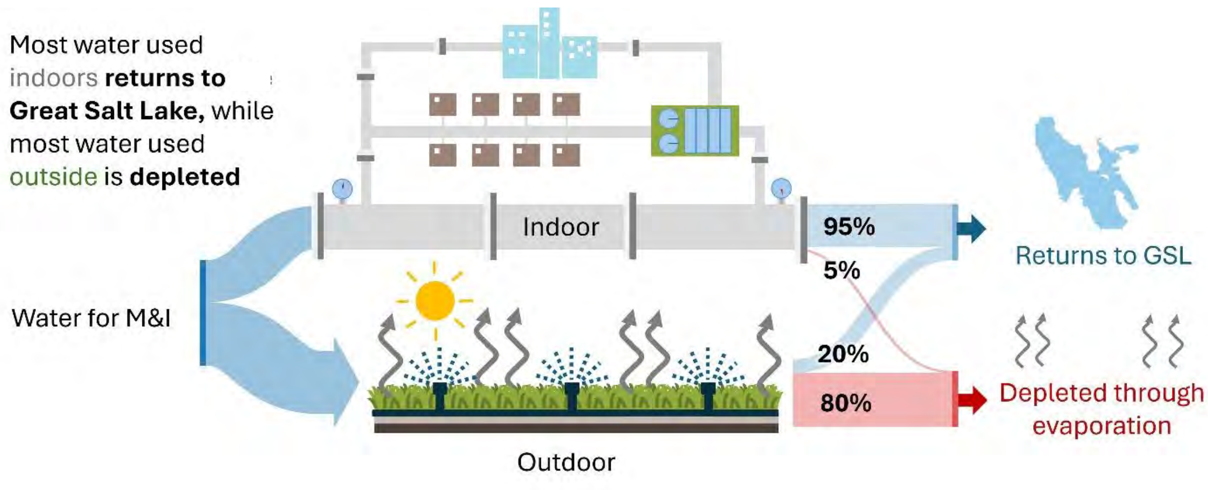


Figure 1. M&I water use and depletion

Outdoor depletion is therefore 24 times greater than indoor depletion. **Outdoor depletion accounts for 96% of total M&I water depletion** (Figure 2). Given the low relative depletion from indoor water use compared to outdoor water use, **water conservation programs that focus on reducing outdoor water use will be most effective in increasing potential flows to GSL**. Complete analyses of M&I demand and depletion are included in Appendices A and B.

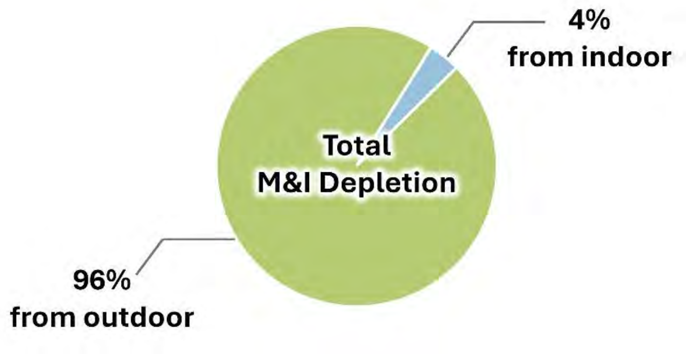


Figure 2. M&I depletion breakdown

Indoor water use has low depletion relative to outdoor depletion because most of it returns to the environment after being treated through the sewer system. For example, water can be diverted for indoor use and *then* returned to GSL, thereby supporting existing communities *and* future development without harming GSL, provided that future development does not increase the depletion rate. Sending water directly to GSL, without going through municipal systems first, requires more water, as it would be meeting two demands. Because indoor demands result in minimal depletion, **it is more efficient to supply indoor uses *on the way* to GSL to be depleted there** (Figure 1).

Historical Trends in Depletion and Conservation

This project analyzes historical trends in depletion throughout the GSL basin (Appendices A and B), impacts of land use conversion on depletion (Appendix C), and outreach to water systems to assess past, existing, and future water conservation efforts (Appendix D).

The analyses indicated the following:

1) Overall, high-level trends indicate that total M&I depletion per capita has not increased significantly and can only remain constant by limiting depletion intensive development (Appendix A; Great Salt Lake Strike Team, 2025). Historical measurement of depletion may not be accurate as methods for estimating have had to account for the lack of long-term metering.
2) A spatial analysis shows that depletion associated with changes in land use declined by 12% from 2016 to 2021, regardless of the type of development (low-density residential to high-density residential or commercial to residential). The range is closer to 15%–20% when considering land use converted from agricultural to municipal. The results indicate that significant savings in depletion can be achieved by developing land responsibly (Appendix C; Appendix K).
3) Outreach indicates that depletion reduction strategies need to be developed in collaboration with multiple water systems and land use authorities to ensure the successful adoption of programs (Appendix D).

The analyses stress the importance of turfgrass area estimates for tracking performance and progress. The existing area of turfgrass in the GSL basin is estimated at 135,000 ac. Quantifying the amount of turfgrass is essential for understanding water conservation opportunities associated with outdoor water usage. Additional analyses quantified turfgrass area by land use and the estimated area of turfgrass installed each year of about 5-10% each year (Appendix E).

BALANCING WATER SUPPLY, DEMAND, AND DEPLETION

During the study, extensive collaboration occurred among DWRe staff, Office of the GSL Commissioner, GSLBIP Steering Committee, GSL Advisory Council, water districts, municipalities, and the team conducting the GSLBIP project called Agricultural Water Conservation Opportunities. The collaboration emphasizes the need to develop strategies that include water demands across all sectors—M&I, agriculture, and the environment. Central to this approach and common to all sectors is the need to reduce depletion.

Current depletion caused by M&I and agriculture is one of the reasons leading to declining inflows to GSL (Wurtsbaugh et al., 2017; Merck & Tarboton, 2024). To reach a mean lake elevation of 4,198 ft by 2054, inflows to the GSL need to increase by 770,000 ac-ft per year. As an interim goal, inflows need to increase by 250,000 ac-ft per year by 2030 to reach healthier lake levels (Great Salt Lake Strike Team, 2025). **As such, a maximum allowed depletion and required return flow should be balanced between M&I and agriculture** (Figure 3)**.** Additionally, a sustainable balance must be maintained to support agriculture as development takes land out of production through voluntary transitions driven by trends and market forces. This is especially important given short- and long-term hydrological variability that further stresses the GSL system.

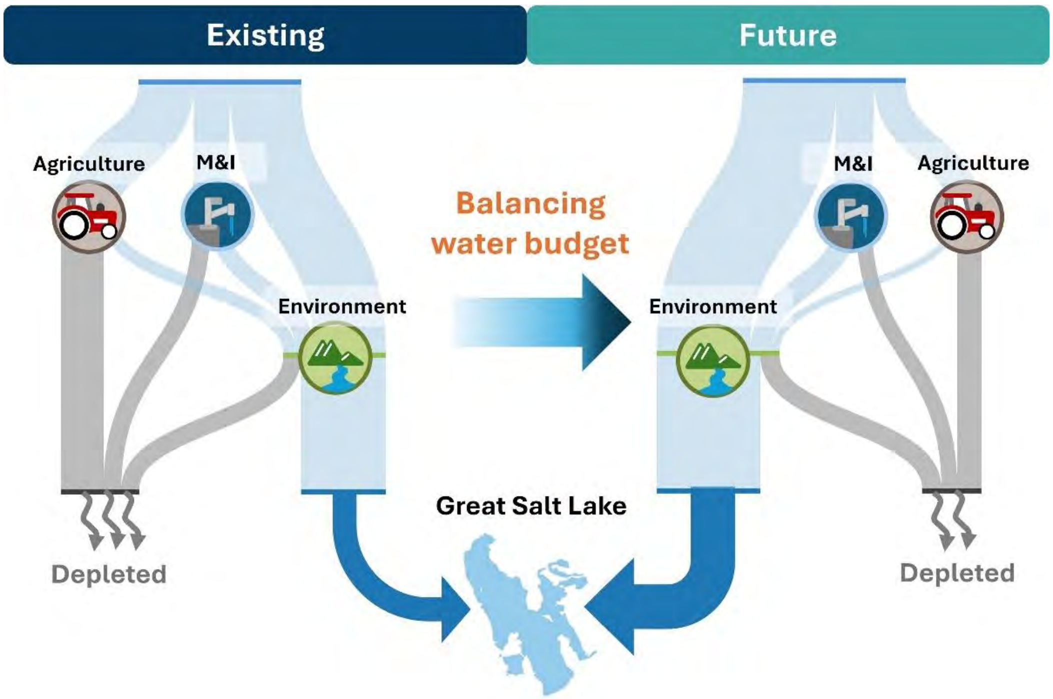


Figure 3. Existing and future water balance

Available water supply in Utah is becoming more constrained by hydrology, infrastructure, and governance (Hopkins & Sowby, 2024). The reliable supply must now support sector-specific demands while also sustaining GSL. **A balance can be achieved by planning demands, including inflows for GSL, based on the reliable water supply**. This study presents several findings that support this conclusion and recommends actions to help future planning efforts at the state, regional, and local levels.

Depletion Budgets & Regional Planning

This study, along with other state efforts, has identified the importance of understanding depletion associated with water demands. From the perspective of M&I, outdoor watering accounts for 96% of existing depletion (see Appendix A). That understanding is critical for identifying strategies to mitigate depletion.

Many of the water conservation programs analyzed in this report already exist in Utah but have not been widely adopted, such as turfgrass-replacement, allotment-based tiered rates, and landscape irrigation efficiency. Furthermore, the collective goal of reducing depletion has not been accepted by all water users. It will require tradeoffs while finding a balance among consumers. Stakeholders' buy-in at the level of citizen, water system, city council, and legislature is necessary to provide long-term solutions to GSL. This can be achieved through more efforts on focused regional planning that encourage collaboration.

The current approach of water planning at the local level is not sustainable; it must be considered at the regional and state levels. Several state-level efforts have been implemented to address these issues, such as the adoption of Senate Bill 110 in 2022, Water as Part of the General Plan. Its goal was to encourage regional planning around land use and water availability. Future efforts can build upon that aimed at developing depletion-focused water planning.

A potential solution is that water budgets—more specifically, depletion budgets—be allocated by region, similar to current regional water conservation goals. This method could better account for local water resource conditions and demands that are not strictly tied to population. The historic per-capita metrics, like gallons per person per day, may not be adequate for certain decisions. Instead, new budgets should identify a depletion limit and required return flow. A reduction in depletion, necessary to provide adequate water supply to GSL, could be determined and allocated to the various GSL sub-basins. Water conservation goals can then be developed based on a regions respective depletion limit. **Region-specific depletion budgets would account for the constraints that different regions experience with water supply and demand.** Regional partnerships can then be used to help allocate depletion to M&I systems. Collaboration is essential to ensure that depletion limits are met while supporting population growth. Similar collaborative efforts have unfolded with groundwater management in Utah County with the Northern Utah County Aquifer Council (NUCAC) and Mt. Nebo Water Agency (MNWA) (Sowby, 2025, 244–245).

Depletion can be budgeted amongst the different subbasins. Budgets should be based on the available water supply and focused on reducing depletion through municipal outdoor watering or agriculture. Splitting things up regionally allows for better allocation of water supply based on current and planned future land uses.

By working together, state water agencies, watershed councils, water districts, and public water systems can develop a depletion budget. This would involve establishing methods to quantify allowable depletion that are based on GSL water levels, allocating that depletion across GSL sub-basins, and developing regional planning strategies that reduce total depletion. This approach would resemble existing regional M&I conservation goals but would focus on managing depletion. This would enable each sub-basin to determine its own preferred balance between agriculture and M&I land use, while staying within its allocated depletion budget.

Depletion Budget Example

Establishing depletion budgets would require significant coordination, as developing budgets, defining required return flows, and allocating them across sub-basin allocations requires thoughtful effort. However, the initial steps could be taken with only slightly more effort than is currently dedicated to conservation planning. Moreover, this could be accomplished without altering existing water policy or state statutes by integrating the budgets into current water conservation goals. Conservation goals can then be developed based on each allocated depletion limit.

Implementing depletion budget strategies would require comparison against a regional depletion limit. Water systems could develop their budget with support from water districts while state water agencies provide approval. Adoption of regional depletion limits can be achieved through small changes to existing water conservation policy. Table 1 outlines two implementation strategies, including important considerations.

Table 1. Potential Depletion Budget Implementation Strategies

<table>
<tr><th>Strategy</th><th>Description</th><th>Important Considerations</th></tr>
<tr><td>Water Conservation Plan</td><td>• Transition from measuring water conservation in terms of per capita.
• Require water systems to determine a budget based on reliable water supply, demand, and depletion.
• Quantify depletion and compare against regional depletion limits and set new conservation goals.</td><td rowspan="2">• Removes one-size fits all criteria associated with per capita conservation goals.
• Implementation does not have to make changes to water rights or existing policy, and solutions could be developed that allow water systems to share water supply or provide additional water to GSL.
• Promotes regional water supply planning that encourages shared redundancy.
• Considers reliable water supply at the regional level, reducing potential of double-counting the available water supply.
• Provides more information on depletion estimates at the local, regional, and state level.
• Works towards better accounting of water supply, demand, and depletion.
• Increases accountability of water users by encouraging regional collaboration.</td></tr>
<tr><td>General Plan</td><td>• Require water systems to determine their balance between reliable water supply, demand, and depletion.
• Plan with neighboring water systems at the regional level to compare impacts to depletion and set new conservation goals.</td></tr>
</table>

Dedication and Delivery

Timing is the ultimate concern when developing solutions for GSL. While future development, such as converting agricultural land for municipal use or increasing residential density, may reduce overall depletion, these changes do not address the immediate need to deliver water to the lake. To meet immediate needs, additional water delivery mechanisms are needed. They could be modest adjustments to existing policies or the development of water management plans that account for water through its entire cycle: production, use, treatment, and return to the natural system.

Throughout the analysis, it became clear that a large number of constraints were related to water rights. **There are few mechanisms to dedicate and deliver water to GSL,** and little incentive to do so. However, water right law has been refined over a century and provides organization that prevents chaos. For this reason, substantial changes to the existing water rights policy are not recommended. Proposed solutions in this realm should focus on careful and collaborative incremental change with an initial emphasis on management plans that account for water from extraction through its return to GSL.

In order for water to return to GSL, conserved water (such as water that is used indoors and is treated and returned to the natural system) should be dedicated to GSL instead of being intercepted by intervening diverters. Short-term solutions are critical for GSL now. Incentives and regional collaboration are needed to encourage water systems to temporarily send conserved water, or water reserved for future use, to GSL without long-term impacts on their water supply portfolio.

M&I WATER CONSERVATION OPPORTUNITIES

This study identifies water conservation strategies that could reduce depletion associated with M&I water demands. These strategies include policy, conservation, and management alternatives. The theme across all strategies: **Water conservation programs should work to reduce depletion.** Regional collaboration bridges the gap between water policy and programs. It helps ensure planning occurs at a regional level—balancing water supply, demand, and depletion. A complete analysis is presented in Appendices F, G, and H. Appendix F identifies water conservation opportunities based on depletion reduction. Costs per acre-foot are quantified for each program in Appendix G and compared against different water supply management alternatives in Appendix H. Key points are summarized here.

Water Policy Alternatives

Future water policy can support M&I depletion reductions and mitigate declining GSL levels. Several strategies could help reduce depletion associated with both existing and future demands. House Bill 274, for example, passed in 2025, requires water utilities to consider conservation when setting water prices. The policy is a proactive step toward mitigating the effects of depletion caused by M&I demands by calling for conservation-based tiered rates. The strategies outlined in the following sections are based on findings from the literature review and outreach conducted during the study.

Future State Legislation for Outdoor Watering

Future policy can be developed with state-level legislation that leads to amendments in local development codes to prohibit non-functional turfgrass in new construction, including but not limited to park strips, and instead promote water-efficient landscaping. Such a policy might target commercial, industrial, and institutional users before moving on to residential users. The policy could include programs that aim to reduce the installation of new turfgrass. See Appendix J. The policy would help prevent new depletion through a reduction in future outdoor watering.

Regional Depletion Budgets

Regional water supply and depletion limits can be designed to provide “budgets” for the different GSL sub-basins. Regional partnerships can be developed that allocate maximum allowed depletion and minimum required return flow among different water systems. Water systems can set water conservation standards for existing and future development’s indoor and outdoor water usage, consistent with their depletion budget, while preserving local autonomy. Regional depletion budgets and goals can be addressed in either the water conservation plan or general plan (Table 1). See Appendix I.

Water Conservation Alternatives

Appendix F contains an extensive list of M&I water conservation programs designed to reduce current depletions in the GSL basin. **Programs targeting outdoor water use consistently demonstrate the greatest potential for depletion reduction.**

In recent years, Utah has prioritized two major programs to reduce outdoor water depletions: secondary water metering and turfgrass conversion. With the passage of House Bill 274 in 2025, tiered water rates are also expected to play an increasingly significant role. The effectiveness of these initiatives and others (see Appendix K) has been analyzed to identify trends and estimate their combined conservation potential across the GSL basin.

Table 2 summarizes the programs with the highest potential for reducing outdoor depletions. It presents both estimated conservation amounts and corresponding costs. Many of these programs are currently in place in Utah and this analysis outlines their potential savings if they were to be expanded. A greater buy-in from all stakeholders is necessary to achieve the estimated depletion savings.

It is important to note that there is an overlap in the depletion reductions targeted by these programs. Therefore, these depletion estimates should not be aggregated across programs. Additional programs and their associated implementation costs are detailed in Appendices F and G.

Table 2. Depletion Reduction Opportunities

Program	Depletion Reduction Estimate *(ac-ft)*	Annualized Unit Cost of Water Depleted	Notes
Basin-Wide Turf Conversion Program	183,000–219,000	$5,100–$17,300	Turfgrass conversion programs can focus on non-functional turfgrass, park strips, and tax-exempt land turfgrass conversion. See Appendix F.
Weather-Based Irrigation Controllers	42,000–135,000	$30–$700	Programs that encourage the installation of irrigation controllers that automatically adjust schedules based on weather to reduce overwatering.
Landscape Irrigation Audits	31,000–106,000	$30–$1,500	On-site audits of irrigation systems to detect inefficiencies/leaks and improve system efficiency.
Secondary Meters & Allotment-Based Tiered Rates	10,000–72,000	$100–$1,400	While tiered rates are crucial for additional depletion savings, especially when combined with the implementation of secondary meters (see Appendix K), their effectiveness is largely influenced by communication: how customers receive and interpret information about their water usage significantly affects outcomes.

Water Management Alternatives

In addition to water conservation strategies, several water management alternatives have been assessed to support the long-term health and water levels of the Great Salt Lake (see Appendix H). These strategies generally fall into two categories: those that aim to increase hydrologic availability by enhancing inflows or reduce consumptive use within the watershed, and those that address the consequences of continued lake decline. Cloud seeding, phragmites removal, and agricultural optimization are designed to shift the basin's water balance by either generating new supply or reducing depletion. While each approach presents unique challenges, costs, uncertainty, and implementation complexity, they share the common goal of improving water availability for the lake.

By contrast, dust mitigation does not improve water availability but rather addresses a growing public health and environmental threat posed by exposed lakebeds. As lake levels continue to fall, the area of dust-emitting hotspots is projected to expand, with associated mitigation costs reaching up to $14.4 billion over 25 years (Appendix H). The expenditures are highly sensitive to lake elevation, underscoring the economic and health benefits of strategies that stabilize or raise lake levels. Dust mitigation should thus be viewed not as a proactive water management strategy but as a reactive and increasingly costly obligation under continued inaction. The implementation of large-scale dust mitigation is typically triggered by violations of federal air quality standards or state-level public health thresholds, making it highly dependent on regulatory enforcement and air quality policy actions. Water management alternative impacts and annualized unit cost are summarized in Table 3.

Table 3. Water Management Alternatives

Strategy	Type of Hydrologic Change	Estimated Hydrologic Change *(ac-ft/year)*	Annualized Unit Cost *($/ac-ft)*
Cloud Seeding	Increased Runoff	102,000	$3.60–$7.10
Agricultural Optimization	Depletion Reduction	44,000 – 467,000	$210 - $2,500
Phragmites Removal	Depletion Reduction	17,000 – 57,000	$610–$4,050
Dust Mitigation	Depletion Increase - Resulting from Dust Control Measures	(−127,000) – (−87,000)	$60–$260[1]

1. Per-unit cost reflects avoided dust mitigation expenses associated with higher lake levels. Each acre-foot of conserved water is estimated to reduce future dust control costs by $60 to $260.

In addition to the water management alternatives shown in Table 3, stormwater optimization has emerged as a potential strategy to capture and deliver water to GSL that might otherwise be lost to evaporation. A case study highlighting the potential benefits and implementation of is provided in Appendix L.

Education and outreach are essential components of effective water conservation, enabling individuals at the local, regional, and state levels to understand the purpose of conservation strategies and how their actions contribute to long-term water sustainability. Initiatives such as the *Slow the Flow* campaign, rebates, and *Localscapes* provide residents with practical tools and educational resources to promote responsible water use. These efforts, and other public outreach programs, help build technical understanding and foster public support for conservation. By empowering individuals with the knowledge, tools, and motivation to change their water use behaviors, these programs are instrumental in advancing basin-wide reduction goals. Continued investment in education and outreach will be critical to sustaining long-term conservation outcomes.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

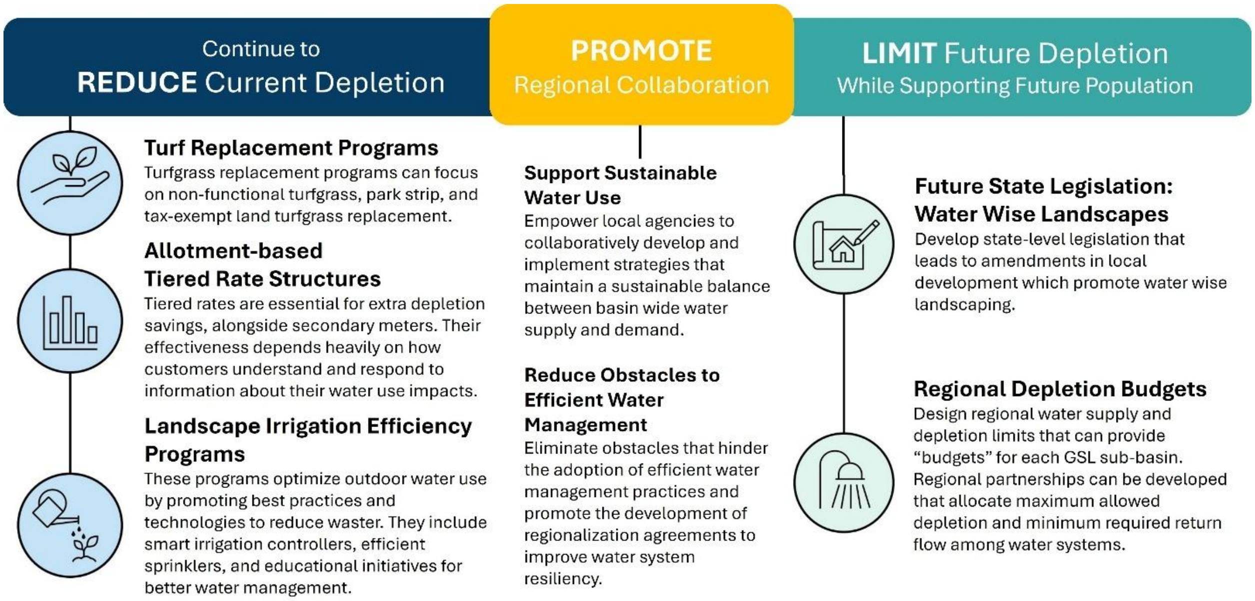
Utah has made significant progress in water conservation over the past few decades, with efforts adapting to the evolving needs of communities. However, recent conditions at the GSL require a renewed focus on conservation, particularly on reducing depletion. This study emphasizes the importance of distinguishing between depletion and other parts of the overall water budget. To reduce human impact on the lake, targeting reductions in depletion is essential.

M&I water consists of two parts: indoor and outdoor use. Indoor use results in relatively low depletion, while outdoor use accounts for 96% of the total M&I depletion. Therefore, water conservation strategies that focus on reducing outdoor demand are essential.

A new balance must be found between water supply, demand, and depletion which includes the health of GSL. Depletion reductions should be allocated fairly among the three main water sectors—M&I, agriculture, and the environment. M&I and agriculture can alter depletion through both engineering and policy solutions. It is possible to balance the water supply for a growing population while conserving agriculture and the environment, by continuing conservation and limiting future depletion through regional collaboration.

Recommendations

Final recommendations are detailed in the Summary of Recommendations figure below. Stakeholders are encouraged to consider the recommendations and work with state agencies on implementation. Additional discussion on these strategies is provided in Appendix I.



Future policies and programs identified through the GSLBIP can help water systems operate within their depletion budget while supporting GSL's recovery. Such policies include establishing regional depletion budgets, modifying land use codes aimed at outdoor watering and landscaping, and further implementation of regional collaboration to facilitate redistribution of water supply. Water conservation programs should focus on turf replacement, outdoor watering efficiency, and tiered rates for outdoor watering.

Strategic planning, combined with the new policy and adoption of conservation programs to establish regional depletion budgets, can help Utah build a more resilient water supply for M&I users, agricultural users, and the environment.

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APPENDIX A HISTORICAL WATER DEMAND AND DEPLETION

M&I Water Demand and Population Growth

While it is often assumed that population growth directly drives increases in water demand, municipal and industrial (M&I) water use across the Great Salt Lake (GSL) basin from 2015 to 2023 do not consistently track with population growth (Figure A-1). It is important to note that, however, increased conservation efforts and management changes in recent years may mask longer-term demand patterns. This suggests that population growth, while a contributing factor, is not the sole driver of declining lake levels. In fact, sustained levels of water demand, regardless of population growth, can continue to limit inflows to the lake. These patterns emphasize the importance of examining depletion trends to understand how to manage M&I depletion proactively. With responsible development and a focus on long term water efficiency, such as implementing reductions in outdoor water use, it may be possible to accommodate future population growth without proportionally increasing pressure on the lake.

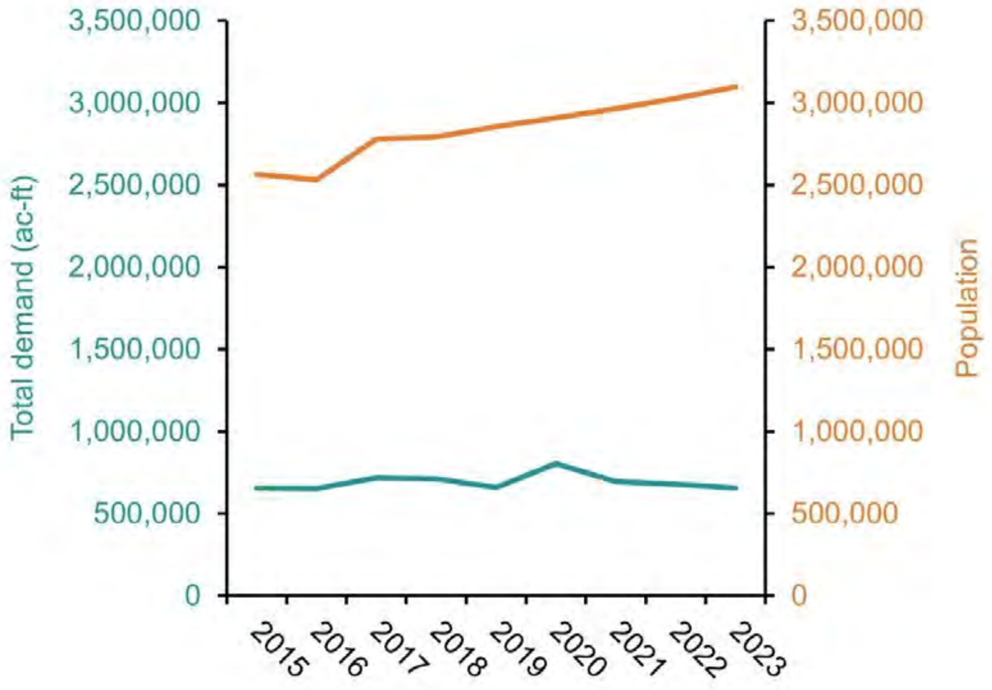
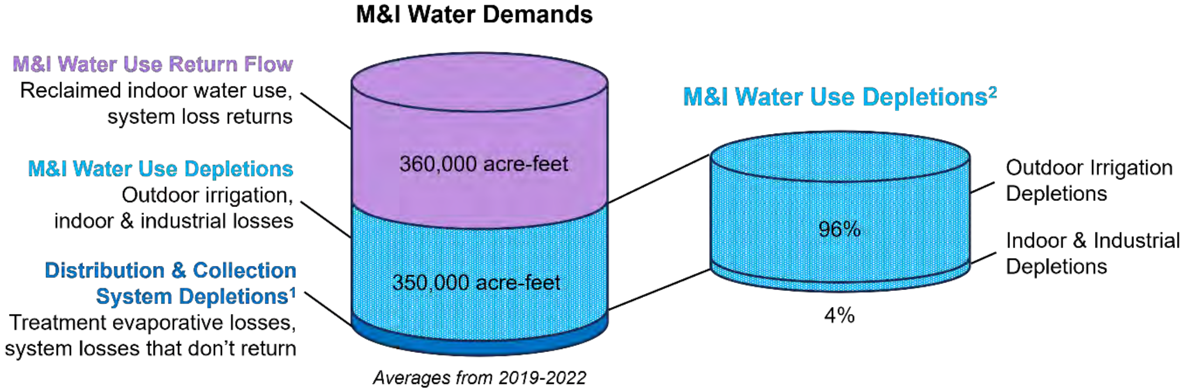


Figure A-1. Total M&I Demand and Population Growth in the GSL Basin

Water use and population data from public water systems within major sub-basins in the GSL basin—Bear River, Jordan River, Utah Lake, Weber River, and West Desert—were obtained from DWRi and DWRe for years 2015 to 2023 and used to generate the data shown in Figure A-1. For each system, potable and secondary water use were combined to calculate total annual demand. System level demands were then summed to determine total annual water demand in the GSL basin. Similarly, reported population counts from each system were aggregated to estimate the annual population in the GSL basin.

Depletion in M&I

Water demand within an M&I system has three pathways: (1) return flows – reclaimed indoor water and recoverable system losses; (2) water use depletion – water that is depleted during outdoor irrigation and indoor/ industrial processes; (3) distribution and collection system depletions – water that is depleted during water treatment and or throughout the system (Figure A-2). Simply reducing the total water demand does not lead to a proportional reduction in water depletion. Although addressing water losses that occur from distribution and collection systems is important, depletion that occurs during water use accounts for a larger share of non-recoverable water loss. As such, understanding water use depletion is critical for developing future policies and programs that can help water systems operate within their depletion budget while supporting GSL's recovery.



1. Distribution & Collection System Depletions are assumed to be on the order of 10% of total M&I depletions, additional data is being collected to substantiate an appropriate range.

2. Percentages based on 60% of M&I water production supporting outdoor use, remaining 40% for indoor use, and depletion factors of 80% and 5% for outdoor and indoor uses respectively.

Figure A-2. Summary of Depletion

Water use data from public water systems within major sub-basins in the GSL basin—Bear River, Jordan River, Utah Lake, Weber River, and West Desert—were obtained from DWRi and DWRe for years 2019 to 2022 and used to generate the data shown in Figure A-2.

Historical Water Demands

Demand Estimate Methodology

Historical water demands across the GSL basin were analyzed to estimate the distribution of water use between indoor and outdoor usage. The data shown in the tables and figures in this section (Table A-1, Figure A-3, and Figure A-4) all reference water demand data from public water systems across the GSL basin that were obtained from DWRe for the years 2019 to 2023. Demands for self-supplied industrial water for mineral extraction, power generation, and others were not included. The water demands were categorized by DWRe as "potable" or "secondary," which represent water used by drinking water and irrigation systems, respectively.

In practice, a portion of potable water is used for outdoor irrigation. However, the potable water demand data did not distinguish between water used for indoor or outdoor purposes – only the total volume used by drinking water systems is reported. To estimate indoor and outdoor demands, the following assumptions were applied:

- Indoor demand: 60% of the total volume used by the drinking water system (potable).
- Outdoor demand: 40% of the total volume used by the drinking water system (potable), plus 100% of the volume used by the irrigation system (secondary).

These assumptions were derived from an analysis of monthly source production data for every water system in Utah from 2019 to 2022 (DWRi, n.d.). In the analysis, average winter production volumes (representing primarily indoor use) were compared to average summer production volumes (representing both indoor and outdoor use). The results indicated that 39% to 42% of potable water was used for outdoor purposes. Based on this range, outdoor demands were estimated as 40% of potable water use, consistent with the assumptions above.

Demand Estimate Results

The average annual water demand across the GSL basin has been approximately 698,000 ac-ft/yr in recent years (Table A-1). Since 2019, the annual total water demand has been about 671,000 ac-ft/yr, apart from 2020, which had a water demand of 803,000 ac-ft. The proportions of indoor and outdoor demands have also remained relatively stable over time, with 60% of total demand used for outdoor purposes and 40% for indoor purposes (Table A-1) However, it is worth noting that outdoor water use has increased over the longer term, dating back to the 1980s (Moore, 2025).

Table A-1. Historical Annual Water Demand in GSL Basin

Year	Indoor Demand (ac-ft)	Outdoor Demand (ac-ft)	Total Demand (ac-ft)
2019	270,000	387,000	657,000
2020	315,000	488,000	803,000
2021	279,000	417,000	696,000
2022	268,000	409,000	677,000
2023	271,000	384,000	655,000
Average	**281,000**	**417,000**	**698,000**

Note: All values in the table were rounded to the nearest 1,000 ac-ft.

Total annual water demand differs by GSL sub-basin, with West Desert typically having the lowest water demand and the Jordan River sub-basin the highest (Figure A-3). Since 2019, the water demand for each sub-basin has remained steady over time, except for 2020, when all sub-basins experienced an increase in demand (the increases for Bear River and West Desert are less apparent in Figure A-3 due to scale).

The distribution of indoor and outdoor water demands also differ by GSL sub-basin (Figure A-4). For example, water demand in the West Desert tends to be evenly split, with approximately 53% of total sub-basin demand used for indoor purposes and 47% used for outdoor purposes. Meanwhile, water demands in Weber River were primarily driven by outdoor use, with approximately 75% of the total sub-basin demand attributed to outdoor use and 25% to indoor. The proportion of indoor and outdoor demands within each sub-basin have remained fairly constant since 2019 (Figure A-4).

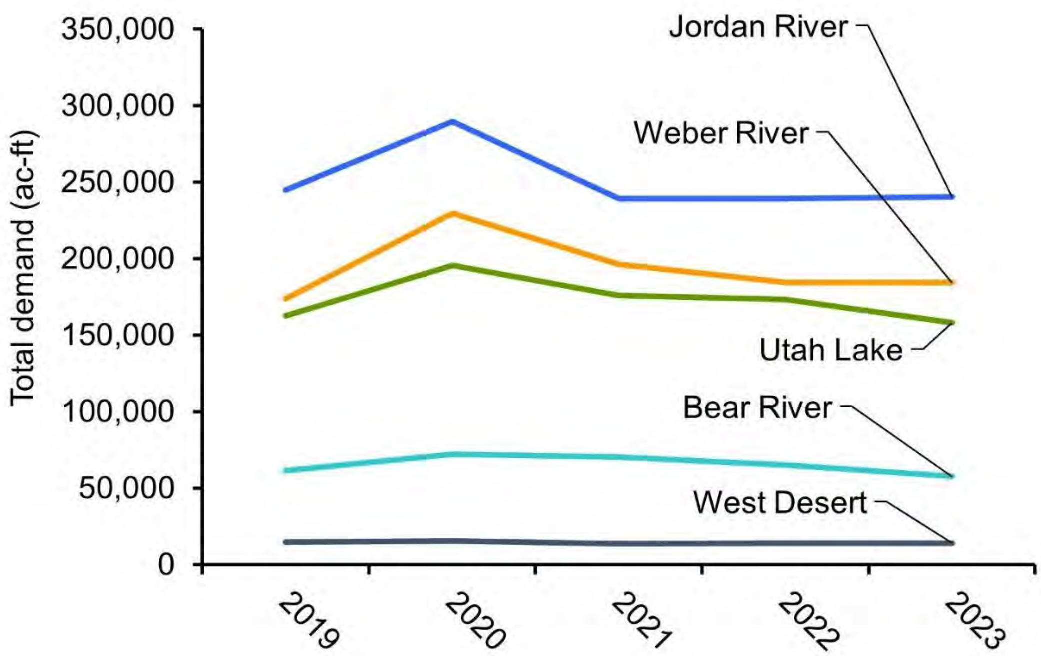


Figure A-3. Total M&I Demand Trends by Sub-Basin

Note: Standard (non-stacked) line chart; each line represents an independent data series.

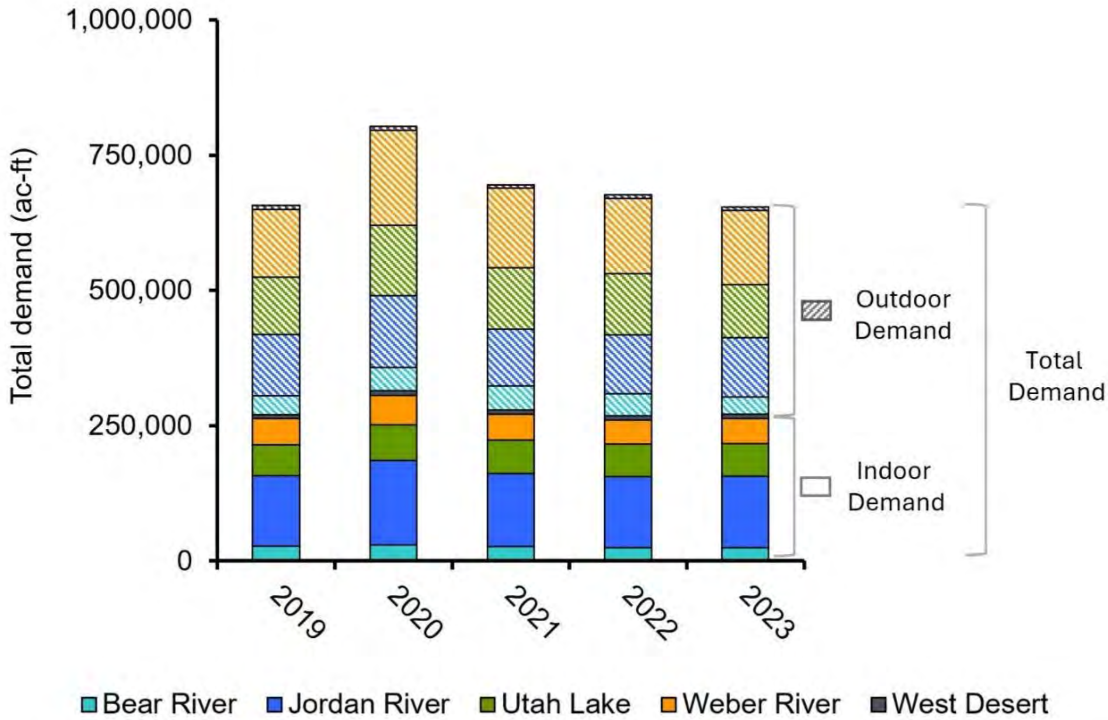


Figure A-4. Indoor and Outdoor Demand Trends by Sub-Basin

Note: Stacked bar chart; each segment represents demand contribution from each sub-basin.

Historical Water Depletion

Depletion Estimate Methodology

After analyzing historical water demand, historical water depletion estimates were made for the GSL basin to analyze the distribution of water depletion associated with indoor and outdoor demands. Unlike water demand, depletion is difficult to measure. As such, water depletion estimates were made using water demand data (the same as described in the Demand Estimate Methodology section) and the following assumptions:

- Indoor depletion: 5% of indoor demand
- Outdoor depletion: 80% of outdoor demand
- Total depletion: indoor and outdoor depletion combined

While the assumptions used to estimate indoor and outdoor depletion were considered representative, the resulting depletion estimates should be viewed as general approximations due to their static nature. Indoor and outdoor depletion estimates will vary as methodologies are improved, and actual depletion will vary over time due to changes in factors such as land use, climate, population, and infrastructure.

The data shown in the tables and figures in this section reference the same water demand data described in the previous section – specifically Figure A-5, Table A-4, Figure A-6, Figure A-7, and Table A-5, unless otherwise stated (e.g., Table A-2 and Table A-3). Briefly, the water demand data from public water systems across the GSL basin were obtained from DWRe for the years 2019 to 2023. Demands for self-supplied industrial water for mineral extraction, power generation, and others were not included. The water demands were categorized by DWRe as "potable" or "secondary," which represent water used by drinking water and irrigation systems, respectively. This data was used to calculate depletion estimates.

Indoor Depletion Estimate Methodology

Indoor water depletion estimate assumptions were based on a report by DWRe, which estimated that about 5% of indoor water demand is depleted (DWRe, 2010). The 5% estimate is expected, given that indoor water remains within enclosed infrastructure – such as pipes and treatment facilities – which limit opportunities for loss through evaporation or depletion processes typical of outdoor use. While some indoor water is lost through system leaks or treatment processes, the majority eventually returns to the environment. Water may also be depleted after it is "lost." For example, water lost due to system leakages or removal during various water treatment processes is likely returned to the GSL through the groundwater system, with a portion of that water being depleted along the way (HAL & LimnoTech, 2023). The 5% estimate was discussed with DWRe staff and was considered as a reasonable assumption to use for quantifying historic indoor depletion in the GSL basin from 2019 to 2023.

Outdoor Depletion Estimate Methodology

Compared to drinking water systems, there is less data about irrigation practices, outdoor water use, runoff, and evaporation. Outdoor watering habits vary significantly between households and irrigation systems in the basin, and losses from sprinkler systems are not consistently measured. In addition, documented measurements of outdoor depletion in Utah are limited.

Outdoor depletion estimate assumptions were developed based on estimated outdoor water losses from turfgrass, as data related to turfgrass in the GSL basin was more readily available compared to data on other sources of outdoor water loss, such as evaporation from hardscapes or trees.

In general, outdoor depletion generally refers to the amount of water lost through evaporation, transpiration, and/or evapotranspiration by agricultural crops. For the M&I sector, outdoor depletion typically refers to the amount of water lost through evapotranspiration (ET) by turfgrass and inefficiencies of irrigation methods. As such, an overall outdoor water loss estimate was calculated using typical water application rates on turfgrass, sprinkler system efficiency and losses, and turfgrass consumptive use:

- Typical water application rate: Estimated using water use data from DWRe and turfgrass data from DWRe Greenspace Model. The resulting calculations indicated an average application rate of approximately 36 inches on turfgrass across the GSL basin.
- Sprinkler system efficiency and losses: Based on literature values. Residential sprinkler systems have operational efficiencies (distribution uniformity coefficients) that tend to range from 40 to 80% (Barker, 2025; Endter-Wada, 2019; Hill, 2000; Hill, 2001; Jackson, 2003; Salt Lake Department of Public Utilities, 2023), which vary based on sprinkler type, operating pressure, nozzle size and spacing, sprinkler maintenance and condition, wind, air temperature, humidity, and irrigation schedule. A sprinkler system efficiency of 65% was selected to reflect a value near the center of the reported range (Leinauer & Smeal, 2018).
- Turfgrass consumptive use: Derived from Utah State University studies that estimated vegetation consumptive use throughout the state of Utah. The estimates in the study were not paired with water usage. The average turfgrass consumptive use and net irrigation requirements for test locations in the GSL basin were 24.5 inches and 17.5 inches, respectively (Table A-2) (Hill et al., 2011).
- Overall outdoor water loss estimate calculation: (36 inches) * (1 − 0.65) + 17.5 inches) / 36 inches = 84%

It is important to note that the assumptions used for water application rates, sprinkler efficiencies, turfgrass consumptive use are general approximations; actual values can vary greatly across different locations and conditions. While the intent of this analysis was to provide an average outdoor water depletion estimate across the GSL basin, the estimates mask the substantial variability observed in the literature and by professionals. Consequently, there is a need to verify these values with more recent, Utah-specific data.

The resulting 84% outdoor water loss estimate was compared to literature and revised accordingly. Although documentation of outdoor depletion measurements in Utah is limited, among them is a study completed by Utah State University that measured the turfgrass depletion at multiple sites throughout Utah from 2002 to 2008 (Hill & Barker, 2010). The study reported average depletion rates ranging from 72% to 86% in the GSL basin (Table A-3). Based on this comparison, the outdoor water loss assumption was adjusted from 84% to 80% to reflect a value near the center of the reported range; 80% was used for quantifying historic outdoor depletion in the GSL basin from 2019 to 2023.

Table A-2. Estimated Annual Consumptive Use of Turfgrass[1]

Location	Estimated Consumptive Use (in.)	Net Irrigation Requirement (in.)	Location	Estimated Consumptive Use (in.)	Net Irrigation Requirement (in.)
Alpine	23.63	16.83	Ogden	27.76	19.59
Bear River Bay	25.4	19.16	Orem	24.7	19.22
Beaver	20.05	16.44	Pleasant Grove	23.85	16.66
Brigham City Waste	26.49	18.88	Provo	24.47	17.14
Coalville	17.54	12.27	Riverdale	25.45	17.13
Draper Point of Mtn	28.19	21.48	Salt Lake City	27.78	20.19
Farmington	28.46	18.34	Santaquin	24.41	16.57
Heber	18.33	13.99	Spanish Fork	24.86	16.22
Logan	23.22	16.35	Tooele	27.44	18.70
Average Consumptive Use		24.5	**Average Net Irrigation Requirement**		17.5

1. Data source from Robert Hill and Burdette Barker. "Crop and Wetland Consumptive Use and Open Water Surface Evaporation for Utah. Appendix I. Updated Consumptive Use Estimates at NWS Stations" *Utah State University*, 2011.

Table A-3. Summary of Turfgrass Consumptive Use[1]

Location	Lowest Measured Consumptive Use			Highest Measured Consumptive Use		
	Measured Consumptive Use (ET), in.	Water Applied (Irr. + Rain + Water Added), in.	Measured Depletion (%)	Measured Consumptive Use (ET), in.	Water Applied (Irr. + Rain + Water Added), in.	Measured Depletion (%)
Logan	11.2	25.21	*44%*	35.2	38.4	*92%*
Murray	22.22	22.57	*98%*	30.51	33.4	*91%*
Spanish Fork	14.16	19.54	*72%*	30.39	40.29	*75%*
Average	**15.86**	**22.44**	***72%***	**32.03**	**37.36**	***86%***

1. Data source from Robert Hill and Burdette Barker. "Verification of Turfgrass Evapotranspiration in Utah." *Utah State University*, 2010.

Depletion Estimate Results

The depletion estimates presented below are based on the methods, data, and assumptions available at the time of this analysis. The results are general approximations for comparison *purposes only and extreme care should be taken when applying them. The intent of this analysis is to highlight broad patterns and differences in the distribution of indoor and outdoor depletion. With time, future refinements in methodology and new available data will lead to more refined insights into historical depletion across the GSL basin.*

The average annual depletion estimate across the GSL basin has been approximately 347,000 ac-ft/yr (Table A-4) in recent years, an estimate that falls within the historical range reported by the Great Salt Lake Strike Team. According to their 2025 report, the average annual depletion ranged from 320,000 ac-ft (1989-1993) to 362,000 ac-ft (2014-2018) (Great Salt Lake Strike Team, 2025).

Over time, the estimated total M&I depletion has remained relatively stable and has mirrored total M&I demand (Figure A-5). Additionally, the estimated proportion of indoor and outdoor depletion has also shown little variation throughout the observed period (Figure A-5).

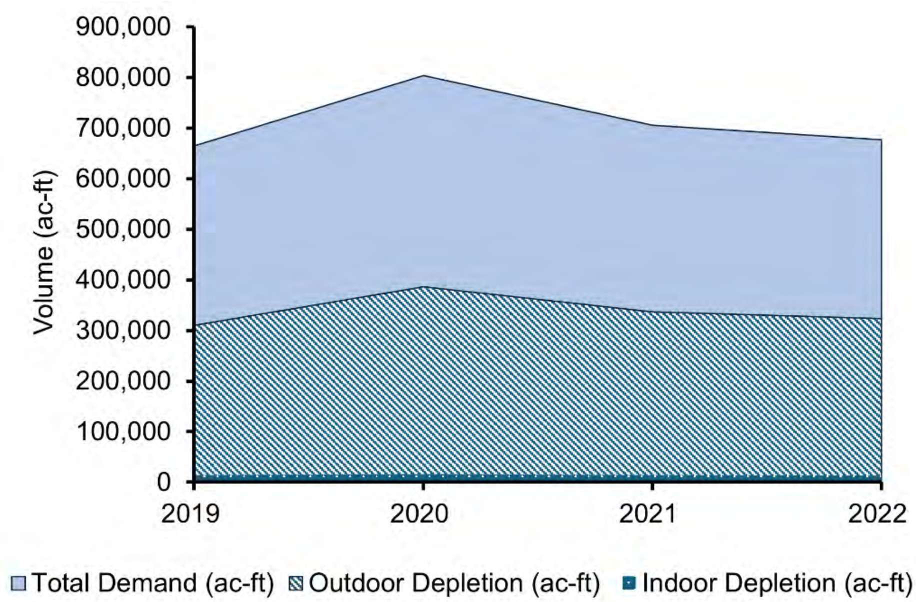


Figure A-5. Demand and Depletion Volume Comparison
Note: Standard (non-stacked) area chart; each line represents an independent data series.

The estimated average annual outdoor depletion has made up about 96% of the total M&I depletion (calculated from average annual depletion values in Table A-4), with depletion estimates showing that outdoor depletion (333,000 ac-ft/yr) has been about 24 times greater than indoor depletion.

Table A-4. Historical Depletion Estimates Across GSL Basin

Year	Indoor Depletion (ac-ft)	Outdoor Depletion (ac-ft)	Total Depletion (ac-ft)
2019	14,000	309,000	323,000
2020	16,000	391,000	406,000
2021	14,000	333,000	347,000
2022	13,000	327,000	340,000
2023	14,000	307,000	321,000
Average	**14,000**	**333,000**	**347,000**

Note: All values in the table were rounded to the nearest 1,000 ac-ft.

The estimated annual depletion differed by GSL sub-basin, with West Desert having the lowest depletion and Weber River sub-basin having the highest (Figure A-6). Since 2019, the depletion for each sub-basin has remained steady over time, except for 2020, when all sub-basins experienced an increase in depletion (the increases for Bear River and West Desert are less apparent in Figure A-6 due to scale). Outdoor depletion accounts for most of the total depletion in each GSL sub-basin, with approximately 93% to 98% attributed outdoor use and 2% to 7% to indoor use (Figure A-7) in recent years. In addition, the estimated distribution of indoor and outdoor depletion within each sub-basin has remained steady since 2019 (Figure A-7).

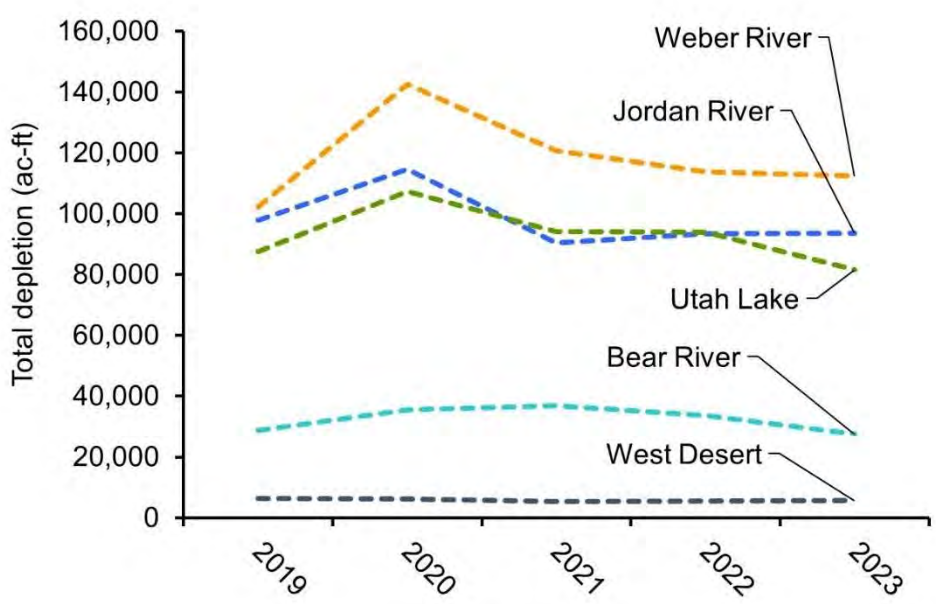


Figure A-6. Total M&I Depletion Trends by Sub-Basin
Note: Standard (non-stacked) line chart; each line represents an independent data series.

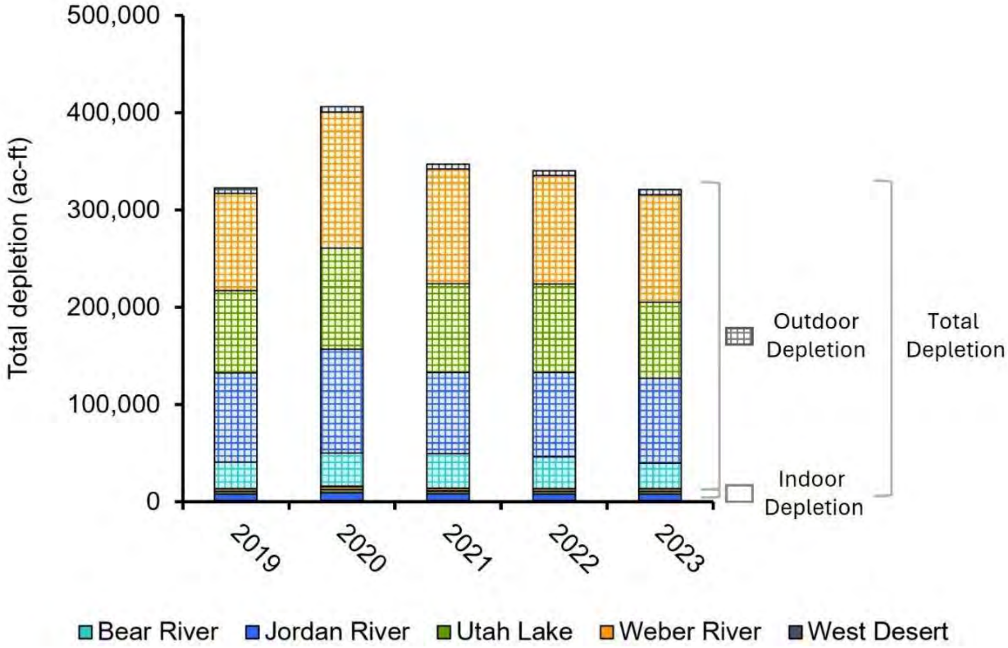


Figure A-7. Indoor and Outdoor Depletion Trends by Sub-Basin

Note: Standard (non-stacked) area chart; each line represents an independent data series.

Table A-5. Historical Depletion Estimates Across Sub-Basin (ac-ft)

Year	2019		2020		2021		2022		2023	
Sub-basin	**Indoor**	**Outdoor**	**Indoor**	**Outdoor**	**Indoor**	**Outdoor**	**Indoor**	**Outdoor**	**Indoor**	**Outdoor**
Bear River	1,000	27,000	1,000	34,000	1,000	36,000	1,000	32,000	1,000	26,000
Jordan River	7,000	91,000	8,000	107,000	7,000	84,000	7,000	87,000	7,000	87,000
Utah Lake	3,000	85,000	3,000	104,000	3,000	91,000	3,000	91,000	3,000	79,000
Weber River	2,000	100,000	3,000	140,000	2,000	118,000	2,000	112,000	2,000	110,000
West Desert	350	6,100	430	5,800	380	5,000	390	5,100	380	5,300
Totals	14,000	309,000	16,000	391,000	14,000	333,000	13,000	327,000	14,000	307,000
Average	**3,000**	**62,000**	**3,000**	**78,000**	**3,000**	**67,000**	**3,000**	**65,000**	**3,000**	**61,000**

Note: Indoor depletion was estimated as 5% of indoor demand, and outdoor depletion was estimated as 80% of outdoor demand (demands shown in Table A-1). The data included in this table is represented in Figure A-7.

Conclusions and Recommendations

Conclusions

- The average annual M&I water demand across GSL basin is estimated to be about 700,000 ac-ft/yr (Table A-1).
    - On average, 60% of the demand is attributed to outdoor use, and 40% to indoor use across the GSL basin.
    - However, the distribution of indoor and outdoor demands varies by sub-basin, reflecting differences in land use, climate, and system characteristics specific to the sub-basin.
- The estimated average annual M&I water depletion across GSL basin is about 350,500 ac-ft/yr (Table A-4).
    - On average, outdoor depletion estimates accounts for 96% of the total depletion and indoor depletion accounts for 4% across the GSL basin.
    - Outdoor depletion estimates accounts for the majority total depletion in each sub-basin, which highlights a potential opportunity to improve M&I depletion.

Recommendations

1. Given how small indoor depletion estimates have been compared to outdoor depletion estimates, conservation efforts targeting outdoor water use, which is expected to reduce outdoor depletion, are likely to be significantly more effective at returning water to the GSL than those focused on indoor water use.
2. Additional measurements of water depletion from outdoor water use in municipal and industrial (urban) landscapes are needed to improve depletion estimates. At the same time, efforts to reconcile changing methodologies that are used to generate the data that inform depletion budgets are important to ensure consistency over time and facilitate meaningful regional comparisons.

Appendix A - References

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APPENDIX B BREAKDOWN OF WATER DEMAND

Water Demands Methodology

Previously, historical water demand across the GSL basin was analyzed on a basin-wide and sub-basin scale (Appendix A). In this section, the same methodology was applied to assess historical water demand and depletion at the county and system levels. Water demand and population count data were obtained from DWRe and DWRi for years 2015 – 2022. The analysis was conducted in 2024, when water demand and population count data for 2023 were not available.

Water Demands by County

Indoor water demand has remained relatively stable for each county within the GSL basin (Figure B-1). Slight decreases in indoor water use were observed in 2021 and 2022 across all counties, which may be related to effective messaging about conservation due to drought conditions in those years (Bruton, 2025). When comparing water demands by county, Salt Lake County had the highest total indoor water use, followed by Utah County, largely due to their significantly larger population compared to other counties (World Population Review, 2025). However, when indoor water demands were normalized by county populations (Figure B-2), Salt Lake and Utah Counties rank among the lowest in per-capita indoor water use. This indicates that changes in population do not necessarily result in proportional changes in water demand and improving water efficiency (per capita water use) can enable communities to support growing populations without needing to significantly increase overall demand.

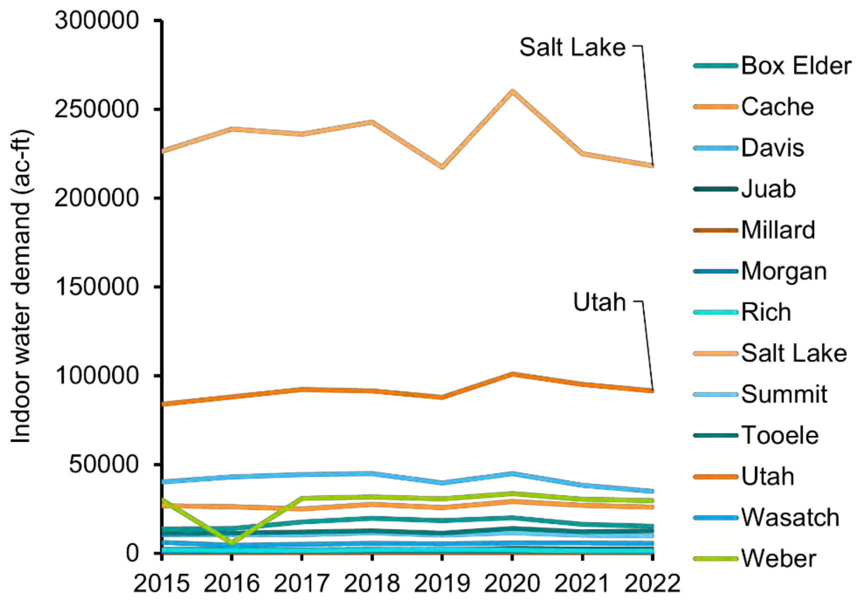

Figure B-1. Indoor Demands by Counties Across GSL Basin

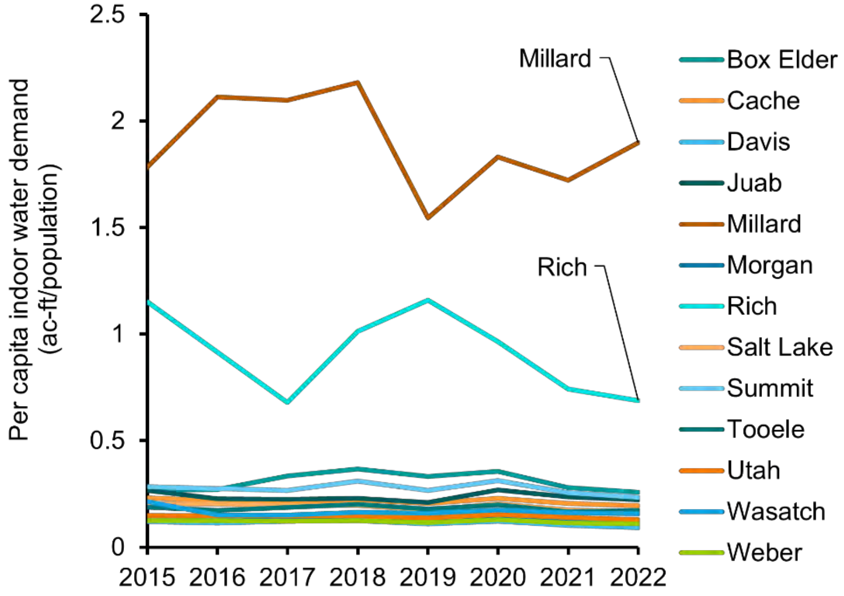

Figure B-2. Per Capita Indoor Demands by Counties in GSL Basin

Figure B-3 shows total outdoor water demands by county. The largest water users by total demand volume are generally Utah County, followed by Davis and Weber counties, Salt Lake County, and Cache County. All of these counties have experienced growth over the study period, and increasing trends appear to be evident in Utah, Weber, and Cache Counties. Davis County has no trend, and Salt Lake County has a decreasing trend. In these two counties, redevelopment with increasing population density and turf removal programs could be making an impact on the total acreage irrigated. Turf removal programs are present in other counties but may be overridden by overall development growth.

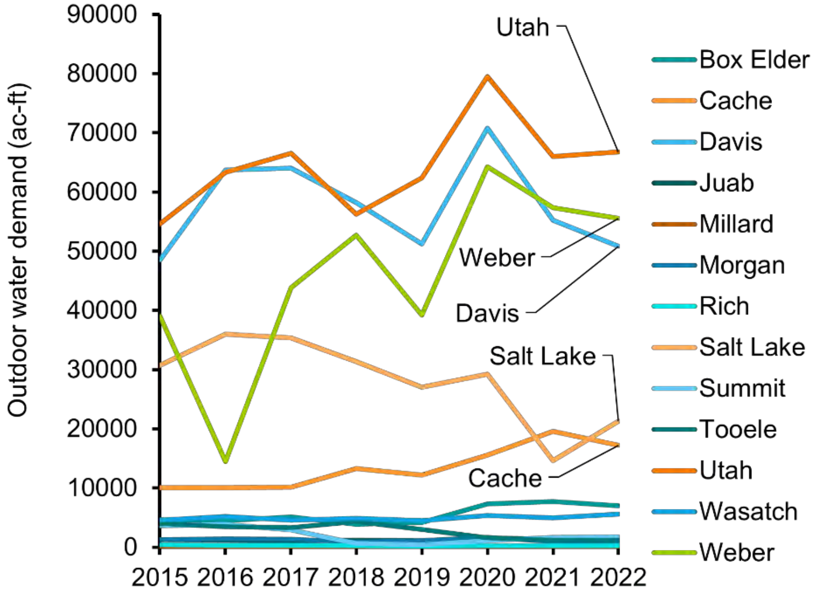

Figure B-3. Outdoor Demands by Counties in GSL Basin

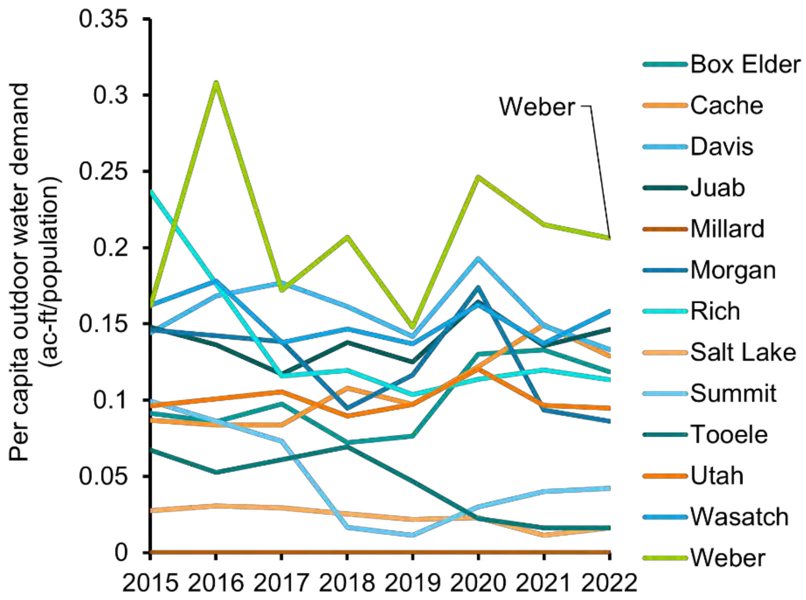

Figure B-4. Per Capita Outdoor Demands by Counties in GSL Basin

Figure B-4 normalizes total outdoor water use to population to produce per capita outdoor water demand. In this context, Weber County has the highest per capita outdoor demand, followed by a cluster of other counties in Utah. Salt Lake, Summit, and Tooele Counties have the lowest per capita outdoor water demands. The per capita outdoor water demand is likely linked to average lot size and irrigated area per resident. Some trends are evident but may not be significant in light of the errors inherent in estimating outdoor water use. Salt Lake County, Tooele County, Summit

County, and Rich County appear to have decreasing outdoor water per capita demands over the study period. Cache County and Box Elder County appear to have increasing outdoor per capita water demands over the study period. The remaining counties appear to have no trend.

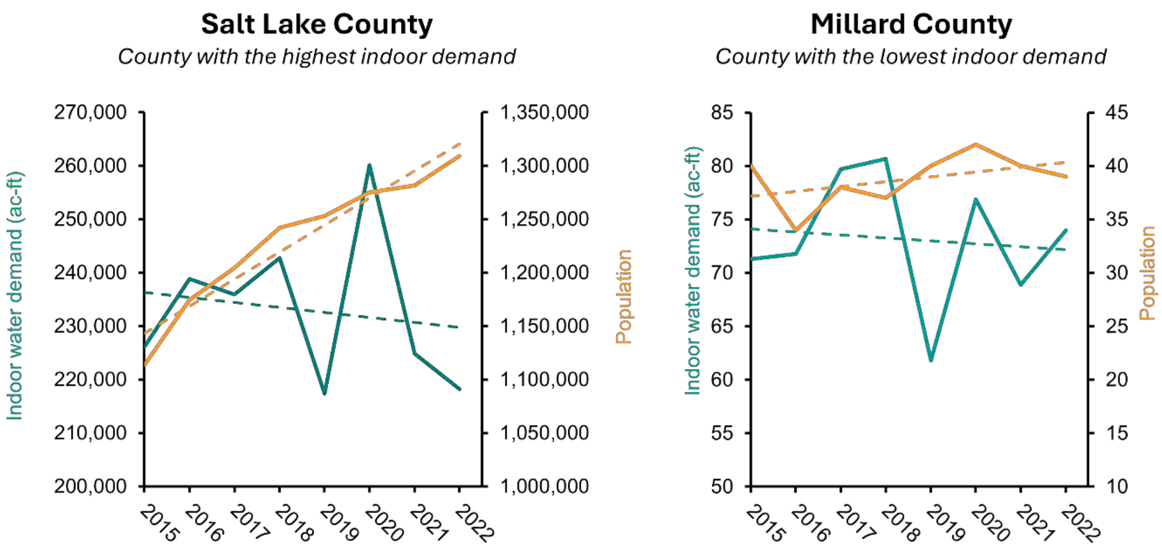

Figure B-5. Indoor Water Demand and Population Trends in Salt Lake and Millard Counties

The indoor water demands were compared between Salt Lake and Millard counties. As shown in Figure B-5, the counties in the GSL basin with the highest and lowest historical water demands were Salt Lake and Millard counties, respectively. Beyond the differences in their populations, both counties experienced increases in their population while simultaneously decreasing overall indoor water demand between 2015 and 2022. This is expected, as population increases tend to be associated with better water efficiency (due to higher population densities) and lower outdoor irrigation.

Appendix B - References

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APPENDIX C HISTORICAL LAND USE CONVERSION

Introduction to Land Use Conversion

Land use and water use are strongly correlated. The type and extent of land use directly influence the amount of water that is consumed. The conversion of one land use to another can create stark differences in water consumption. For example, the conversion from agriculture to M&I changes water usage, just as the conversion from a natural environment to M&I does. It is important to understand these trends to assess the impact on GSL and inform future development patterns.

An analysis was conducted to assess the impact of urban development on evapotranspiration (ET). In developed areas, much of the natural vegetation is replaced by impervious surfaces, such as roads and buildings, which channel water into stormwater systems before it can evaporate. This reduction in vegetation typically leads to a decrease in ET. However, development often involves replacing drought-tolerant native vegetation, such as desert grasses, with high-water-use landscaping, including turfgrass and ornamental plants. This raises important questions regarding the net effect of development on ET, particularly with turfgrass, and whether different types of development influence evapotranspiration in distinct ways. The following analysis provides a high level comparison of ET before and after development, using 2016 and 2021 land use and OpenET datasets, to illustrate how land use conversion influence ET.

Land Use Conversion Methodology

ET can be difficult to accurately measure, especially at a large spatial resolution. Estimates for ET are provided by datasets such as OpenET (OpenET, n.d.), which offers ET estimates at a 30-meter spatial resolution. OpenET provides an ensemble value for ET, meaning the values are calculated by combining results from multiple satellite-based models to improve accuracy and reliability. OpenET has been providing continuous annual coverage since 2013. OpenET was the primary source of ET data for this analysis, and ET estimates from 2016 and 2021 were used to assess changes associated with land use conversion between those two years.

Table C-1 shows the average ET, as reported in the OpenET data, for each county in the GSL Basin as a benchmark for the analysis. From the data presented in Table C-1, it is expected that the majority of developed areas will show a decrease in water consumption.

Table C-1. Average ET (inches) per County for 2016 and 2021

County	2016 Average ET	2021 Average ET	2021 to 2016 Difference
Box Elder	18.3	15.7	-2.6
Cache	24.9	25.0	0.1
Carbon	16.7	16.3	-0.3
Davis	33.0	31.2	-1.8
Juab	11.4	10.6	-0.8
Rich	19.2	18.1	-1.0
Salt Lake	24.5	23.0	-1.5
Tooele	15.6	23.4	7.8
Utah	23.4	21.5	-1.9
Total	20.8	20.5	-0.2

National Agriculture Imagery Program (NAIP) imagery (USDA, n.d.), known for its high-resolution coverage (approximately 1 meter), was used to calculate the percentage of vegetated areas across each county. NAIP imagery is available for select years, and for this analysis, data from 2016 and 2021 were selected to match the OpenET data. Vegetation was classified using the Normalized Difference Vegetation Index (NDVI) and a low threshold of 0.05 to capture all vegetation, including sparse or low-lying growth.

Two different datasets were used to identify areas that were developed between 2016 and 2021: the "Water Related Land Use" dataset produced by the State (Method 1) and the "Dynamic World" dataset produced by Google and the World Resource Institute (Method 2). Inaccuracies in land cover classification are among the primary sources of error in the resulting data, so conducting a similar analysis using different datasets serves as a valuable means of cross-validation. Each of the analyses performed are described below.

Method 1 (Water Related Land Use) Methodology

The effect of turfgrass on ET was analyzed by comparing areas that were developed between 2016 and 2021. The "Water Related Land Use" datasets from the State (DWRe, 2024) classify areas by land use. The "Label_Class" field within the dataset categorizes each area by specific land type usage, including various agricultural, open space, and developed categories. A visual cross-verification was conducted by comparing some areas basemap imagery to confirm consistency between the assigned "Label_Class" and visible ground features. For example, areas classified as agricultural were checked to ensure that the imagery showed field patterns or cultivated land. The shapefiles for 2016 and 2021 were compared to identify and isolate areas that were classified as agricultural or open space in 2016 and then classified as developed in 2021. A unique GIS layer was created to represent areas developed over the five-year window.

For each development area identified, the NDVI equation (with a threshold of 0.05) was used to calculate the percentage of area vegetated in both 2016 and 2021. Vegetated area in 2016 was assumed to be agricultural, while vegetated area in 2021 was assumed to be turfgrass. The OpenET data was then used to calculate the annual ET for 2016 and 2021 over each development.

This resulted in a GIS layer of polygons (development areas) with four variables per polygon: the polygon's percentage of area covered by vegetation (agricultural) in 2016, the percentage of area covered by each polygon that was vegetation (turfgrass) in 2021, the average ensemble ET over each polygon in 2016, and the average ensemble ET over the polygon in 2021. The difference in average ET between 2016 and 2021 represents the change in consumptive use, or change in volume of water used, resulting from land development.

Method 1 (Water Related Land Use) Results

Figure C-1 shows the difference in average ET per polygon, normalized to ac-ft per 100 acres, and graphed against the percentage of the polygon area that was agricultural in 2016. The points on the graph are color-coded by percentage of turfgrass in 2021. The spread in the data shown on Figure C-1 is quite large due to the resolution of the OpenET and NAIP imagery data, inaccuracies in land use classifications, and additional factors that affect ET. Best-fit linear trendlines are applied for each category of turfgrass development to visualize the trends.

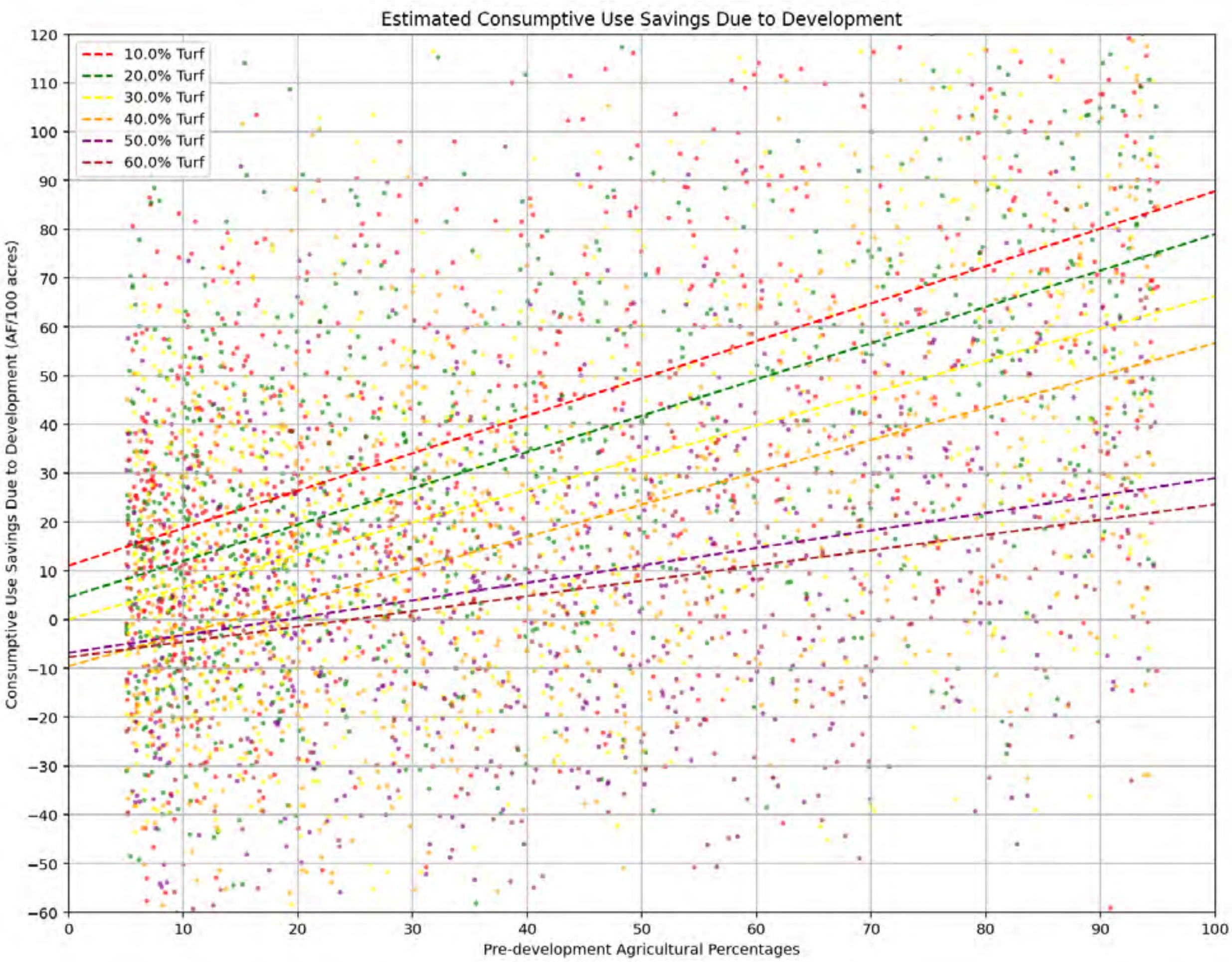

Figure C-1. Change in ET by Agriculture to Turfgrass Conversion

Figure C-1 shows that generally, areas with higher proportions of agricultural vegetation converted to development with turfgrass had higher average reductions in ET. As an example, land that was covered by 60% agricultural vegetation in 2016 was developed into land with 20% landscaped area saw an average reduction in ET of 50 ac-ft per 100 acres. Figure C-1 also shows that water consumption savings increased sequentially with decreasing proportions of turfgrass coverage. For example, an area that was 90% agricultural in 2016 had average reductions of 20, 25, 50, 60, 70, and 80 ac-ft per 100 acres for areas developed to 60%, 50%, 40%, 30%, 20%, and 10% turfgrass, respectively.

Method 2 (Dynamic World) Methodology

The effect of turfgrass on ET was also analyzed by comparing areas that developed between 2016 and 2021 with a different dataset. The "Dynamic World" dataset (Brown et al., 2022), which is derived from Sentinel-2 satellite imagery to track land cover changes, was utilized in this method. This dataset offers detailed land cover classifications, such as developed areas, vegetation, and other land types, at a 10-meter resolution. By comparing land cover between 2016 and 2021, areas that transitioned from undeveloped to developed were identified. This allowed for an analysis of ET changes specifically associated with new development.

The high-resolution NAIP data (1-meter) were resampled to match the 30-meter resolution of the OpenET dataset. For each OpenET cell, the number of vegetated NAIP cells within it was divided by the total number of NAIP cells it contained. This produced a GIS layer (raster) at the same resolution as the OpenET data, which contained the percentage of vegetated land under each OpenET cell. The developed areas from the Dynamic World dataset were then used to calculate the average percentage of vegetation and average ET of each land class area for 2016 and 2021.

Method 2 (Dynamic World) Results

The datasets for each year were examined, and while there was a large spread in the data, it was observed that generally parcels with higher percentages of vegetation of any type (trees, grass, crops, scrub, etc.) had higher ET than parcels with lower percentages of vegetation (data not shown).

Figure C-2 shows the change in ET between 2016 and 2021 compared to the change in percent vegetated between 2016 and 2021. While there is a fairly large spread in the data due to inaccuracies, environmental factors, etc., Figure C-2 shows that on average, developing an area results in a significant decrease in ET. For example, if an area was 50% vegetated in 2016 and then was developed with 25% grass, it experienced a -25% change in percent vegetated and a -3% (approximately) change in ET. On average, vegetation could increase by up to about 25% over the pre-development conditions without a change in ET over the study period.

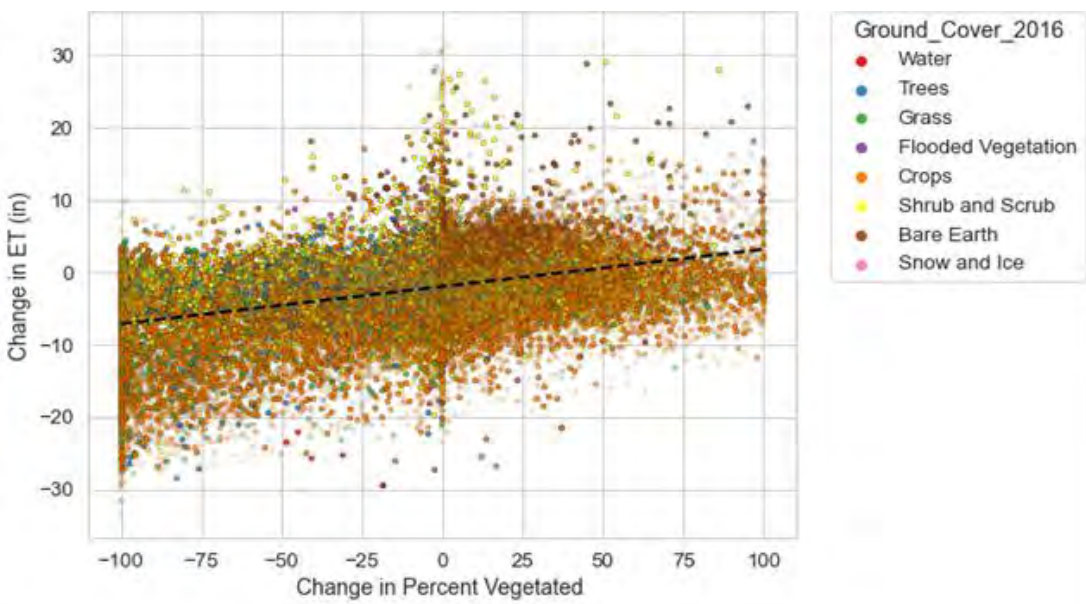

Figure C-2. Change in Annual ET with Percent Vegetated

To investigate whether different land cover types play a role in the change in ET observed, we looked at the average change in ET for each of the categories provided by the Dynamic World dataset individually. Table C-2 shows the average ET change with development for land classified in pre-development as tree, grass, crops, shrub and scrub, and bare earth. All categories except bare earth decreased in ET as a result of development, presumably due to the increase of impervious surface and decrease in vegetated area with development.

Table C-2. Average Change in ET by Land Class

Land Classification	Mean Change in ET (inches)
Trees	-2.4
Grass	-3.7
Crops	-3.5
Shrub and Scrub	-1.3
Bare Earth	0.9

Figure C-3 shows the distribution of ET change for each land classification. Again, the range is large, but the clusters are close to the normal distribution. While there are many cases where ET increases with development, the means show a decrease for all categories except bare earth.

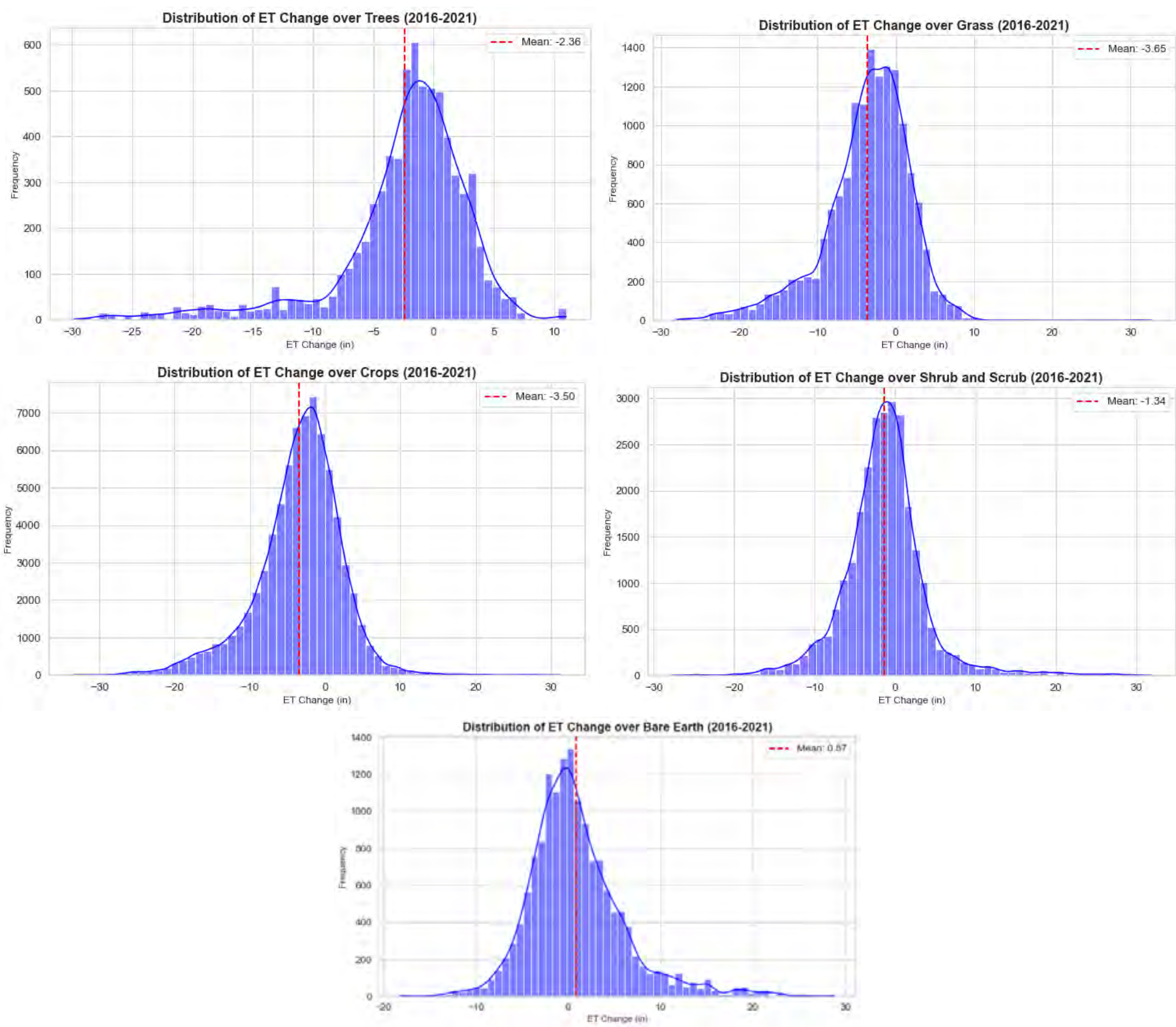

Figure C-3. Change in ET by Ground Cover Type

Land Use Conversion Limitations

To evaluate how depletion may have changed between 2016 and 2021, the amount of ET was compared using datasets with inherent limitations that may affect the precision of the results.

First, ET is influenced by a wide range of factors, such as vegetation type and age, soil type and texture, ground cover, hardscape, distribution uniformity, irrigation system type, region, etc. These complexities make ET a difficult parameter to estimate accurately. Although OpenET provides ensemble values for ET that were used in this analysis, those values may not fully account for conditions across the areas included in the study.

Second, the 2021 NAIP imagery used in the analysis was collected over several flights between June and November of that year. Atmospheric conditions and the number of shadows in the imagery vary substantially between each of those flights, which may have underrepresented vegetation and ET values. An analysis of the shadows found in 2021 NAIP imagery for each county in the GSL basin (Appendix E, *Analysis of Shadows*) found that the percentage of dark shadows over pervious areas (vegetated area) ranged between 2.2% and 3.3%, which created an uncertainty of about 5% to 10% in turfgrass estimation across the basin.

In addition, the analysis did not distinguish vegetation types such as riparian corridors or areas with high shallow groundwater, which may have overrepresented areas unrelated to land use development. While these areas should have been excluded from the analysis to improve the accuracy of ET results, excluding them would require higher-resolution imagery and more analytical effort. More importantly, these areas generally remained the same over the 5-year period analyzed, so the influence on the comparison of ET changes over time was considered minimal.

Despite these limitations, the primary goal of the land use conversion analysis was not to precisely quantify annual ET, but to examine the overall changes in ET over time in relation to changes in land use. While dataset improvements could yield more accurate absolute values, the differences in ET observed for 2016 and 2021 are believed to be robust and informative.

Land Use Conclusions

The effect of turfgrass on ET was analyzed by comparing areas that developed between 2016 and 2021. The “Water Related Land Use” and “Dynamic Earth” datasets for 2016 and 2021 were compared to identify areas that developed between those years. Vegetation in developed areas was assumed to be turfgrass.

The amount of ET was compared between 2016 and 2021 for different land uses to understand overall differences in depletion. There was a spread in the results from the analysis, but differences in the data were clear with consistent results. The large spread in the overall data primarily resulted from the resolution of the data, inaccuracies in land use classification, and the significant number of factors that can influence ET. Variability could be due to partial development, landscapes under construction, and limitations of the imagery.

The analysis showed that conversion from agriculture to municipal land use has reduced the estimated ET. Similar results were found in the GSL Stormwater Study (HAL & LimnoTech, 2023). Overall, depletion decreased by 12% from 2016 to 2021, regardless of development type. The range is closer to 15-20% when looking only at the land use converted from agriculture to municipal. The results indicate that significant savings in depletion can be achieved by developing responsibly.

The results of this analysis reinforce the idea that the water savings associated with development depend on prior land use. For most land use classifications, the results indicated that development reduced ET and consumptive use. The exception to this was for bare earth, where ET increased after development (Table C-2 and Figure C-3), which is likely due to the introduction of irrigated greenspace to land that had low prior water use. To strengthen water planning recommendations, a more detailed examination of the water savings associated with specific land use transitions is needed to understand the net effect of development on ET. In addition, analysis using controlled data is needed to identify specific values for consumptive use depletion and account for variability in ET outcomes. With the analysis at hand, the results suggests that developed areas, even with landscaping, have the potential to consume significantly less water than agricultural or otherwise vegetated areas.

Overall, the study's results illustrate the importance of ensuring that future development is approached to limit potential depletion. Greater reductions in ET can be achieved by reducing potential outdoor watering. Advocating for and implementing legislation that promotes more sustainable alternatives to water-intensive land use and landscaping is a crucial strategy for water conservation in Utah. Such legislation would encourage the transition from high-water-use landscapes to drought-resistant and water-efficient alternatives. This shift would significantly reduce water depletion, helping to preserve vital water resources. By supporting land use conversion through conservation standards for new construction, the state can foster more sustainable development patterns, reduce the strain on water supplies, and enhance the resilience of communities to drought and climate change.

Appendix C - References

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APPENDIX D WATER SYSTEM OUTREACH

A large portion of the M&I Conservation Opportunities Study included outreach to water systems to better understand current conservation efforts occurring in the Great Salt Lake (GSL) basin. Outreach provided the opportunity to ask water systems questions about water conservation programs and ultimately gave insight into report recommendations. It also provided a gauge for potential buy-in from communities.

Water System Outreach Methods

Outreach efforts were relatively limited but designed to capture input from water systems across each GSL sub-basin, including those of different sizes. Outreach occurred through various methods, including individual meetings and group presentations. Table D-1 summarizes the different outreach efforts.

Table D-1. Outreach Summary

Type	Water Systems
Individual Meetings (Survey)	1. Washington County Water Conservancy District (Not included in the GSL basin; interviewed to understand how their programs have seen such widespread adoption) 2. Central Utah Water Conservancy District 3. Sandy City 4. South Jordan City 5. Logan City
Group Presentations	1. Great Salt Lake Steering Committee: includes each of the conservancy districts, Salt Lake City, and other federal agencies. 2. Mount Nebo Water Agency (MNWA): agency focused on groundwater management in Utah County. Includes most municipalities and large water users in South Utah County: Payson, Salem, Santaquin, and Spanish Fork. 3. Northern Utah County Aquifer Coalition: group focused on groundwater management in Utah County. Includes most municipalities in northern Utah County: Alpine, American Fork, Cedar Hills, Highland, Lehi, Lindon, Orem, and Pleasant Grove.
Group Collaboration	Several recurring meetings with Central Utah Water Conservancy District, Jordan Valley Water Conservancy District, and Weber Basin Water Conservancy District to discuss depletion reduction strategies.

Individual meetings were aimed at reviewing conservation efforts throughout GSL basin. Questions were developed to assess historical and current programs, water conservation performance, and future conservation goals. The additional group presentations and collaboration helped develop recommendations for the report and note conservation plans, hurdles, and key items to consider. Furthermore, this analysis highlights the water systems that have adopted these programs and seen success in reducing water demands.

Water System Outreach Results

The analysis had several key results that were important for completing the study and formulating recommendations. Results are summarized in the following sections.

Historical and Current Programs

The following is a summary of responses regarding historical and current programs:

Table D-2. Water System Outreach Summary

Program	Notes
Turfgrass Replacement	• Seen as one avenue to reduce outdoor watering demands. • Not widely adopted; moderate participation based on numerous barriers and difficulties with making citizens aware. • Unable to track progress because not everyone is completing turfgrass replacement through the programs. • Most common usage is for “flipping your strip.” • Difficult to measure actual water savings; performance data is not widely available. • Costs to install waterwise landscaping are high and may be a barrier for most, not completely covered by the rebate. • South Jordan City provides gravel instead of the rebate, gets a lot of positive feedback from residents, and repeat customers. • Some municipalities don’t offer this incentive. • Municipalities don’t track non-functional turfgrass or turfgrass areas, mostly completed by the Districts. • Utah needs to define non-functional turfgrass. • Installations of new turfgrass exceed historical replacements. • More cost effective to reduce new turfgrass installations instead of focusing on taking out existing turfgrass.
Smart Irrigation Controllers	• Commonly used program and incentive that has been offered statewide since 2018. • Can be used to reduce water usage. • Statewide rebates of $100 available.
Secondary Metering	• Some municipalities saw reductions in water use with installations only. • Additional reductions only come from pairing with tiered rates and/or an education component. • Recent legislation will help with the installation of secondary meters and the adoption of tiered rates. • Irrigation companies face the challenge of being expected to function as a utility, but most lack the necessary resources and staffing because they are often operated by volunteers.
Leak Detection	• Primary focus for most municipalities. • Water systems want to reduce leaks because it can help preserve water supply and increase overall system performance. • Leak checks are a priority and are usually fixed immediately. • Pipeline replacement programs are common. • Leak detection software has proven successful for identifying small leaks before they develop into large breaks.
Land Use Ordinances	• City codes often require large amounts of turfgrass to be installed for new developments. • Need state legislation to help reduce the installation of new turfgrass in developing areas. • In order to receive state funds for Landscape Incentives, cities must adopt ordinances that limit the amount of grass installed in new construction.

Program	Notes
Other Programs	• Rebates or requirements for water efficient fixtures (toilets and other plumbing devices) are common and have been offered statewide since 2019. • Education programs are utilized often in conjunction with social media and messaging. Districts are usually the ones that lead this effort.

In addition to the responses outlined in Table D-2, it was apparent that conservation efforts vary by system size and location. Often, smaller water systems lack the resources to implement rigorous conservation policies or programs. Their primary objective is to ensure that water supply is available to all of their residents. This must be considered when developing conservation strategies. The majority of the water systems discussed future conservation efforts centered on increased education to help make citizens aware of current programs.

Water Conservation Goals

The objectives of water systems vary based on size, location, and age. Each system had varying priorities based on the problems it was facing. Additionally, each system had varying conservation goals that were also shaped by its priorities now and in the future. The following is a summary of responses and feedback based on existing and future conservation goals.

<u>Existing Conservation Goals</u>

- There were mixed opinions on the usefulness of the regional conservation goals. There are water systems that will not meet the goals due to the lot size and land use.
- There is a need to develop a standard for quantifying gallons per capita day (GPCD) and establishing a standard for what should be considered consumptive use or production. Additionally, establishing which water uses should be tracked and measured.
- Currently, there is no way to account for permanent residents in regions that have high commercial or industrial water uses.
- In some instances, the variability among the different water systems made the direct application of regional goals difficult. Even in the same region, water system conditions vary drastically.
- Water conservation varies by the water system age:
    - <u>Older systems with little growth</u>: Water usage continues to trend down. The lack of revenue makes it difficult to recoup costs to maintain the system, including replacing aging infrastructure.
    - <u>Newer systems</u>: Difficulty managing rapid growth, many city ordinances do not reduce the amount of turfgrass or outdoor watering. Can't obtain water supply to meet growth.
- Separate drinking water and secondary water systems make conservation difficult because they have different rate structures.

<u>Future Conservation Goals</u>

- Most systems aim to conserve water, mainly to meet future demands with the available supply. There is little focus on meeting the regional conservation goals.
- Water systems want to conserve water but are concerned about sustaining adequate revenue.
- Future conservation should focus on balancing the available supply with demand.
- Equivalent residential connections (ERCs) don't provide a useful metric for tracking and comparing progress between water systems. ERCs change often and are specific to water systems.

- There is a need to differentiate between indoor and outdoor usage in water conservation goals.
- Focus on developing more system-specific goals. Each water system has different land uses, lot size, and population. Goals could be set on available supply, demand, and depletion limits.
- Legislation or state ordinances are necessary to help standardize landscaping for future development.

Water Conservation Feedback

Throughout the study, feedback was provided for the overall feasibility and implementation of water conservation in the GSL basin. The following list highlights the main elements:

- The concept of dedicating and delivering water to GSL was met with numerous questions, confusion, and concerns.
- Water systems don’t want their conserved water being sent to GSL to evaporate and not be available for future beneficial use.
- Balancing water demands among M&I, agriculture, and the environment is important to ensure all needs are met.
- There needs to be collaboration among water systems, state agencies, and the legislature to develop win-win solutions for water conservation strategies that benefit each sector.
- Rather than conserving to send the older, more affordable water supply to GSL and developing new, expensive supply to meet demands, conservation efforts should be used to preserve the existing supply for growth and reduce the need to develop new sources. This would reduce the impact that new supply development may have on GSL. There must be buy-in at the community level to make significant changes.
- More education is necessary to help residents understand types of water usage that impact GSL.
- It is important to recognize the success of water systems that have adopted water conservation programs and are making significant efforts to reduce their water demands.

APPENDIX E HISTORICAL TURFGRASS AREA ESTIMATES

Introduction to Historical GSL Basin Turfgrass Estimates

The Great Salt Lake (GSL) watershed is vast, encompassing over 36,000 square miles and comprising five river basins: Bear River, Weber River, Jordan River, Utah Lake, and the West Desert. While much of the watershed is undeveloped, it is home to more than 80% of Utah's population, with the majority concentrated in urban areas along the Wasatch Front.

Most of the developed area throughout the GSL basin is landscaped with turfgrass. A model developed by the Division of Water Resources (DWRe), known as the Greenspace Model, uses the Normalized Difference Vegetation Index (NDVI) equation on 2021 NAIP aerial imagery to identify turfgrass throughout the state of Utah. The Greenspace Model measured approximately 135,000 acres of turfgrass in the GSL basin. The exact value is difficult to derive given the uncertainty in publicly available data, shadows and tree cover, and complexities associated with analyzing such a large area. Furthermore, the additional effort to derive a more accurate estimate does not yield commensurate value and may not justify the extra time and costs.

Findings from the water usage analysis in Appendix A show the significance of depletion associated with outdoor demands and indicate the need for developing accurate estimates of the existing turfgrass area. This appendix documents an analysis that was performed to verify the Greenspace Model results are reasonable and to identify additional methods of estimating acreage of turfgrass across the GSL basin.

In addition, the area of turfgrass associated with various land uses was quantified in this analysis to better understand water conservation opportunities. The analysis focused on quantifying types of non-functional turfgrass (NFT) and turfgrass areas associated with different land uses, such as residential, commercial, and tax-exempt properties. Areas derived from the analysis were used in subsequent appendices to determine potential water and depletion savings through various turfgrass replacement programs.

Verification of the Greenspace Model

Verification by Water Usage Methodology

The NDVI equation is widely used to identify healthy vegetation by using remote sensing technology. It has been used in various applications, including turfgrass identification. While it performs well at identifying and quantifying turfgrass, several factors influence the accuracy of the results:

- The resolution of the imagery
- The consistency of the imagery (e.g., was the imagery flown in multiple flights, during the same time of year, with similar atmospheric conditions, etc.)
- The percentage of the imagery in shadow (the NDVI equation often classifies shadowed vegetation as non-vegetated)
- The percentage of trees or other healthy non-turfgrass vegetation

The NAIP imagery used has an average resolution of 0.6 meters. This resolution may miss smaller features, but is sufficient for identifying the overall vegetated area of individual lots, such as turfgrass. The 2021 NAIP imagery was collected over several flights between June and November of that year. Atmospheric conditions and the number of shadows in the imagery vary substantially between each of those flights. This makes it difficult to quantify the amount of error in the Greenspace Model. Several case studies were performed to understand the errors that may exist due to shadows or non-turfgrass vegetation.

First, water usage data provided by the DWRe was used to estimate the area of turfgrass in the Great Salt Lake basin and compared to the area of turfgrass calculated by the Greenspace Model. This was done using the following steps and assumptions:

1. Estimate the amount of water from drinking water systems that was used for irrigation. An analysis of average winter and summer productions for water systems in the Great Salt Lake basin, as reported to the Utah Division of Water Rights set this number at 40% of annual production used for irrigation.
2. Add estimated irrigation from drinking water to reported water use from secondary systems.
3. Divide by the average water usage per acre of turfgrass (3 ac-ft per irrigated acre of turfgrass was used based on previous studies and experience of HAL personnel).

Similar to the Greenspace Model, the water usage method also has limitations. It assumes that all outdoor water use is for turfgrass, even though a portion of the water is allocated to other uses, such as irrigating non-turf vegetation or watering livestock. The selected irrigation factor of 3 ac-ft per irrigated acre is higher than the amount of water required for healthy turfgrass. While the value selected was intended to account for overwatering and a portion of the outdoor water used for non-turf purposes, the actual irrigation requirement can vary due to poorly installed irrigation systems and old sprinkler technologies. In addition, the many variables that affect watering behavior across the basin, such as lot size, cost of water, income, and annual rainfall, make it difficult to know and account for the degree of error in this method. However, over a large area, the errors and outliers become less significant.

Results of the Water Usage to Greenspace Model Comparison

Calculating the turfgrass area for each county in the Great Salt Lake basin using both water usage and the Greenspace Model resulted in turfgrass estimates within 0.7% of each other. Table E-1 gives the total turfgrass area estimates from each method. Figure E-1 shows a comparison of each method by county.

Table E-1. Turfgrass Estimates from Water Usage and the Greenspace Model

Method	Turfgrass Area
Greenspace Model	135,374 acres
Water Usage	136,295 acres

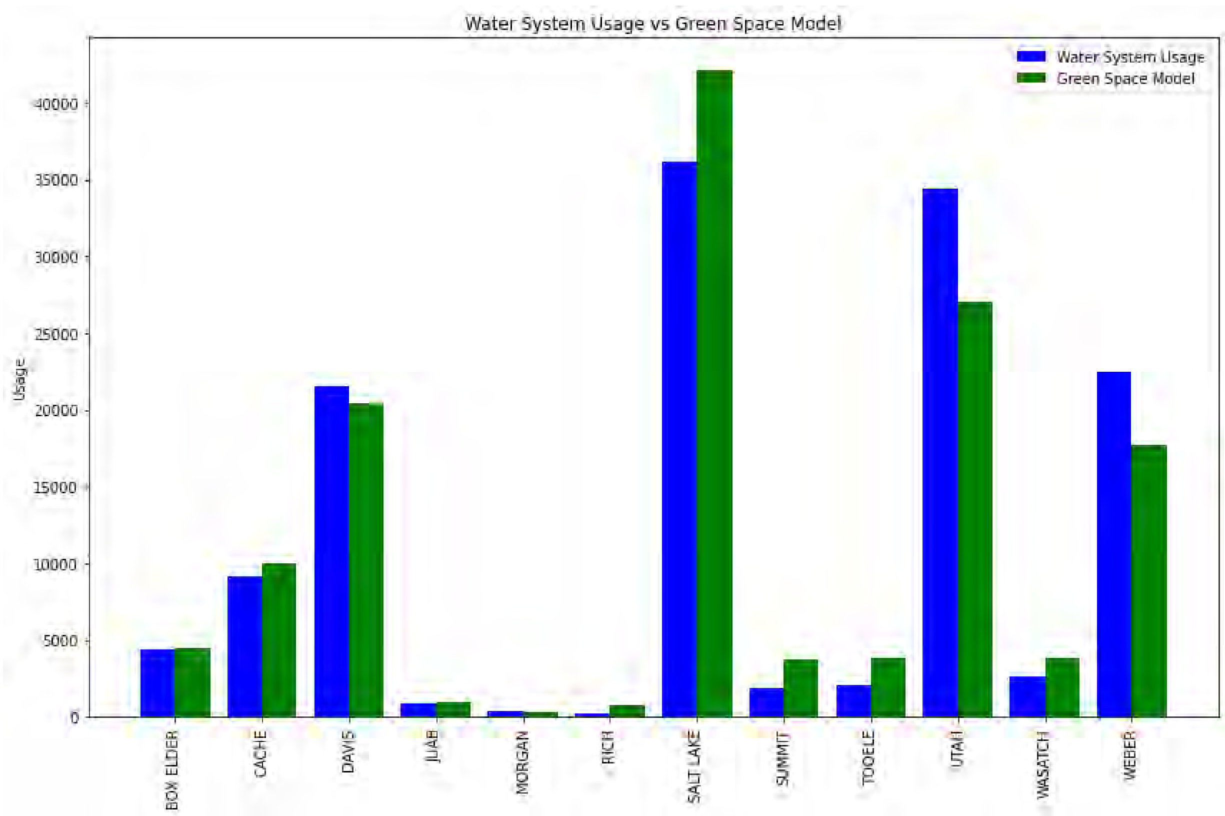


Figure E-1. Turfgrass Estimates by County

Table E-2. Table of Values for Figure E-1.

County	Water Usage	Green Space Model	% Difference
Cache	9,174	10,019	8.4%
Davis	21,567	20,467	-5.4%
Wasatch	2,612	3,852	32.2%
Box Elder	4,363	4,507	3.2%
Weber	22,447	17,735	-26.6%
Juab	893	943	5.3%
Rich	243	733	66.8%
Tooele	2,070	3,889	46.8%
Summit	1,852	3,709	50.1%
Morgan	445	304	-46.2%
Salt Lake	36,182	42,133	14.1%
Utah	34,446	27,084	-27.2%
Total	**136,295**	**135,374**	**-0.7%**

Note in Figure E-1 that the Greenspace Model estimates more turfgrass than the water usage method in Salt Lake County, while the water usage method estimates more turfgrass than the Greenspace Model for Utah and Weber counties. Other counties have a larger difference by percentage, but the water usage in these counties is small enough that it minimally impacts the overall total. Outliers and data errors are also more likely to skew the result in smaller counties compared to larger counties.

The differences seen in Figure E-1 are likely due to the type of developments in Salt Lake versus Utah/Weber counties. Salt Lake County is more developed than Utah/Weber Counties, with smaller lots and more buildings. Smaller lots are often overwatered (Shurtz et al., 2022), and it is likely that the estimate of 3 ac-ft of water per acre of turfgrass is too low, with the opposite being true for Utah and Weber Counties, where the lots on average are larger. Figure E-2 and E-3 show the number of lots by size in Salt Lake and Utah counties, respectively.

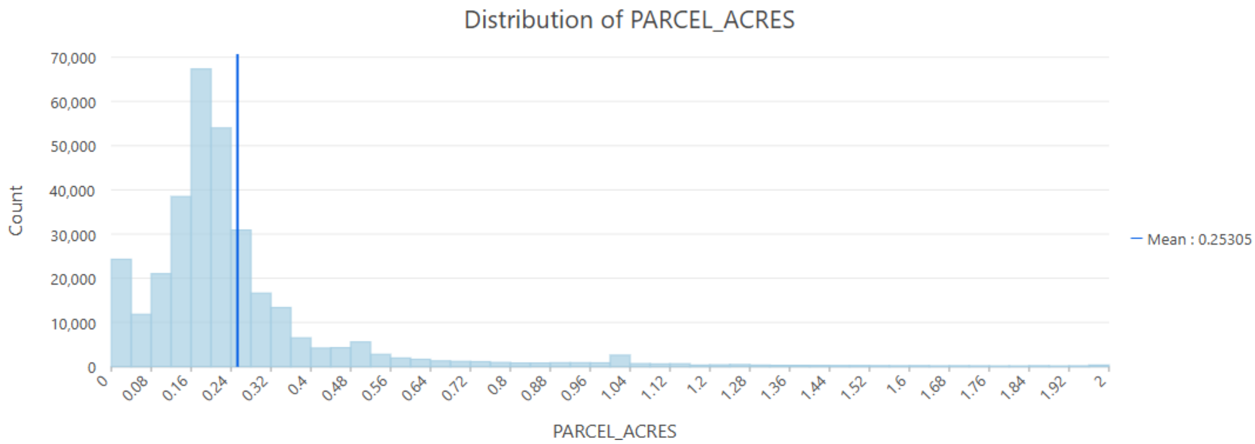


Figure E-2. Histogram of Parcels by Lot Size in Salt Lake County

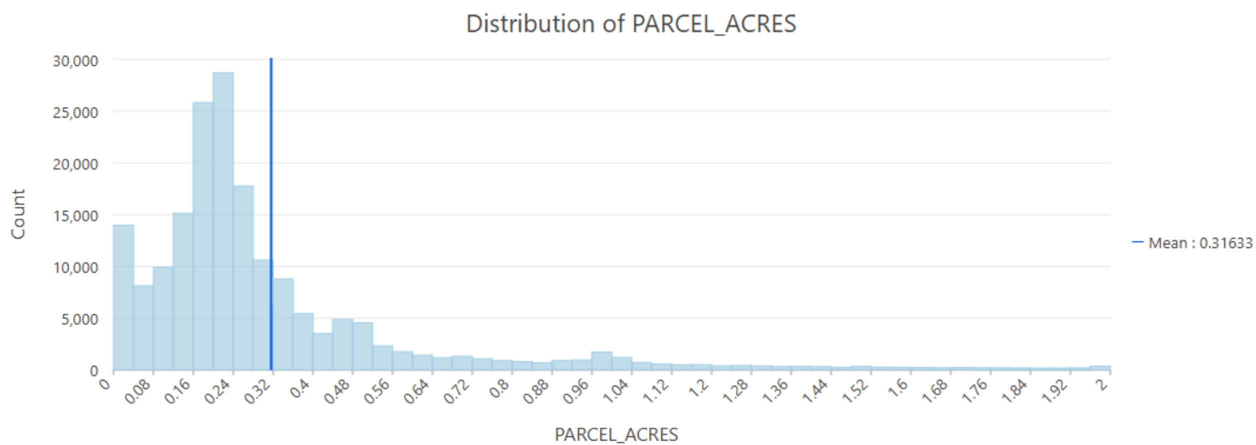


Figure E-3. Histogram of Parcels by Lot Size in Utah County

Verification by Case Studies Methodology

Several case studies were conducted over areas where turfgrass estimates had already been determined. Turfgrass estimates for these areas were made using ArcGIS Pro's imagery classification tool, which uses supervised machine learning on a trained dataset to classify the imagery. The amount of turfgrass identified in Mapleton, Provo, and Vineyard (by municipality boundaries) was compared across each methodology. In the case of Mapleton, additional analysis was done using the NDVI equation and manual inspection to determine turfgrass area.

Results of the Mapleton Case Study

Mapleton is characterized by an above average number of larger lots. While manually determining turfgrass across the city, it was observed that many lots have a small portion of turfgrass, with the remainder being agricultural. The Greenspace Model overpredicts turfgrass estimates due to the large amount of non-turfgrass vegetation on residential lots. Table E-3 compares turfgrass estimate results from the different methods. Figure E-4 shows results from the supervised machine learning model.

Table E-3. Turfgrass Estimates from Varied Sources over Mapleton

	Master Plan	Imagery Classification	From State Water Usage	Greenspace Model
Turfgrass (acres)	637	887	735	1,334
% of Mapleton	7.5%	10.4%	8.6%	15.6%

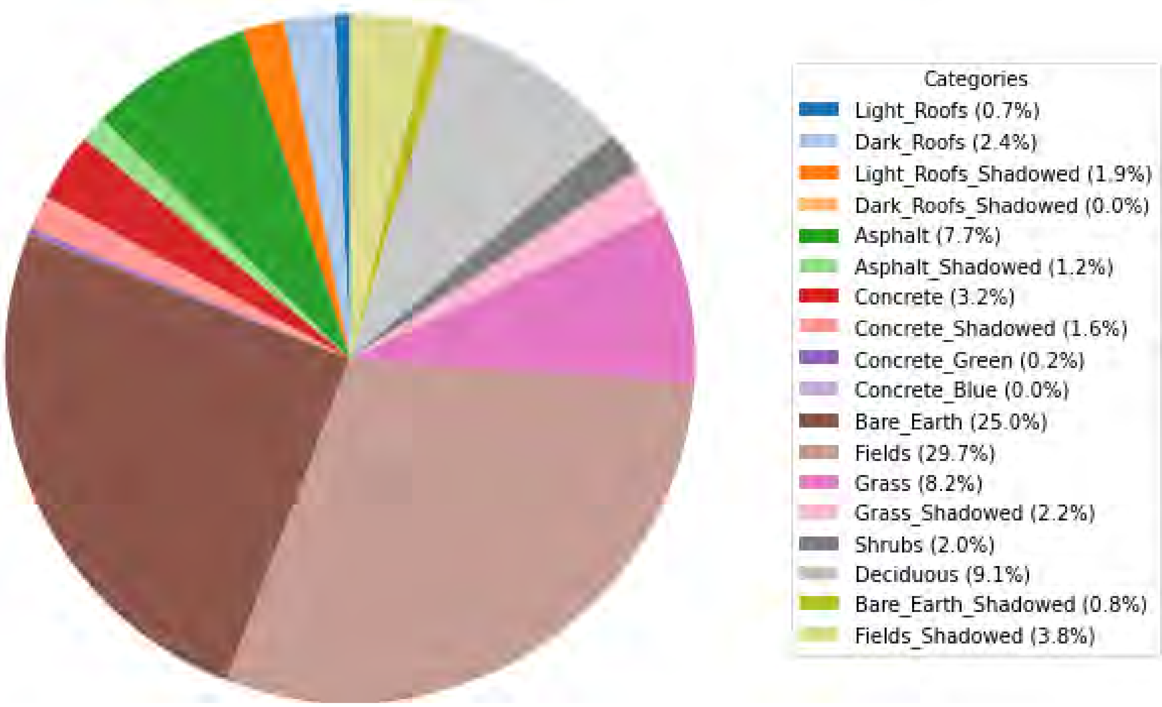


Figure E-4. Results of Imagery Analysis over Mapleton

Results of the Provo Case Study

Provo is an older city with a notable number of trees. It was anticipated that the imagery classification would underestimate the turfgrass area, while the Greenspace Model would likely overestimate. This case study illustrates the impact of trees on the Greenspace Model. It is impossible to determine what vegetation exists under a tree. Trees often overlap roads or structures, resulting in an overestimation of turfgrass. However, if trees are sparsely placed, then the shadow of the tree likely compensates for some of the overestimation, helping to average out the result. Table E-4 compares turfgrass estimate results from the various methods. Figure E-5 shows results from the supervised machine learning model.

Table E-4. Turfgrass Estimates over Provo

	Imagery Classification	From State Water Usage	Greenspace Model
Turfgrass (acres)	2,356	3,188	3,033
% of Provo	8.3%	11.2%	10.7%

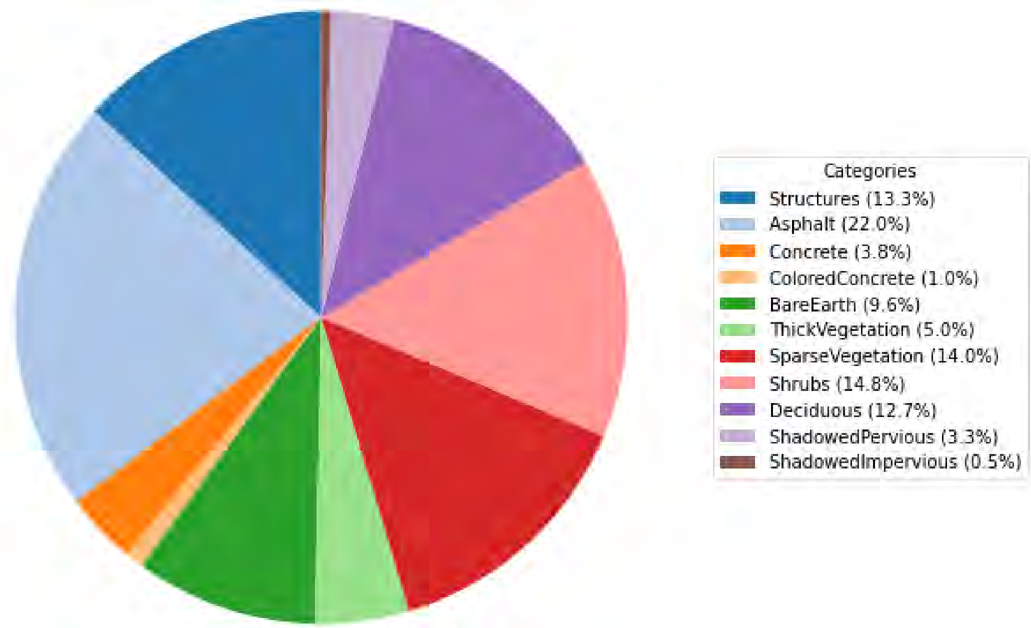


Figure E-5. Results of Imagery Analysis over Provo

Results of the Vineyard Case Study

Vineyard is a relatively new city that still has a fair amount of open space and agricultural land use. Developed areas of Vineyard are representative of future development that can be expected throughout the GSL basin. The imagery classification for Vineyard was not trained to distinguish between turfgrass and non-turfgrass vegetation, resulting in the imagery classification classifying any agricultural area as turfgrass. Table E-5 compares turfgrass estimate results from the various methods. Figure E-6 shows results from the supervised machine learning model.

Table E-5. Turfgrass Estimates over Vineyard

	Imagery Classification	From State Water Usage	Greenspace Model
Turfgrass (acres)	461	271	271
% of Vineyard	11.3%	6.6%	6.6%

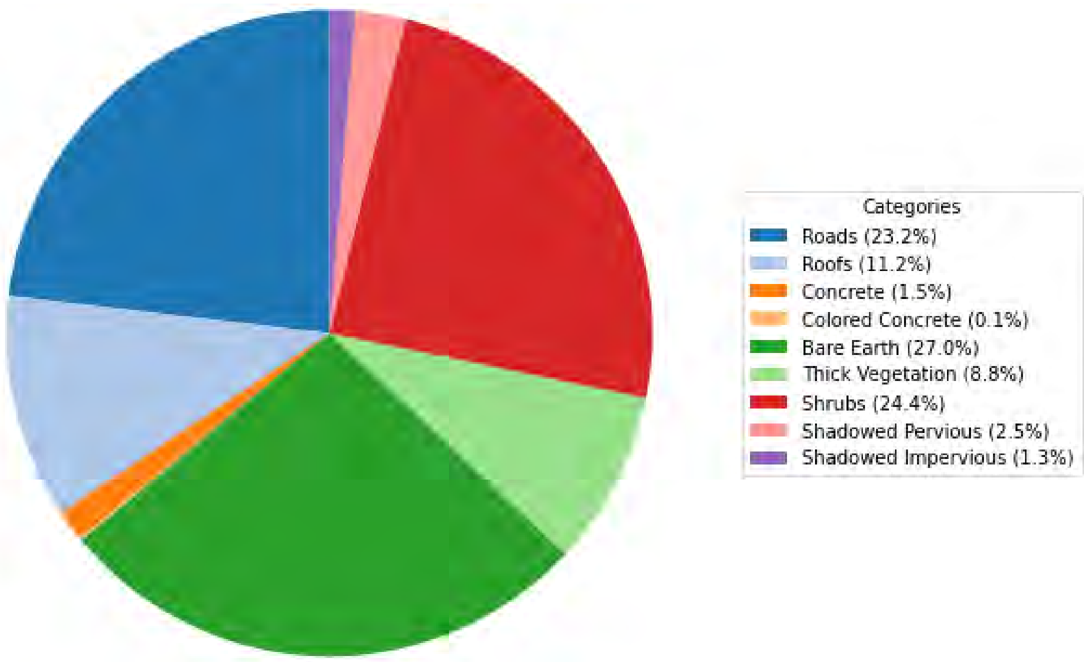


Figure E-6. Results of Imagery Analysis over Vineyard

Analysis of Shadows

Shadow Analysis Methodology

Shadows are likely the largest cause of error in the Greenspace Model, as they are highly prevalent in the NAIP aerial imagery. NAIP imagery tiles in Salt Lake and Utah Counties were classified using K-means clustering with 9 clusters to estimate the percentage of shadows in the NAIP imagery. Additionally, in each of the case studies from the previous section, shadowed pervious area was included as a training class.

Shadow Analysis Results

Figure E-7 and E-8 show the percentages of dark shadows in Salt Lake and Utah Counties, respectively.

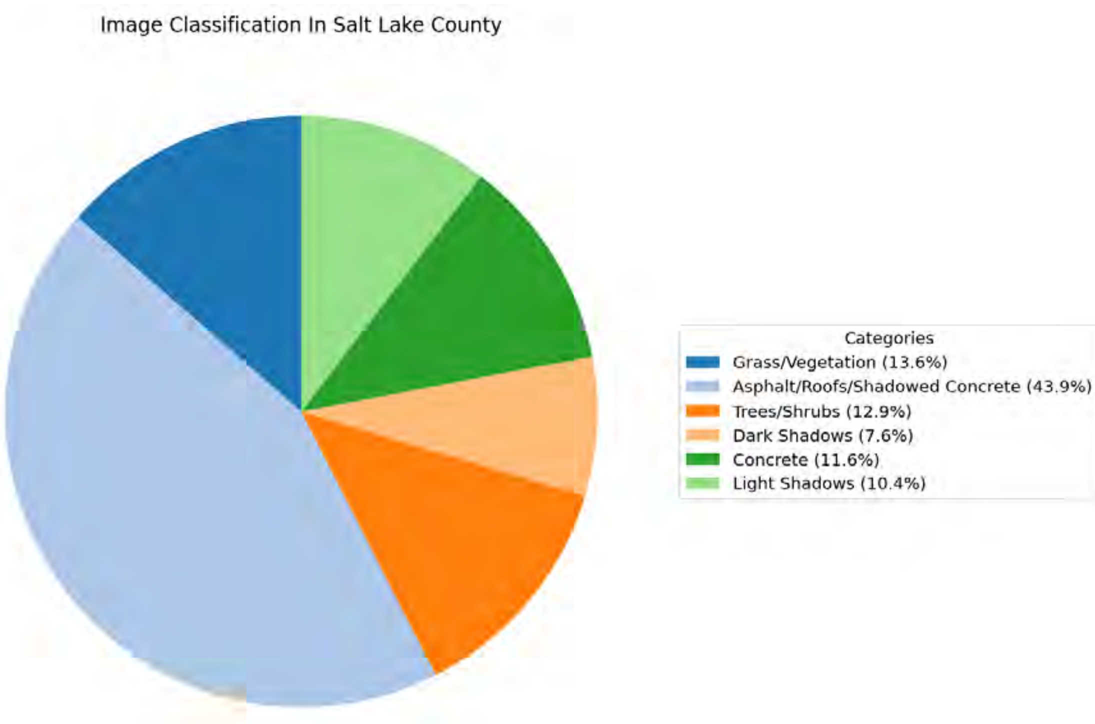


Figure E-7. Imagery Classification by Percentage in Salt Lake County

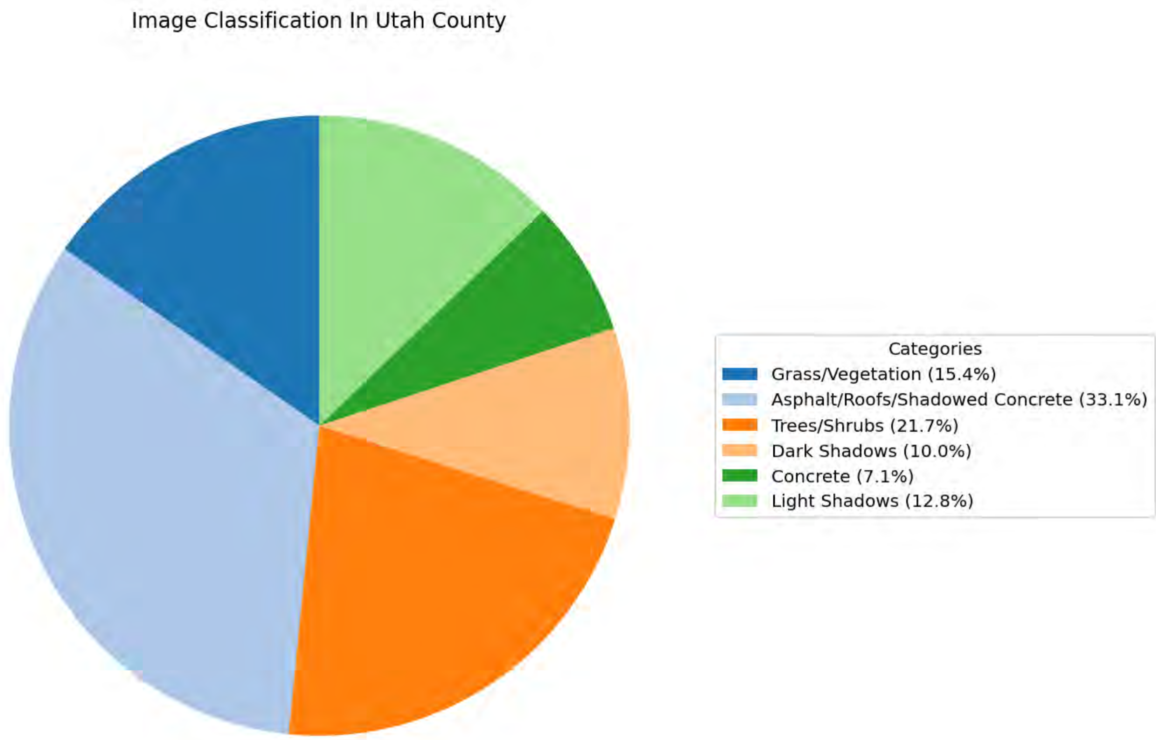


Figure E-8. Imagery Classification by Percentage in Utah County

From Figures E-7 and E-8, the percentage of shadows (dark shadows) in the NAIP imagery ranged from 10% to 20%. For turfgrass estimation, shadows over non-vegetated areas can be ignored.

In the case studies, the results for shadowed pervious areas ranged between 2.2% and 3.3% and remained generally consistent between the different case studies (see Figures E-4 through E-6). It can be assumed that the percentage of shadowed vegetated area would proportionally increase with the number of shadows in Salt Lake County, with approximately 4% to 7% of turfgrass in Salt Lake County being under shadow.

Non-Functional Turfgrass Estimates

While there is no standard definition, communities that have sought to categorize functional and non-functional turfgrass often ask whether the turfgrass has a purpose for recreation, pet relief, or green space, as well as if its size, slope, or accessibility are conducive to such a purpose. A recent report by the Alliance for Water Efficiency (2024) describes these points well.

Areas of non-functional turfgrass (NFT) present an excellent opportunity for water conservation, as they are often too narrow to irrigate efficiently. For the purpose of this study, it was assumed that NFT closely aligns with park strips. Park strips are the most visible example of NFT, but NFT takes many forms. It appears in parking lots, side yards, fenced areas, medians, and more, making quantification difficult. Given the complexity of determining these volumes, a more conservative approach was taken.

An analysis was completed to measure grass in park strips in turfgrass-dense residential areas of GSL basin. It considered two components: 1) hand delineation of greenspace in several neighborhoods throughout the GSL basin, and 2) utilizing the Greenspace Model to determine the volumes compared to hand delineation.

Park Strip NFT Delineation Methodology

Ten case study residential neighborhood blocks, averaging seven acres each, were evaluated by hand. The greenspace was measured and the area of turfgrass associated with lawns and landscaping was compared to the area of turfgrass within park strips.

After completing the case study, the same number was estimated using the Greenspace Model. To test the DWRe Greenspace Model against the hand delineation, the DWRe data were used to obtain estimates of park strip percentages of the same study areas where possible. As park strips are generally municipal property and therefore lie outside of privately owned parcels, parcel boundaries were used to demarcate lawn from park strip. These results were generally within a few percentage points of the case study estimates. The same calculation was performed over a larger residential area to obtain overall estimates for residential areas within these municipalities.

Park Strip NFT Delineation Results

Table E-6 shows the case studies produced values ranging from 6% to 21% by neighborhood, with an overall average of 11.5%. The Greenspace Model found results within a couple of percentage points of the hand delineated effort, indicating that park strips data generally aligns with the industry estimate of 5% to 15% of total turfgrass area.

Table E-6. Summary of Park Strip Analysis

Municipality	Park Strip % - Case Study Estimate	Park Strip % - Case Study Area – Est from Greenspace Model	Park Strip % - Overall Resi Area –Est from Greenspace Model
Provo	13.9	20.1[1]	-
Saratoga Springs	11.0	-	13.2
Mapleton	12.0	-	-
Tooele	8.8	-	-
Ogden	18.2	-	-
Brigham City	14.4	14.9	20.1
SLC (Sugarhouse)	20.8	24.4	13.4
West Valley City	8.8	-	-
Payson	6.1	-	-
Syracuse	7.8	7.4	6.9
Average	**12.2**	**16.7**	**13.4**

1. Exact estimate may vary; parcel boundaries and addresses are inconsistent in Utah County parcel data.

There is some correlation between park strip percentage and lot size; denser neighborhoods with smaller lots tend to have a higher percentage of turfgrass in park strips. Some neighborhoods have wider park strips than others, and some neighborhoods have no park strip at all.

Using remote sensing to identify greenspace has limitations. First, it is difficult to distinguish between different types of vegetation. Second is the need to limit study areas to residential areas:

Many of the municipal-level data sets include large agricultural parcels, Forest Service land, or other open space, making the percentage of turfgrass within park strips an unusably small number. Another limitation is that commercial areas also contain park strips absent any other landscaping features, so while these park strips are good candidates for conservation, it is not possible to use the same metric for commercially zoned properties.

Government, School, and Church-owned NFT Methodology

Other candidates for water conservation include areas of landscaped turfgrass that may appear functional at first glance but are not typically used for recreation or other human functions. Examples include turfgrass on property owned by governments (municipal, county, and state), schools, and churches. It is difficult to use remotely sensed data to determine whether turfgrass on these parcels is functional or non-functional; for example, there is no practical way to distinguish between a school's soccer field and an ornamental lawn at the same school. Limitations on county record keeping may compound the difficulty of extracting usable data. For example, poorly drawn parcel boundaries combined with low resolution imagery may erroneously lead to the conclusion that an area of turfgrass exists outside a parcel boundary.

DWRe provided Greenspace Models at the county level for Salt Lake, Davis, Weber, and Utah counties. The data were filtered to estimate the percentage of urban turfgrass belonging to government, schools, and churches, while excluding park strip area and non-landscaped open space. Because each county keeps property records differently, tax exemption status and parcel address were used as starting points to filter county models, applying additional filters as needed depending on county data. In addition, high-level estimates were completed for residential and commercial properties. Numerous issues with Utah County data, including parcel boundaries and parcels with no address, prevented a usable estimate at the county level.

Government, School, and Church-owned NFT Results

Table E-7 summarizes the percentage of tax-exempt properties for each county. The average percentages in Table E-7 were applied to the existing 135,000 acres of the turfgrass in the GSL basin and are shown in Table E-8. Areas derived in Table E-8 are used in subsequent appendices to determine potential water and depletion savings through various turfgrass replacement programs.

Table E-7. Percent of Properties by County and Land Use

Land Use	Salt Lake County	Davis County	Weber County	Utah County	*Average*
Residential (%)	51%	36%	68%	67%	*56%*
Commercial (%)	3%	4%	6%	3%	*4%*
Tax-Exempt Properties (%)	11%	10%	9%	12%	*11%*

Table E-8. Estimated Turfgrass Area by Land use Type

Land Use	Average Percentage	Total Area (acres)
Residential	56%	75,600
Commercial	4%	5,400
Tax-Exempt Properties	11%	14,850

Turfgrass Estimates by Year

In addition to quantifying existing turfgrass volumes, the estimated area of turfgrass installed each year was reviewed to understand broader over time, particularly in the context of evolving water efficiency standards and landscaping regulations. This was a high-level analysis based on available data was limited and inconsistent, which likely introduces a large margin of error. The results indicate that there has historically been a 5% to 10% annual increase in turfgrass area each year.

Turfgrass Estimates by Year Methodology

The Normalized Difference Vegetation Index (NDVI) equation can be used to identify healthy vegetation using aerial imagery. The NDVI equation, calculated as:

$$NDVI = (NIR - Red) / (NIR + Red)$$

NDVI measures vegetation health by comparing the reflectance of near-infrared (NIR) light, which healthy vegetation strongly reflects, to red (Red) light, which vegetation absorbs. Using the NDVI equation results in a range of values from -1 to 1, where lower values indicate less healthy vegetation and higher values indicate more healthy vegetation. By picking a threshold value, the imagery can then be classified as vegetated area or non-vegetated area.

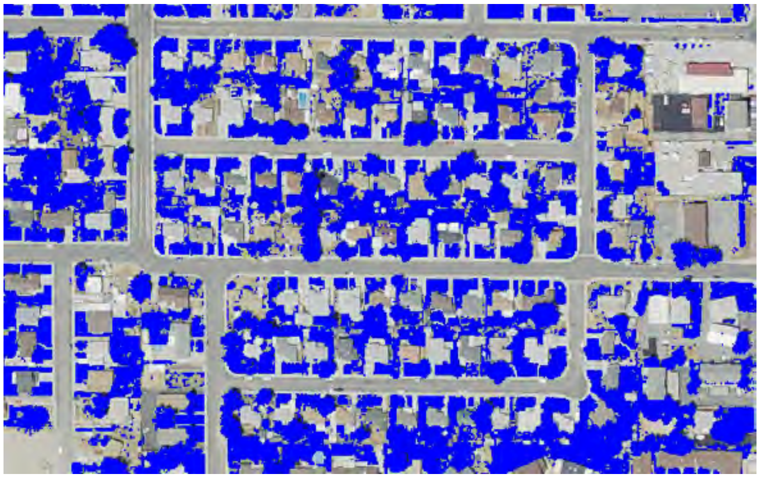
Every 3 to 5 years, the National Agriculture Imagery Program (NAIP) (USDA, n.d.) collects 4-band aerial imagery (red, green, blue, and near-infrared) at 1 meter resolution. Google Earth Engine was used to calculate the NDVI equation on NAIP imagery for the years 2014, 2018, and 2021 to estimate the area of turfgrass each year.

Calculating turfgrass area in this manner has several drawbacks. The NDVI equation picks up any healthy vegetation. While vegetation in developed areas tends to be predominantly turfgrass, undeveloped or agricultural areas will often have healthy vegetation that will be picked up. Accordingly, only developed areas can be considered when trying to identify turfgrass. When trying to compare different years, the time of day and the time of year the imagery was collected also have an impact. Imagery with more shadows will have a lower accuracy rate since the NDVI equation does not pick up vegetation in shadow. If vegetation is collected in the spring of one year and summer of another, it is likely that there will be more healthy vegetation in the spring. Even areas with little change in the landscape or vegetation from year to year will often encounter discrepancies in the NDVI equation. Figure E-9 shows the same area for the years 2014, 2018, and 2021 classified using the same threshold value of 0.1. It is clear that the 2018 imagery is much more sensitive, picking up roads and houses, and requires a much higher threshold value to get a similar result to 2014 and 2021.

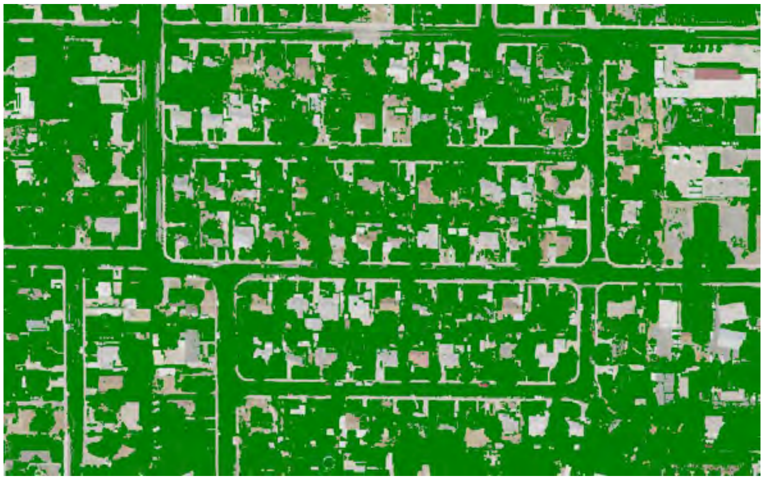
To account for this discrepancy in data, a custom threshold value was selected for each year. The values were selected by visually inspecting the resulting classification until a reasonably close match was achieved. The values shown in Table E-9 were selected. Figure E-10 shows the same area shown in Figure E-9 with the selected threshold values.

Table E-9. Threshold Values Selected for Various Years

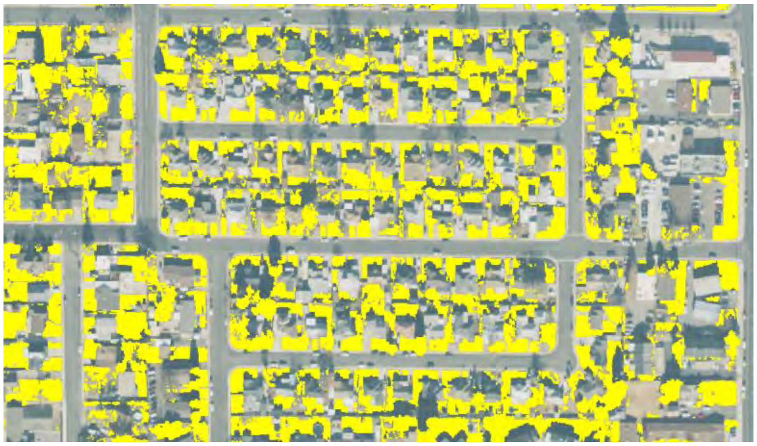
Year	Threshold Value
2014	0.21
2018	0.35
2021	0.15



2014 NAIP Aerial Imagery



2018 NAIP Aerial Imagery



2021 NAIP Aerial Imagery

Figure E-9. Aerial Imagery from 2014, 2018, and 2021. Classified Using an NDVI Threshold of 0.1

2014 NAIP Aerial Imagery

2018 NAIP Aerial Imagery

2021 NAIP Aerial Imagery

Figure E-10. Aerial Imagery from 2014, 2018, and 2021. Classified Using Custom NDVI Thresholds

To isolate developed areas each year, the Dynamic World V1 (Brown et al., 2022) dataset was used. This dataset uses 10-meter Sentinel 2 imagery to classify land cover into 9 different classifications, one of which is “built”. While this data does not perfectly classify land cover, it provides a reasonable approximation of developed area. Figure E-11 shows a graph of developed area as captured by the Dynamic World dataset across counties in the Salt Lake Basin, including Cache, Davis, Wasatch, Box Elder, Weber, Juab, Rich, Tooele, Summit, Morgan, Salt Lake, and Utah.

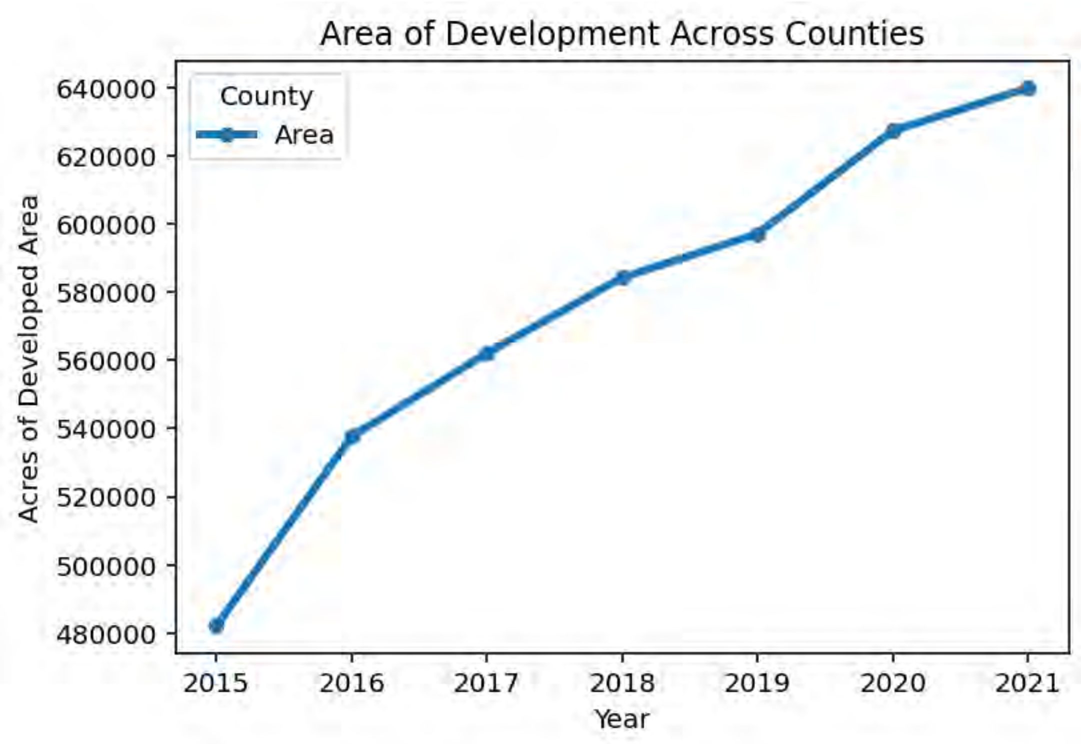


Figure E-11. Developed Area by Year Across Counties in the Great Salt Lake Basin

The developed area from the Dynamic World dataset was used for each year to isolate areas of interest in the Great Salt Lake basin. The NDVI equation was then used to classify the area within the areas of interest as vegetated or non-vegetated. For this analysis, it was assumed that all vegetated area within the developed areas of interest was turfgrass.

Turfgrass Estimates by Year Results

Table E-10 shows the estimated turfgrass area each year for each county in the Great Salt Lake Basin. Figure E-12 displays the same data graphically.

Table E-10. Estimated Turfgrass Area in Utah Counties by Year

County	2014	2018[1]	2021	Annual % Change
Box Elder	6,128	5,823	10,094	7%
Cache	13,385	11,771	16,873	3%
Davis	15,566	22,517	27,517	8%
Juab	5,624	726	1,872	-15%
Morgan	774	1,251	2,221	16%
Rich	1,083	678	1,084	0%
Salt Lake	33,689	54,322	47,263	5%
Summit	2,624	6,454	7,694	17%
Tooele	2,600	36,46	5,748	12%
Utah	25,675	31,180	33,242	4%
Wasatch	3,099	4,904	7,010	12%
Weber	16,612	20,316	29,885	9%
Total	126,859	163,587	190,502	6%

1. 2018 appears to be overestimating turfgrass in most counties even with the higher threshold value.

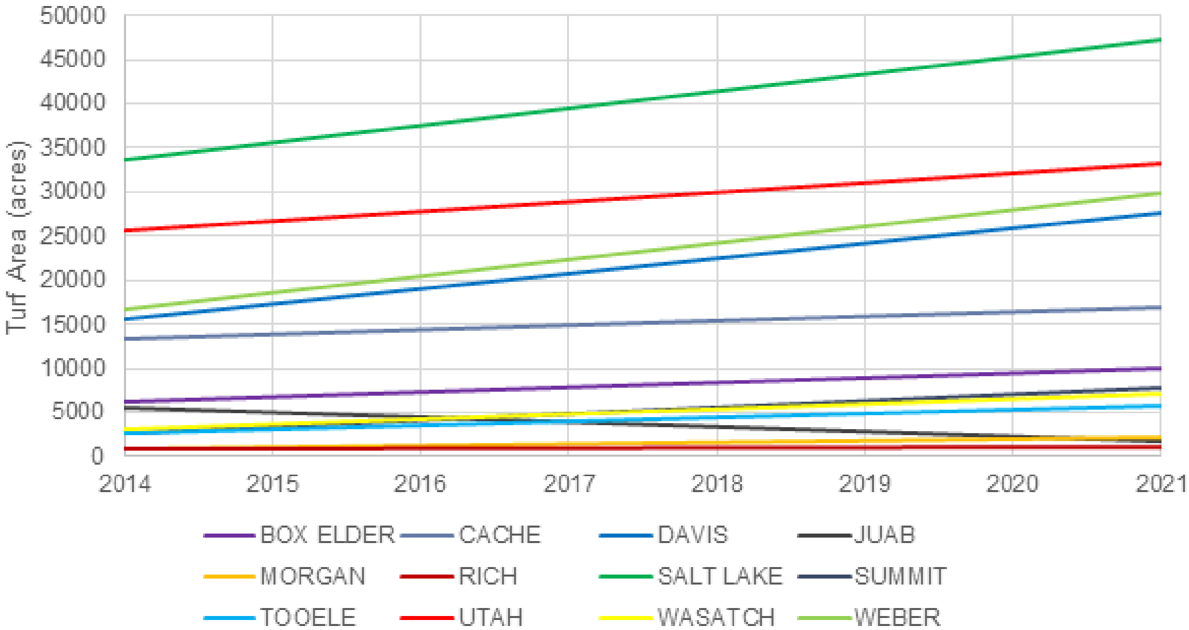


Figure E-12. Estimated Turfgrass Area by Year Across Counties in the Salt Lake Basin

This analysis showed a consistent 5% to 10% annual increase for more populated counties and 10% to 15% annual increase for less populated counties, with an estimated 6% annual increase for the basin as a whole. Using the area of turfgrass for the whole basin previously estimated and the 6% annual increase results in the estimated yearly areas of turfgrass for the Great Salt Lake basin shown in Table E-11.

Table E-11. Estimated Area of Turfgrass in the Great Salt Lake Basin by Year

Year	Area of Turfgrass (acres)
2021	135,000
2020	126,900
2019	119,300
2018	112,100
2017	105,400
2016	99,100
2015	93,100
2014	87,500

Due to the scarcity of data and the inconsistency in the available data, estimates of the area of turfgrass in the Great Salt Lake basin inherently have a large margin of error. Also, due to the nature of the data, it is only possible to estimate the turfgrass area at a few discrete points in time. As more data becomes available, additional studies may be able to establish more accurate trends and more precise estimates.

Turfgrass Analysis Conclusions

The methodology behind the Greenspace Model is robust. Water usage data conforms with the basin wide estimate within 1% overall, and while both methods have inherent flaws, it is unlikely that an additional method would provide a more accurate result with a smaller margin of error. Further efforts also may not provide a net positive benefit as conditions are constantly changing. An overall estimate of turfgrass can help inform planning efforts and indicate trends in outdoor watering.

Shadows and tree cover represent the primary sources of error in the Greenspace Model, with shadow-induced uncertainty ranging from 5% to 10% across the basin. Additional factors, though not quantifiable, contribute to the overall uncertainty. Considering these probabilities of error, the Greenspace Model maintains a reasonable degree of accuracy.

NFT as park strips was estimated as 6% to 21% by neighborhood, with an overall average of 11.5%. Park strip results from the Greenspace Model were within a couple of percentage points of the hand delineated effort, indicating that park strips data generally aligns with the industry estimate of 5% to 15% of total turfgrass area. NFT as government, school, or church-owned turfgrass was estimated as an additional 11% on average based on property records.

The analysis of turfgrass with time showed a consistent 5% to 10% annual increase for more populated counties and 10% to 15% annual increase for less populated counties, with an estimated 6% annual increase for the basin as a whole between 2014 and 2021. Turfgrass was estimated to increase from 87,500 acres in 2014 to 135,000 acres in 2021.

Appendix E – References

Alliance for Water Efficiency. 2024. *Non-Functional Turf: 2023 Summary of Programs and Policies*. https://allianceforwaterefficiency.org/resource/non-functional-turf-2023-summary-of-programs-and-policies/#:~:text=AWE%E2%80%99s%20latest%20report%2C%20Non-Functional%20Turf%3A%202023%20Summary%20of,protect%20and%20conserve%20water%20in%20the%20CRB%20region

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APPENDIX F M&I WATER CONSERVATION OPPORTUNITIES

Conservation Programs Effective at Reducing Depletion

A comprehensive list of M&I water conservation programs was compiled from consultations with water conservation experts, water utilities that had implemented effective conservation programs, and a literature review. The programs and policies were screened for further evaluation and ranked by their estimated effectiveness in reducing depletion and implementation feasibility. Programs were assigned a ranking including “Very High,” “High,” “Medium,” “Low,” and “Very Low.” Table F-1 presents the policies and programs ranked as “Very High,” indicating they likely provide the best opportunity to reduce depletion across the GSL basin. The “Very High” priority programs in Table F-1 include programs focused on turf replacement, irrigation efficiency improvements, tiered rate structures, and metering. Following this, Table F-2 details the “High” ranked policies and programs, which may also be effective in reducing depletion. However, these policies and programs may be either more challenging to implement or have lower estimated potential depletion savings. The “High” priority programs in Table F-2 focus on rebate programs, audits and surveys, and policies, standards, and regulations.

Table F-1 and Table F-2 also present a range of estimated potential annual depletion savings for each program. These estimates represent the maximum potential depletion savings if the policies or programs were fully adopted by all M&I water utilities and users within the Great Salt Lake basin. While acknowledging that 100% adoption is currently infeasible and not necessarily recommended, these values provide water resource managers with insights into which programs offer the greatest opportunities for depletion reduction. The depletion savings estimates are further broken down by sub-basin. The estimated volumes are based on average historical M&I demand conditions from 2019 – 2023 and assumptions derived from observed savings in similar programs in other locations. A range in low and high estimated depletion savings is included to account for uncertainties in these estimates. Detailed assumptions and methodologies for developing these depletion estimates are provided in Appendix M and summarized below.

The estimated depletion savings opportunities across the Great Salt Lake basin vary due to the distinct characteristics of its sub-basins. Each sub-basin has a unique climate, population size, mix of land uses, and existing metering infrastructure, which influence the range of depletion savings opportunities from various conservation programs and policies. Turf replacement and other outdoor irrigation optimization programs show the greatest potential in sub-basins with higher populations, such as the Weber River, Jordan River, and Utah Lake where there is a greater extent of turf grass acreage compared to less populated sub-basins like Bear River and West Desert.

Sub-basins with a larger proportion of unmetered water use, such as the Bear and Weber River sub-basins, present greater opportunities for depletion savings through the introduction of water use metering programs. These areas can benefit significantly from additional metering and increased consumer awareness of high water use and likely higher water bills when tiered rate structures are implemented (Utah House Bill 274, 2025). Allotment-based and conservation-focused tiered rate structures implemented only where metering infrastructure currently exists would be of most benefit in the Weber River, Utah Lake, and Jordan River sub-basins. The implementation of tiered rate structures could increase depletion savings by approximately 4,000 to 72,000 ac-ft basin-wide if universal metering were implemented. The uncertainty in tiered rate structure programs is considerable, mainly due to the variability in conservation savings observed in similar programs from which these estimates are derived. Interviews with local water conservation districts suggest that the success of tiered rate programs in achieving conservation savings largely depends on the level of education and customer awareness regarding water usage.

Overall, the effectiveness of conservation programs and policies varies across each sub-basin. Tailoring these initiatives to the unique characteristics of each area ensures that the most impactful strategies are employed, maximizing the potential for reducing water depletion across the Great Salt Lake basin. Stakeholder involvement is crucial in incorporating these strategies into regional conservation planning efforts, as local knowledge and collaboration can enhance the effectiveness and acceptance of these programs. Engaging stakeholders such as water utilities, community organizations, and residents helps ensure that conservation measures are practical, well-supported, and aligned with the specific needs and conditions of each sub-basin. This is discussed further in Appendix I.

It is important to note that there is an overlap in the depletion reductions targeted by the individual programs and policies identified. Therefore, the depletion reduction estimates presented in these tables cannot be directly aggregated across programs. An ac-ft depletion reduction achieved by a reduction in turfgrass acreage is subsequently unavailable for reduction by the implementation of a metering program. While estimated maximum potential annual depletion savings are provided for the programs, such estimates are not determined for the policies. This is because policies primarily support the adoption rate of the programs listed, but it is challenging to determine specific savings estimates tied directly to these policies. It should be noted that many of the programs listed in the tables are already being implemented in Utah but still provide significant depletion savings opportunities if they are to be expanded.

Table F-1. Very High Priority Depletion Reduction Strategies

Turfgrass Replacement Programs: Turfgrass replacement with native or low water-use plants and hardscape materials implemented by land use type

Program/Policy	Description	Variable	Bear River		Jordan River		Utah Lake		Weber River		West Desert		GSL Basin Wide	
			Low	*High*	*Low*	*High*	*Low*	*High*	*Low*	*High*	*Low*	*High*	*Low*	*High*
			Thousand ac-ft		Thousand ac-ft		Thousand ac-ft		Thousand ac-ft		Thousand ac-ft		Thousand ac-ft	
Basin-wide Turf Replacement Program	Replacement of all turfgrass across the basin.	Depletion Reduction Estimate	16	21	50	59	54	65	60	72	2	3	**183**	**219**
		Total Water Use Reduction Estimate	42	49	115	132	144	166	120	138	7	8	**429**	**492**
Park Strip Turfgrass Replacement Program	Turfgrass replacement programs for non-functional turfgrass in park strips.	Depletion Reduction Estimate	3	4	15	20	13	18	16	22	<1	1	**46**	**63**
		Total Water Use Reduction Estimate	4	4	20	23	18	20	22	25	1	1	**64**	**74**
Tax-Exempt Land Turfgrass Replacement Programs	Turfgrass replacement programs for land owned by tax-exempt entities.	Depletion Reduction Estimate	3	4	9	12	10	14	8	11	1	1	**31**	**42**
		Total Water Use Reduction Estimate	4	5	13	14	14	16	11	13	1	1	**43**	**49**

Landscape Irrigation Efficiency Programs

Program/Policy	Description	Variable	Bear River		Jordan River		Utah Lake		Weber River		West Desert		GSL Basin Wide	
			Low	*High*	*Low*	*High*	*Low*	*High*	*Low*	*High*	*Low*	*High*	*Low*	*High*
			Thousand ac-ft		Thousand ac-ft		Thousand ac-ft		Thousand ac-ft		Thousand ac-ft		Thousand ac-ft	
Weather-Based Irrigation Controllers	Programs promoting irrigation controllers that adjust schedules based on weather to reduce overwatering. Prioritize users with a history of over-irrigating.	Depletion Reduction Estimate	4	13	12	37	12	37	15	46	1	2	**42**	**135**
		Total Water Use Reduction Estimate	6	15	16	43	16	43	20	54	1	3	**59**	**157**
Landscape/Irrigation Audits	On-site audits of irrigation systems to detect inefficiencies, leaks, and improve system efficiency.	Depletion Reduction Estimate	3	10	9	29	8	29	11	36	1	2	**31**	**106**
		Total Water Use Reduction Estimate	4	12	12	34	12	34	15	42	<1	2	**43**	**123**
Statewide Turfgrass Mapping Data	Statewide aerial turfgrass data purchase with annual updates to support planning and tracking conversion.	Depletion Reduction Estimate	Not Available											
		Total Water Use Reduction Estimate												
Water Conservation and Efficiency Plan	Develop long-term water conservation plans with measurable goals, demand forecasts, and alignment with utility priorities.	Depletion Reduction Estimate	Not Available											
		Total Water Use Reduction Estimate												
End Use Water Conservation and Efficiency Analysis	Comprehensive analysis of end-use water conservation opportunities, targeting high-use customers and non-revenue water loss.	Depletion Reduction Estimate	Not Available											
		Total Water Use Reduction Estimate												

Tiered Rate Structure and Metering Opportunities														
Program/Policy	**Description**	**Variable**	**Bear River**		**Jordan River**		**Utah Lake**		**Weber River**		**West Desert**		**GSL Basin Wide**	
			Low	***High***	***Low***	***High***	***Low***	***High***	***Low***	***High***	***Low***	***High***	***Low***	***High***
			Thousand ac-ft		Thousand ac-ft		Thousand ac-ft		Thousand ac-ft		Thousand ac-ft		Thousand ac-ft	
Universal Metering (including secondary metering)	Implementation of universal metering to monitor all drinking water and secondary connections, ensuring accurate accounting of water usage.	Depletion Reduction Estimate	1	5	2	7	1	4	3	12	<1	<1	**6**	**29**
		Total Water Use Reduction Estimate	2	6	2	8	1	5	4	134	<1	<1	**8**	**33**
Allotment Based Tiered Rates (Using Existing Meters)	Implement allotment-based tiered rate structures based on user's irrigated area and local climate. Rates increase as user exceeds budgeted water use. Success depends on well-designed implementation, including the development of informed tiers and rate levels. Applies only to metered customers.	Depletion Reduction Estimate	0	0	1	8	1	10	2	12	0	0	**4**	**30**
		Total Water Use Reduction Estimate	0	0	1	9	2	11	2	14	0	0	**6**	**34**
Allotment Based Tiered Rates (Post-Universal Metering)	Same as above but only applies to all unmetered customers.	Depletion Reduction Estimate	1	8	3	18	2	16	4	30	0	<1	**10**	**72**
		Total Water Use Reduction Estimate	1	9	4	21	3	19	6	35	<1	<1	**14**	**84**
Conservation Focused Tiered Rates (Using Existing Meters)	Design conservation-oriented water rate structures to incentivize efficient use while ensuring financial sustainability. Rates increase as user exceeds budgeted water use. Applies only to metered customers.	Depletion Reduction Estimate	0	0	1	7	1	9	2	11	0	0	**4**	**27**
		Total Water Use Reduction Estimate	0	0	1	8	2	10	2	13	0	0	**6**	**31**
Conservation Focused Tiered Rates (Post-Universal Metering)	Same as above but only applies to all unmetered customers.	Depletion Reduction Estimate	1	7	3	16	2	15	4	27	0	<1	**10**	**65**
		Total Water Use Reduction Estimate	1	8	4	19	3	17	6	31	<1	<1	**14**	**76**

Table F-2. High Priority Depletion Reduction Strategies

Commercial Rebate Programs: Financial incentives to businesses to encourage the adoption of water-saving technologies and practices.

Program/Policy	Description	Variable	Bear River		Jordan River		Utah Lake		Weber River		West Desert		GSL Basin Wide	
			Low	*High*	*Low*	*High*	*Low*	*High*	*Low*	*High*	*Low*	*High*	*Low*	*High*
			Thousand ac-ft		Thousand ac-ft		Thousand ac-ft		Thousand ac-ft		Thousand ac-ft		Thousand ac-ft	
Cooling Tower Retrofit Rebates	Rebates and incentives for retrofit to high efficiency cooling towers.	Depletion Reduction Estimate	<1	<1	<1	1	<1	<1	<1	<1	<1	<1	**1**	**1**
		Total Water Use Reduction Estimate	<1	<1	<1	1	<1	<1	<1	<1	<1	<1	**1**	**1**
Vehicle Washing/ Carwash	Rebates for carwashes that install water-saving technologies. Water use surveys and audits for residential properties to identify indoor water savings opportunities.	Depletion Reduction Estimate	0	<1	0	<1	0	<1	0	<1	0	<1	**0**	**<1**
		Total Water Use Reduction Estimate	0	<1	0	2	0	1	0	1	0	<1	**<1**	**5**

Audits and Surveys: Assessing and analyzing water consumption patterns in a residential, commercial, or industrial setting to identify opportunities for improving efficiency and reducing waste.

Program/Policy	Description	Variable	Bear River		Jordan River		Utah Lake		Weber River		West Desert		GSL Basin Wide	
			Low	*High*	*Low*	*High*	*Low*	*High*	*Low*	*High*	*Low*	*High*	*Low*	*High*
			Thousand ac-ft		Thousand ac-ft		Thousand ac-ft		Thousand ac-ft		Thousand ac-ft		Thousand ac-ft	
Annual Irrigation Inspection	Ordinance requiring annual irrigation inspection requirement for properties over a specific size to prevent water waste.	Depletion Reduction Estimate	Not Available											
		Total Water Use Reduction Estimate												
Indoor Residential Water Use Surveys/Audits	Water use surveys and audits for residential properties to identify indoor water savings opportunities.	Depletion Reduction Estimate	1	1	3	4	1	1	<1	1	<1	<1	**4**	**7**
		Total Water Use Reduction Estimate	14	18	49	77	10	27	2	17	3	4	**78**	**145**
Commercial Water Use Audits	Conduct water audits for commercial, industrial, and institutional users to identify savings, including cooling tower audits for large facilities.	Depletion Reduction Estimate	Not Available											
		Total Water Use Reduction Estimate												

Policies, Standards, and Regulations: Policies including regulations, standards, prevention, and technical assistance in executing conservation such initiatives.

Program/Policy	Description	Variable	Bear River		Jordan River		Utah Lake		Weber River		West Desert		GSL Basin Wide	
			Low	*High*	*Low*	*High*	*Low*	*High*	*Low*	*High*	*Low*	*High*	*Low*	*High*
			Thousand ac-ft		Thousand ac-ft		Thousand ac-ft		Thousand ac-ft		Thousand ac-ft		Thousand ac-ft	
Reduction Targets at Regional Level	Reduction target goals and conservation standards by equivalent residential connection, established by regional government.	Depletion Reduction Estimate	Not Available											
		Total Water Use Reduction Estimate												
Conservation Standards for New Construction	Water conservation standards for new construction, including requirements for irrigation and plumbing fixtures.	Depletion Reduction Estimate	Not Available											
		Total Water Use Reduction Estimate												
Water Waste Prevention	Water waste prevention policies, such as prohibiting runoff, hose washing, and single-pass cooling systems.	Depletion Reduction Estimate	Not Available											
		Total Water Use Reduction Estimate												
Home-Owner Association Regulations	Home-Owner Associations are strongly encouraged to adopt and enforce water use restrictions in their rules and regulations.	Depletion Reduction Estimate	Not Available											
		Total Water Use Reduction Estimate												
Conservation Technical Assistance	Continued efforts by the state to support utilities in understanding and implementing water conservation initiatives, regulations, and policies remain critical. The state can maintain and expand its suite of programs and resources aimed at improving water efficiency and promoting conservation across all regions. This may include increased collaboration with utilities by offering targeted guidance, financial assistance, and technical support to enhance their capacity to manage water resources effectively and sustainably.	Depletion Reduction Estimate	Not Available											
		Total Water Use Reduction Estimate												

Appendix F - References

Utah House Bill 274. 2025. *Water Amendments*. Utah State Legislature. https://le.utah.gov/~2025/bills/static/HB0274.html

APPENDIX G COSTS OF M&I CONSERVATION OPPORTUNITIES

Cost estimates for the conservation strategies presented in the previous chapter were developed to support evaluation of their relative cost-effectiveness. This analysis calculated the cost per ac-ft of water saved for each strategy, providing a consistent metric for comparison. These estimates are intended to inform prioritization and planning by illustrating the trade-offs between water savings and financial investment. The methodology used to develop these cost estimates is provided in Appendix M.

Table G-1 summarizes the estimated unit costs for the prioritized M&I conservation measures. Costs vary widely across strategies due to differences in implementation approach, required infrastructure, and reliance on user participation. For example, turf replacement programs typically involve high initial material and labor costs, whereas tiered rate structures rely more on administrative adjustments and pricing signals. Programs that depend on behavioral change—such as tiered rate structures or water use audits—tend to show more variability in cost-effectiveness, reflecting uncertainty in the participation rate and actual water savings achieved per dollar spent. While the implementation costs for the Indoor Residential Water Use Efficiency program are relatively low, it results in the highest cost per acre-foot of depletion saved. This is because the volume of depletion savings is very low, making the denominator in the calculation small. Reducing indoor water use does not lead to significant depletion savings, as there is minimal depletion associated with indoor use, as detailed in Appendix A. It should also be noted that the cost associated with this program is likely to be higher than the cost of developing a new source of supply.

While some conservation programs may carry high implementation costs, they can also generate measurable utility savings. As outlined in AWWA Manual M52, conservation measures can reduce operational expenses by decreasing demands on treatment processes, chemical usage, pumping, and other system functions. These cost offsets enhance the overall cost-effectiveness of a strategy and are factored into the costs shown in Table G-1. When these operational benefits are included in the cost analysis, many conservation options become more financially viable—and in some cases, result in negative net costs, indicating that long-term savings may fully exceed the initial investment.

The Statewide Turf Mapping Program did not quantify water savings and therefore did not calculate a cost per acre-foot (AF) of water conserved or depleted. However, an estimate was provided by the environmental consulting firm Land IQ for the Great Salt Lake (GSL) Basin. This estimate includes turf classification and analysis of changes in turf area over a defined time frame, with a total cost of $697,800 for these tasks.

This information aids in prioritizing strategies that offer the greatest water savings relative to their implementation costs. Table G-1 serves as a tool for stakeholders to make informed decisions about which strategies to pursue, balancing water conservation goals with financial considerations. Cost estimates are only provided for strategies for which depletion estimates are available (see Table F-1 and Table F-2 in Appendix F).

Table G-1. Costs of M&I Conservation Programs

Program	Annualized Cost per Acre-foot of Water Conserved	Annualized Cost per Acre-foot of Water Depleted
Conservation Tiered Rate Structure–w/ Only Existing Meters	$0–$40	$0–$60
Allotment Based Tiered Rate Structure–w/ Only Existing Meters	$0–$40	$0–$50
Weather-Based Irrigation Controllers	$30–$510	$30–$710
Allotment Based Tiered Rate Structure–w/ Universal Metering	$90–$1,020	$100–$1,410
Conservation Focused Tiered Rate Structure–w/ Universal Metering	$100–$1,020	$120–$1,410
Large Landscape/ Irrigation Audits	$30–$1,060	$30–$1,480
Universal Metering	$230–$1,740	$270–$2,420
Aggregate: Conservation Tiered Rates & Tax-Exempt Park Strip Turf Replacement	$210–$2,340	$240–$3,250
Cooling Tower Retrofit Rebates	$1,570–$9,400	$1,570–$9,400
Park Strip Turf Replacement	$2,280–$7,380	$2,650–$10,250
Tax-Exempt Park Strip Turf Replacement	$2,280–$7,430	$2,660–$10,320
Turf Replacement Program	$2,280–$7,380	$5,140–$17,250
Indoor Residential Water Use Efficiency	$160–$1,050	$3,140–$21,010

APPENDIX H WATER SUPPLY MANAGEMENT ALTERNATIVES

In addition to conservation strategies, several alternative water supply management strategies are considered to support the health and increased water levels of the Great Salt Lake. These strategies focus on either reducing depletion from the watershed, increasing inflows into the lake, or mitigating the negative effects of low lake levels. While this study does not evaluate every possible intervention, it provides a focused assessment of five key alternatives: dust mitigation, cloud seeding, phragmites removal, water reuse, and stormwater and agricultural optimization. Depletion savings and cost estimates for each management alternative are in Table H-2.

Cloud Seeding

Cloud seeding has been employed in Utah since the 1950s as part of a long-standing effort to enhance snowpack and subsequently increase runoff volumes (DNR, 2018). This atmospheric water augmentation strategy involves the release of silver iodide into storm systems to stimulate precipitation formation where it might not occur otherwise. In recent years, Utah's cloud seeding program has expanded in both coverage and investment, with assessments indicating that relatively modest financial investments have been associated with measurable increases in snowpack and runoff volume. However, establishing a direct link between cloud seeding and observed increases in runoff is inherently difficult. The effectiveness of the program depends on complex interactions among meteorological conditions, storm trajectories, and hydrologic responses, all of which introduce uncertainty into estimates of program outcomes.

Current estimates suggest that cloud seeding generated approximately 102,000 ac-ft of additional runoff between 2017 and 2022 at a cost of approximately $3.60 to $7.10 per ac-ft (Jennings, pers. comm., 2025). These values reflect only cloud seeding efforts conducted within the Great Salt Lake Basin to date, although there is potential to increase the cloud seeding application area. However, cloud seeding performed in areas adjacent to the Basin may also influence water supply and availability due to Utah's inter-basin transfer operations. It is important to note that estimates of cloud seeding impacts are derived from complex modeling approaches that are subject to considerable variability and uncertainty. As such, these estimates may either overstate or understate the actual potential of the programs to generate additional runoff. Despite these limitations, they represent the best available data for assessing the potential contribution of cloud seeding to water supply.

Phragmites Australis Management and Removal

Another potential strategy for reducing depletion is the removal and management of *Phragmites australis* (Phragmites), an invasive wetland plant species that has proliferated across the Great Salt Lake watershed. Phragmites often displaces native vegetation, degrades wetland habitat, and is associated with increased water consumption relative to the native species it supplants. Estimates suggest that Phragmites consumes between 17,000 and 57,000 additional ac-ft of water per year compared to native wetland vegetation, depending on density and site conditions (DWQ, 2017). Effective control of Phragmites is difficult due to its aggressive growth and regenerative capacity, but it can be achieved through a combination of mechanical removal, herbicide application, reseeding with native species, and long-term management. Accessing Phragmites in dense wetland areas can be challenging due to the thick vegetation, waterlogged conditions, and difficult terrain, which hinder movement and the use of equipment. While costs vary by method and site, current estimates indicate an average treatment cost of approximately

$1,270 to $2,540 per acre (Hambrecht, pers. comm., 2025). If Phragmites were successfully removed and replaced with native vegetation throughout its known distribution in the Great Salt Lake watershed, total water savings could range from 17,000 to 57,000 ac-ft per year at an estimated cost between $610 and $4,050 per ac-ft. In addition to water savings, Phragmites control supports a range of ancillary benefits including improved habitat quality, increased biodiversity, and enhanced ecological function of wetland systems.

Dust Mitigation

The drying of terminal lakes such as the Great Salt Lake often present significant public health risks due to the exposure of lakebed sediments that contain fine particulate matter and other pollutants. Once exposed and desiccated, these bare soils can become mobilized by wind, contributing to regional air quality degradation and increasing the incidence of respiratory and cardiovascular health conditions. The scale of this risk is substantial, as demonstrated by large-scale dust mitigation efforts at Owens Lake and the Salton Sea in California, where dust mitigation—annualized over 25 years—is estimated to cost from $5,460 to $10,930 per acre.

As of early 2025, the Great Salt Lake water surface elevation is approximately 4,192 feet, corresponding to roughly 480,000 acres of exposed lakebed. While this is a substantial area of exposed playa, the actual area requiring dust control is governed by localized hydrogeologic and atmospheric conditions that determine the location of dust "hotspots," as shown in Figure H-1. Research by Dr. Kevin Perry at University of Utah indicates that only about 11 percent of this exposed area—approximately 52,800 acres—is currently contributing to the generation of airborne dust (ECONorthwest & M&NEC, 2019).

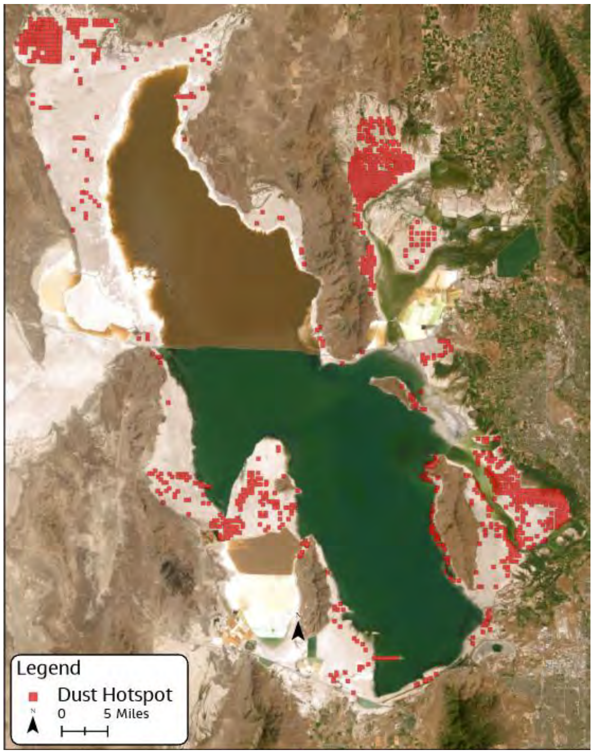

Figure H-1: GSL Dust Mitigation Hotspots

If current hydrologic trends persist and no substantial conservation actions are taken to raise lake levels, dust mitigation would be required across the full extent of these active hotspots. Under this "no action" alternative—where lake levels remain at their current levels—total project expenditures are estimated between $7.2 and $14.4 billion, translating to annualized dust control costs of $290 million to $575 million over a 25-year period. These figures illustrate the long-term financial burden of maintaining public health and air quality protection without addressing the root cause of lakebed exposure.

These potential costs are highly sensitive to lake elevation. According to the GSL 2025 Strike Team report, increasing annual inflows by 250,000 ac-ft could raise the lake's average elevation to 4,194 feet by 2054, while 770,000 ac-ft of added inflows would raise it further to 4,198 feet (Great Salt Lake Strike Team, 2025). These elevations reduce the area of dust hotspots to 50,140 acres and 34,320 acres respectively, leading to notable reductions in mitigation costs (Perry, pers., comm., 2025). Annualized dust control expenses decrease approximately $15 million to

$30 million under the 250,000 ac-ft scenario, and $100 million to $200 million with the 770,000 ac-ft scenario. On a per-unit basis, each ac-ft of conserved water could avoid between $60 and $250 in dust mitigation costs—highlighting the direct economic benefits of conservation and water management interventions that stabilize or raise lake levels. It should be noted that the percentage of dust-producing hotspots may increase or decrease over time due to changes in surface and groundwater dynamics, which could significantly alter the cost of implementation.

In addition to cost, water demand associated with dust mitigation practices must also be considered. One common approach, shallow flooding, consumes substantial volumes of water due to high rates of evaporation. If shallow flooding were applied to the industry standard 75% of dust-generating areas, and assuming an annual evaporative demand of 39.65 inches (DNR, 2011), the resulting annual water depletion under current lake elevations could total approximately 130,900 ac-ft. If lake levels were to rise to 4,194 ft and 4,198 ft, this loss would decrease to 124,300 and 85,100 ac-ft, respectively—representing savings of 6,600 and 45,800 ac-ft.

It is important to note that shallow flooding is just one of several dust mitigation techniques. Other strategies include gravel capping, vegetative stabilization, tilling, and the use of chemical dust suppressants such as magnesium chloride which could be sourced from local mineral extraction operations. Moreover, dust mitigation efforts are often seasonal, targeting periods of high dust mobilization risk and remaining dormant during low-risk periods. Therefore, the estimates presented here reflect upper-bound values for water consumption. The selection and combination of mitigation methods should be informed by ongoing monitoring, adaptive management, and localized assessments in order to optimize both environmental and economic outcomes. A summary of estimated costs and water demands associated with dust mitigation are provided in Table H-1.

While dust mitigation at the Great Salt Lake is not currently mandated by law, it is recommended by public health experts due to the risks posed by airborne particulate matter. If dust emissions contribute to violations of federal air quality standards or create significant public health hazards, legal requirements for mitigation could be triggered under existing environmental regulations. Due to the complex and dynamic nature of dust mobilization and mitigation, including interactions with surface and groundwater conditions, a more detailed and targeted analysis of these relationships is warranted to better inform long-term management strategies.

Table H-1. Dust Mitigation Costs and Water Use by Inflow

Inflow Scenario	**Lake Elevation**	**Area Requiring Dust Mitigation**	**Hot Spots Inundated**	**Total Cost Annualized over 25-Years**	**Cost Savings per ac-ft of Additional Inflow**	**Mitigation Water Demand** *(Shallow Flooding)*	**Water Depletion Avoided Through Conservation**
	(ft)	*(acres)*	*(%)*	*($/Year)*	*($/acre-ft)*	*(acre-ft)*	*(acre-ft)*
Current Trend	4,191	52,800	0%	$290M - $577M	-	130,900	-
250,000 AF/Year	4,194	50,160	5%	$275M - $550M	$60 - $120	124,300	6,600
770,000 AF/Year	4,198	34,320	35%	$187M - $375M	$130 - $260	85,100	45,800

Agricultural Optimization

Agricultural water use represents the largest source of depletion in Utah, giving on-farm conservation strategies strong potential to support efforts to stabilize Great Salt Lake levels. A study performed by USU, M.Cubed, and Jacobs Engineering Group, completed in June 2025, evaluated agricultural depletion reduction opportunities in the Great Salt Lake Basin (Jacobs, USU, and M. Cubed, 2025). The study identified three key agricultural conservation strategies: land leasing, crop substitution, and irrigation system changes. The following conservation strategies resulted were identified as most cost-effective, with costs per acre-foot of less than $300: converting wheel line systems to LESA or LEPA pivots, upgrading from MESA to LESA pivots, and ceasing alfalfa irrigation after June 30 or full season leasing. While these upgrades improve on-farm efficiency, without reductions in total water application, they may not lead to depletion savings and could even increase depletions through increased consumptive use. To ensure meaningful depletion reductions, it is important that these strategies be implemented in a coordinated and well-designed manner, with multiple approaches used in tandem where possible.

This approach offers the greatest water savings potential but may result in localized economic impacts, particularly in communities with high agricultural dependency. These impacts can be mitigated through direct compensation for leasing and careful program design to avoid clustering. Partial season leasing of alfalfa after one cutting would result in 1.0 acre-feet per acre savings. Combined with the lower cost per acre-foot of $210, partial season leasing is a high-water-savings, temporary water conservation measure with lower economic impacts than full season leasing.

Crop substitution, such as shifting from alfalfa to corn or winter wheat, can reduce depletion by approximately 0.1 or 0.5 acre-feet per acre. This equates to an overall depletion savings on the order of 20-100 thousand acre-feet per year. However, the associated costs are as high as $897 per acre-foot, reflecting market and agronomic barriers. This strategy may be best suited for areas with existing infrastructure and crop flexibility but is less scalable in high-elevation regions where production risk is greater.

Irrigation system conversion, specifically from center pivot to subsurface drip irrigation (SDI), can reduce depletion by 0.4 acre-feet per acre when paired with partial land retirement. Irrigation system conversion could yield up to 120,000 acre-feet of depletion savings per year at highest level of program implementation considered. Costs range from $420 to $529 per acre-foot, depending on the existing system. These upgrades can offer moderate savings and temporary economic stimulus but require substantial capital investment and careful program design to ensure depletion reductions. Depletion savings and associated costs for agricultural water use optimization values are presented in Table H-2.

Table H-2. Summary of Agricultural Conservation Savings Potential and Cost

Strategy	Estimated Annual Savings (25–75% Enrollment)	Depletion Reduction	Depletion Reduction Cost
	(ac-ft/yr)	*(ac-ft/yr/acre)*	*($/ac-ft)*
Land Leasing[1]	130,000-140,000	0.1-1.5	$210-$325
Crop Substitution	0-150,000	0.1–0.3	$780–$2,500
Irrigation System Conversion	0-120,000	0.1-0.5	$170–$870

1. Assuming 10% of the total fields are enrolled in the leasing program

No Action

The *Assessment of Potential Costs of Declining Water Levels in Great Salt Lake* estimates that continued reductions in lake elevation could impose substantial economic burdens on Northern Utah, with annual costs totaling approximately $2.1 - $2.8 billion and over 6,500 jobs lost (ECONorthwest, 2025). Over a 20-year period, these impacts could total approximately $33.8 - $44.6 billion (with 3% annual discount rate). The primary sources of economic loss include diminished mineral extraction output, losses in recreation and brine shrimp industry revenue, and health-related expenses from worsened air quality which can be seen in Table H-3. These projections are conservative and do not include all potential planning, legal, or coordination costs. In addition to monetized impacts, there are also quantified and non-monetized costs such as property value reductions, invasive species management, loss of non-use value, and degradation of bird habitats.

These escalating costs are the direct result of insufficient action to manage the lake's decline or mitigate its impacts. The report underscores that without proactive water management and policy interventions, the Great Salt Lake's deterioration will continue to accelerate, exacerbating economic losses and environmental degradation.

Table H-3. Projected Economic Impacts of Inaction[1]

Type of Cost	Annual Cost	20-Year Cost	Potential Job Losses
Loss of Mineral Extraction Output	$1.7 billion	$27 billion	5,368
Loss of Lake Recreation Output	$100.7 million	$1.6 billion	615
Loss of Brine Shrimp Industry Output	$16.4 – $98.6 million	$0.3 – $1.6 billion	574
Landscape Mitigation Costs	$239.4 - $754.0 million	$3.8 – 12.0 billion	
Loss of Recreation Economic Value	$59.3 - $131.7 million	$0.9 - $2.1 billion	
Health Costs	$3.1 - $13.6 million	$49.2 – $216 million	
Loss of Ski Resort Spending	$7.0 – $11.7 million	$111.1 - $185.8 million	>0
Total:	**$2.1 - $2.8 billion**	**$33.8 – $44.6 billion**	**6,557**

1. (ECONorthwest and Martin & Nicholson Environmental Consultants, 2025)

Beyond financial considerations, the report underscores how declining lake levels are degrading the region's quality of life. Dust from exposed lakebeds exacerbates Northern Utah's already severe air pollution, with implications for public health and visibility. Reduced snowpack, worsened by increased dust and diminished lake effect, poses challenges for water supply and winter recreation. Additional non-economic consequences include diminished aesthetics and increased burdens on wildlife management. These impacts could drive outmigration and reduce the region's ability to attract and retain businesses. The report concludes that proactive investment in water conservation and lake restoration offers a cost-effective path forward—one that could yield tens of billions of dollars in long-term benefits while preserving the environmental and cultural integrity of the Great Salt Lake region.

Comparison Summary

The analysis of water management alternatives identifies a range of costs, strategies, and potential outcomes across several high-profile alternatives. Agricultural optimization and phragmites removal offer direct depletion reductions, though implementation feasibility varies. Cloud seeding provides a potential method for increasing snowpack and runoff at relatively low cost. Dust mitigation, while not a water conservation measure, addresses the public health and environmental risks associated with continued lake decline and exposed lakebed. It represents a reactive cost that increases as lake levels fall, therefore its cost per ac-ft should be viewed as an avoided cost, not direct program cost. Collectively, these strategies reflect different roles within an integrated approach to managing water use and associated impacts in the Great Salt Lake Basin. Table H-4 summarizes estimated water savings potential and unit cost for each strategy. It should be noted that there are other risks and costs, such as loss of habitat and impacts to mineral extraction economies, that were not quantified as part of this analysis.

Table H-4. Water Management Alternative Savings and Cost

Strategy	Type of Hydrologic Change	Estimated Hydrologic Change *(ac-ft/year)*	Annualized Unit Cost *($/ac-ft)*
Cloud Seeding	Increased Runoff	102,000	\$3.60–\$7.10
Agricultural Optimization	Depletion Reduction	44,000 - 467,000	\$210–\$2,500
Phragmites Removal	Depletion Reduction	17,000 - 57,000	\$610–\$4,050
Dust Mitigation	Depletion Increase - Resulting from Dust Control Measures	(127,000) – (87,000)	\$60–\$260[1]

1. Per-unit cost reflects avoided dust mitigation expenses associated with higher lake levels. Each acre-foot of conserved water is estimated to reduce future dust control costs by \$60 to \$260.

Appendix H – References

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APPENDIX I WATER CONSERVATION GOALS

This chapter presents the foundational components necessary for developing water conservation goals. Developing a basin-wide M&I conservation standard aimed at reducing outdoor water use and associated depletion requires a multi-faceted approach. This process is synthesized through five sequential steps, of which the first three have already been initiated as part of this effort. The following discussion outlines this general process and provides supporting data and information to guide the remaining steps—steps four and five—toward completion.

Step 1: Conduct a comprehensive assessment of current water usage patterns

The first step involves identifying areas and usage types with particularly high depletion rates. This report includes an analysis (Appendix B) provides a characterization of 2019 – 2023 M&I water use by sub-basin. The analysis identifies outdoor water use as the category where the majority of depletion occurs. Appendix C provides additional detail on current turf cover estimates and highlights turf irrigation-related programs, such as turf replacement, as a significant opportunity to reduce depletion.

Step 2: Identify conservation opportunities to prioritize

Appendix K examines historical M&I conservation efforts to evaluate the effectiveness of existing programs and support the identification of future conservation opportunities. Key areas of focus included assessing the number of households with and without tiered rate structures and meters, as well as quantifying the amount of turf area historically replaced through M&I water conservation programs. Once the effectiveness of these measures was evaluated, the potential for their further adoption quantified, along with additional strategies. All strategies were then prioritized based on effectiveness and potential for future expansion of the programs was analyzed in Appendices F and G. The feasibility of implementation should be carried forward for further evaluation.

Step 3: Evaluate cost and benefits

Costs and benefits of prioritized conservation strategies were evaluated relative to one another (Appendix G) and compared to other management strategies such as developing new water supply or mitigating impacts of no action (Appendix H).

Completion of the first three steps in developing a basin-wide M&I conservation standard provides the foundation for step four, “Set clear, achievable goals,” and step five, “Develop a conservation plan.” The following sections provide the information and analysis needed to support the remaining steps.

Step 4: Set clear, achievable goals

Defining the appropriate level of water conservation across the Great Salt Lake basin is a complex process. One approach, which is covered herein, starts with determining the optimal level of water required to address specific environmental and economic impacts of the declining water levels in the Great Salt Lake. These water requirements then need to be translated into the establishment of fundamental goals that will guide the planning and evaluation of conservation strategies across municipal, industrial, agricultural, and environmental sectors. These goals are crucial for selecting cost-effective approaches and for ensuring the long-term success of basin-wide conservation programs.

Goals should be grounded in realistic projections of achievable depletion reduction requirements, aligned with cost effective opportunities, and directly linked to the unique ecological and socioeconomic challenges posed by the Great Salt Lake's low water levels. The required level of conservation will depend on the amount of water identified to manage the environmental and economic impacts of the declining lake level. Simply increasing flows to the lake is less effective in fostering a healthier environment than developing a comprehensive plan that identifies specific mitigation uses for that water. Thus, it is critical to identify specific solutions for challenges such as dust generation, habitat loss, brine shrimp stress, and mineral extraction economic impacts.

Future water policy can support M&I depletion reduction goals and mitigate declining Great Salt Lake levels. Strategies to reduce should focus on flexible, adaptive approaches that encourage meaningful progress without imposing rigid mandates to foster progress and stakeholder buy-in. For example, House Bill 274, passed in March 2025, requires water utilities to consider conservation when setting water prices. This policy is a proactive step towards mitigating the effects of depletion caused by M&I demands by calling for conservation-based tiered rate structures. The initial goal should be to avoid further harm and conserve water while seeking solutions to mitigate the adverse effects of low lake levels. This can be achieved through the water policy recommendations outlined in Table I-1, which are suggested at the state and basin levels. Additionally, Appendix F provides conservation policies and programs recommended at the water supplier level.

Table I-1. Water Policy Recommendations

Recommendation	Description
Future State Legislation for Outdoor Watering	Develop state-level legislation that leads to amendments in local development codes to prohibit non-functional turf in new construction, including but not limited to park strips, and instead promote water-efficient landscaping. See Appendix J.
Regional Collaboration	Promote regional collaboration to support basin-wide water depletion limits and more efficient management of shared resources. Coordinated efforts among communities and water providers can balance supply and demand, reduce inefficiencies, and make better use of existing infrastructure. Flexible agreements allow systems with surplus to support those with shortages, enabling more equitable and resilient outcomes while preserving local autonomy. This approach reduces the need for costly or environmentally harmful development of new water supplies.
Regional Depletion Budgets	Design regional water depletion limits that establish clear water "budgets" for each Great Salt Lake sub-basin. These budgets would define maximum allowable depletions and minimum required return flows, providing a framework for coordinated management across water systems. Regional collaboration can support the equitable allocation of these limits while allowing each sub-basin the flexibility to determine how to meet its assigned targets. Water providers can adopt conservation standards—both for existing demand and future growth—in a manner consistent with their regional depletion budget.

Although the depletion saving estimates for M&I conservation opportunities in this report focus on existing water users, the goals must also consider potential increases in depletion due to growth in the M&I sector. Therefore, the initial objective should be to limit any future increases in depletion. The most effective tool for basin wide action is the implementation of the "Future State Legislation for Outdoor Watering" policy, which would amend local development codes to prohibit non-functional turf in new construction and promote water-efficient landscaping. Turfgrass landscaping has become a detriment to the sustainable water balance of the Great Salt Lake Basin, and the state should prevent future land developers from continuing this detrimental practice in the basin. “Regional Depletion Budgets” and “Regional Collaboration” are discussed further below.

The Great Salt Lake Basin has a limited water supply to meet the various demands across the system. Depleting water beyond this limit is unsustainable, leading to lower lake levels that negatively impact the environment, public health, and local economies. Establishing a depletion budget for each sub-basin based on an acceptable water balance accounting can help water suppliers set appropriate conservation targets. The Great Salt Lake Strike Team Report (2025) revealed that an additional 250,000 ac-ft per year of runoff is needed to halt the declining lake level trend. These estimates are based on the annual average runoff from 2000 to 2024. This analysis used historical streamflow and climate data to generate 1,000 simulations of potential lake levels over the next 25 years and do not consider the effects of climate change. Overall, it provides an initial benchmark for reducing depletion and/or increasing water supply to manage the adverse effects of the declining lake levels through incremental solutions.

The same report also indicated that 770,000 ac-ft per year of additional runoff is required to fully mitigate the risk of lake levels reaching the 'serious adverse effects' zone and to keep the lake level in the more beneficial 'transitionary' and 'healthy' zones. Achieving this deeper level of conservation would require more significant action and may be considered further in the future. In both cases, establishing specific planning horizons, such as 2035 for the 250,000 ac-ft goal and 2050 for the 770,000 ac-ft goal, supports the evaluation of performance against set goals.

The requirement of 250,000 to 770,000 ac-ft of additional runoff to mitigate the declining levels of the Great Salt Lake is substantial and necessitates the collaboration of all sectors, including M&I, agricultural, and environmental. Given the extensive volume of water needed, it is imperative that each sector contributes to conservation efforts to achieve this goal. This report focuses on the M&I sector, and Table I-2 presents three example scenarios that demonstrate the potential volumes sourced from this sector if it contributes 25%, 50%, and 75% of these additional runoff requirements through depletion reducing conservation measures. These scenarios offer insight into the potential volume range needed to meet these M&I conservation goals.

Table I-2. Scenarios of range in M&I share of depletion reduction targets

M&I Share Scenario	Depletion Reduction Target of 250,000 ac-ft	Depletion Reduction Target of 770,000 ac-ft
25%	62,500	192,500
50%	125,000	385,000[1]
75%	187,500	577,500[1]

1. The average annual depletion rate from 2019 to 2023 was estimated to be approximately 350 thousand acre-feet across the GSL basin (see Table A-4 in Appendix A). Therefore, these values exceed current depletion estimates, are not achievable, and should not be considered a plausible scenario and are only provided here for reference.

Table I-3 breaks down the overall basin wide depletion savings goal into specific targets for each sub-basin based upon their portion of the basin wide water use. These portions align with their historical water usage patterns from 2019 to 2023 for both M&I and agricultural use. By allocating goals proportionally to each sub-basin’s recent water use, the plan ensures that the conservation burden is distributed fairly. Sub-basins that have historically used more water are expected to contribute more to the savings, while those with lower usage have correspondingly smaller targets. Additionally, this dataset allows for the creation of customized conservation objectives that are relevant and achievable for each sub-basin, considering their unique water use characteristics and potential for reduction. Clearly defined, quantifiable goals for each sub-basin promote transparency in the conservation process. Understanding the specific contributions expected from each sub-basin allows for more efficient allocation of resources, both financial and technical, to support conservation effort where they are most needed. It is important to note that a river basin's use and associated depletions occurring in adjacent states are not included in this quantification.

Table I-3. Depletion Savings Targets by Sub-basin

Depletion Savings Target (ac-ft)	**Bear River**	**Jordan River**	**Utah Lake**	**Weber River**	**West Desert**
250,000	89,002	23,550	56,799	55,165	25,484
770,000	274,127	72,533	174,939	169,909	78,491

1. Sub-basin values are rounded for simplicity in this report and may not precisely sum to the total value presented in the first column.

While Appendix F presents the total potential depletion savings by conservation program, there is uncertainty regarding the actual adoption rate of those programs in the future, as they can be influenced by factors beyond the control of water resource managers at the customer/user level. Table I-4 shows the potential depletion reduction achievable through the Very High Priority conservation programs at various adoption rates ranging from 20% to 100%. This data helps identify which conservation measures could be most effective at various adoption rates. For example, aiming for a 20% adoption rate of turf replacement basin wide could achieve approximately 60,000 ac-ft in depletion savings, or nearly all of the 25% M&I Share Scenario of the 250,000 ac-ft depletion reduction target shown in Table I-2. Note, this assumption is based on the 2019–2023 depletion estimates for turf irrigation detailed in Appendix F and does not consider potential increases in turfgrass from new development. To achieve these depletion volume savings, the 'Future State Legislation for Outdoor Watering' policy must be implemented to limit the increase in turfgrass irrigation depletion associated with new development.

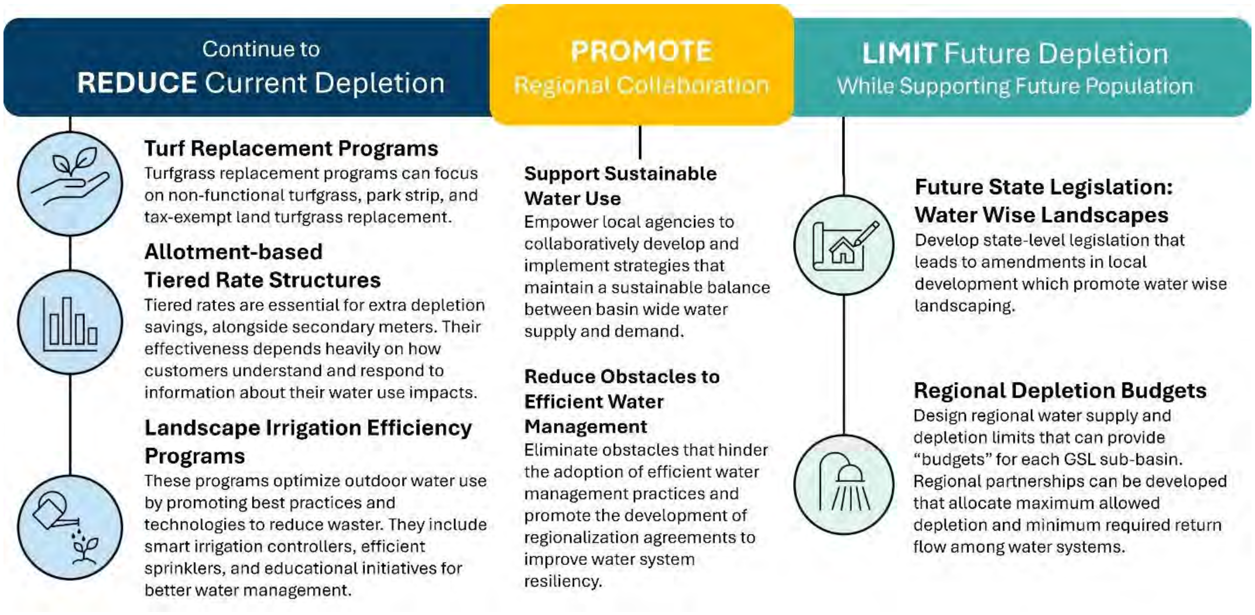
Depletion saving volumes by percent adoption of very high priority conservation programs (in thousand ac-ft per year) are shown in Table I-4. Low to high ranges are provided to capture the range in uncertainty, as described in Appendix F.

Table I-4. Depletion Savings (ac-ft/yr) by Percent Adoption of Very-High Conservation Programs

Percent Adoption	20%	40%	60%	80%	100%
Turf Replacement	44 - 60	87 - 120	131- 180	175- 240	219- 300
Tiered Rate Structure	1 - 14	2 - 29	2- 43	3 - 58	4 - 72
Landscape Irrigation Efficiency[1]	6 - 27	12- 54	18 - 81	25 - 108	31 - 135

1. Includes both weather-based irrigation controllers and landscape irrigation audit programs.

Together, these tables inform the development of water conservation goals that can effectively reduce depletion in the Great Salt Lake basin. They offer insights into the potential contributions of the M&I sector, the effectiveness of various conservation measures, and the specific needs of different sub-basins and for basin wide policy, all of which are critical for informed decision-making and successful implementation. These key recommendations are summarized in the infographic presented below.



Step 5: Develop an Integrated Management Plan

With goals in place, the plan should outline specific strategies and actions to achieve the desired water depletion savings. This step aligns with the broader framework of the Great Salt Lake Basin Integrated Plan, which emphasizes coordinated effort to manage water use and improve lake outcomes. The following considerations are important when developing a conservation plan aimed at reducing M&I water depletion:

1. **Assess Funding Capacity:** The state should evaluate its ability to fund conservation programs. Offering a variety of funding opportunities for utilities to choose from can help

engage managers, elected officials, and the broader community in meaningful dialogue about water conservation.

2. **Leverage Regional Partnerships:** To meet the regional water depletion limits outlined in Step 4, it is essential to establish structured partnerships at the local and sub-basin levels. These partnerships should bring together water providers, conservation districts, municipalities, and other regional stakeholders to collectively manage water use within the context of their specific sub-basin. Regional partnerships can align conservation strategies with the depletion budgets assigned to their area. This localized, collaborative structure enables tailored implementation of basin-wide goals while fostering accountability, resource sharing, and adaptive planning that reflect the unique priorities and constraints of each sub-basin.

   One example of this type of regional approach can be found in California's Sustainable Groundwater Management Act (SGMA), which requires local agencies within each groundwater basin to form Groundwater Sustainability Agencies (GSAs) responsible for developing and implementing basin-specific sustainability plans. While the state provides overarching goals, each GSA has the flexibility to determine how to meet them based on local conditions. This structure has facilitated cooperation among diverse stakeholders, promoted regionally tailored solutions, and established mechanisms for shared responsibility — principles that could similarly support integrated planning efforts in the Great Salt Lake Basin.

3. **Align Local Agencies with Integrated Approach:** City and county departments—such as planning, building, zoning, and parks—can support water conservation by integrating efficiency into development codes, landscaping standards, and public space management. Coordination with these departments ensures that conservation is embedded in local policy, helping to reduce long-term demand and support shared sustainability goals.

4. **Plan for Growth:** Without clear conservation standards, new development can increase demand and reduce available runoff, placing additional strain on the basin's water supply. Integrating conservation into land use planning helps ensure that growth does not come at the expense of long-term water availability.

5. **Continuous Improvement:** Conservation plans should remain flexible and adaptive. Regularly reviewing progress and incorporating new data, technologies, and stakeholder feedback will help ensure the plan stays effective and responsive to changing conditions over time.

   Involving stakeholders in the development of the comprehensive plan is crucial for its success. This process requires significant effort to ensure that all perspectives are considered and that conservation levels are mutually agreed upon. Engaging stakeholders from the beginning fosters transparency and trust, making it easier to communicate the benefits of conservation efforts and garner support. By including diverse perspectives, the plan can address the specific needs and concerns of different water users, leading to more effective and sustainable solutions. This collaborative approach not only helps in identifying the most critical areas for water management but also promotes a sense of ownership and commitment among stakeholders, ultimately driving the success of the conservation initiatives.

Appendix I – References

Great Salt Lake Strike Team. 2025. *Great Salt Lake Data and Insights Summary: A Synthesized Resource Document for the 2025 General Legislative Session, Version 1.0*. Utah State University, University of Utah, Utah Department of Natural Resources, Utah Department of Agriculture and Food, and Utah Department of Environmental Quality. https://d36oiwf74r1rap.cloudfront.net/wp-content/uploads/2025/01/GSL-Jan2025.pdf

APPENDIX J THEORETICAL LAND USE CONVERSION

Land use and water use are strongly correlated. The type and extent of land use directly influences the amount of water that is consumed. The conversion of one land use to another can create stark differences in water consumption. Future land use planning can have a direct impact on the amount of water required to serve the needs of a developing community.

Great Salt Lake Basin Hydrology

The Great Salt Lake (GSL) watershed is a closed basin with no outlet. All precipitation, rivers, and streams within the basin flow into the GSL. The water is held in reservoirs, stored within the groundwater system, or stored in the GSL until it leaves the basin through evapotranspiration (ET) processes. The levels of the GSL balance between the inflows to the lake through precipitation and losses through ET.

Water managers have little control over how much precipitation falls throughout the GSL watershed, but water managers do have some control over the ET budget throughout the GSL basin, particularly the choices related to irrigation practices. The amount of ET throughout the basin before it arrives at the lake represents one of the largest opportunities for water managers to make an impact on the GSL water level. If ET demands are increased by increased consumptive use through irrigation practices, this will ultimately translate to a lower average GSL elevation. Conversely, if ET demands are reduced throughout the basin, then average GSL lake levels would increase.

Development throughout the GSL basin also plays a role in the overall water balance of the GSL. Previous studies have shown that as impervious surfaces increase through development, it will lead to an increase in water volume arriving at the GSL through both surface and subsurface pathways. However, this should be balanced with preserving natural landscapes, utilizing low impact development (LID), and prioritizing water quality (HAL & LimnoTech, 2023).

Existing Beneficial Water Use

Throughout the history of the GSL basin many decisions have been made regarding water use practices. Agriculture represents one of the largest ET demands within the basin. The water being used for agricultural purposes produces crops that provide benefit to local communities and even communities outside the GSL basin. The beneficial use of the water should not be overlooked; however, it is important to create the proper balance and be wise stewards of the limited resources available within the GSL basin.

Conversion of Agricultural Land to Municipal

Development in the GSL basin often involves a change in land use from agricultural to municipal. It has been observed that water use required to support this change decreases. Depending on which agricultural crops are replaced and the density of the development, the decrease in water use can vary widely.

Consumptive use changes as land is converted from agricultural to municipal uses can be estimated using data from the consumptive use report prepared by Utah State University (Hill et al., 2011). These studies identify ET requirements for various plant types, as well as an estimate for how many inches of water need to be applied, accounting for natural precipitation during the growing season.

Average ET for the typical distribution of crop types (based on "Water Related Land Use" dataset produced by the State) was used to establish a composite 100-acre plot of agricultural land. The amount of water required for those crops was assumed to come from irrigation water. Comparing a before and after development scenario with regards to consumptive use is helpful when considering the GSL water balance.

Conversion of agricultural land to developed municipal land provides an opportunity to reduce overall consumptive use in the GSL basin. However, this can only be achieved if new developments also seek to reduce depletion. In some cases, new development could increase depletion if it were to be developed with abundant amounts of turfgrass. To help illustrate the potential reduction, or increase, in consumptive use through future development, several possibilities were calculated and graphed. It shows the range of possibilities in water savings to GSL through 2030. Figure J-1 only includes outdoor consumptive use changes. The variables and assumptions considered in creating this graph include the following:

- The percentage of the converted area was irrigated agricultural land. Assumed ranges are between 100% and 0% (i.e. entirely non irrigated).
    - Net consumptive use from irrigation water - 16.9 inches
- The percentage of turfgrass cover is anticipated in the future development scenario (assumed ranges are between 50% and 0% (i.e. xeriscape)
    - Net consumptive use from irrigation water for turfgrass – 14.4 inches
- Increases in runoff that are projected to arrive at the GSL due to development are included (HAL & LimnoTech, 2023).
    - Increased runoff to GSL due to development is 23.5 ac-ft/100 acres.
- Future development projection is based on previous stormwater LID study (HAL & LimnoTech, 2023)
    - Future development from the present to 2030 is 20,000 acres.

Additional reductions could be realized by requiring turfgrass that has a lower consumptive use. Several options have been developed in recent years that would reduce consumptive use of turfgrass by 30-60% (Hill et al., 2011; Shurtz et al., 2022) for the same amount of coverage.

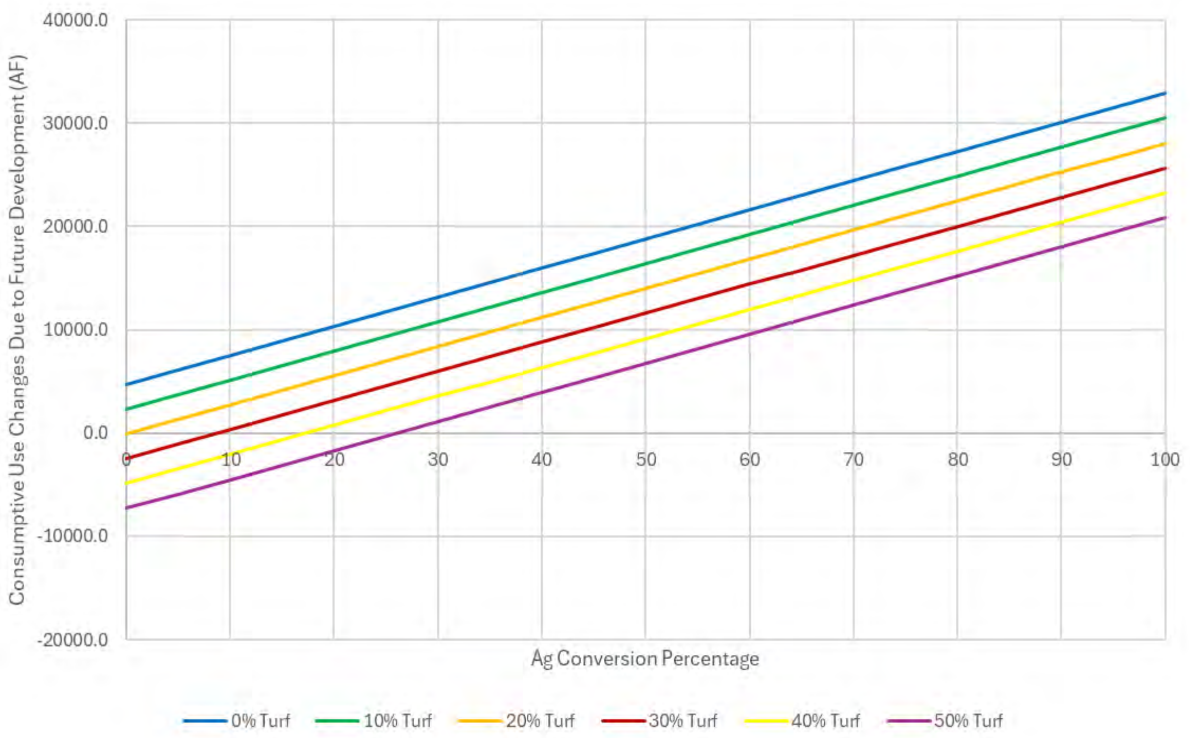


Figure J-1.Projected Changes to Consumptive Use and Stormwater through 2030 through Conversion of Agricultural Land to Municipal

As illustrated in Figure J-1, converting more than 25% of irrigated agricultural land becomes more water efficient, even if the replacement development includes up to 50% turfgrass. Further reductions in consumption can be achieved by reducing the proportion of turfgrass that is installed in the developed areas. If 20% turfgrass can be achieved, then water is saved even when replacing non-irrigated land. This can be accomplished via legislation that limits both the area and type of turfgrass that is installed in future developments, as well as incentive programs that encourage both the installation of water-wise turfgrass in future projects, as well as the removal and replacement of inefficient turfgrass that may already be installed.

Appendix J – References

DWRe (Utah Division of Water Resources). 2024. *Utah water related land use*. Utah Geospatial Resource Center. https://gis.utah.gov/products/sgid/planning/water-related-land-use/

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APPENDIX K WATER CONSERVATION PROGRAM PERFORMANCE

Two conservation programs have recently been a focus throughout the state: 1) secondary metering and 2) turfgrass replacement. These two programs have been effective in reducing water demand by targeting outdoor water use. Recent legislation, supported by several studies, has suggested that effective implementation could lead to significant water savings (HAL & BC&A, 2019). This section reviews the recent effectiveness of these programs and their potential for additional water conservation.

Introduction to Secondary Metering

Increased use of secondary meters is critical to reducing depletion. Results in Appendix A show that most of the municipal and industrial (M&I) depletion in the Great Salt Lake basin is from outdoor watering, and it is here that gaps in accountability exist: many customer endpoints are unmetered. Secondary meters enable an entire suite of water conservation options—education, pricing, social norming—but without them, water suppliers can only “ask nicely” for customers to conserve.

Secondary metering can reduce depletion through enabling comparison and education (Boyer et al. 2018; Hilaire et al., 2008), reducing inefficient sprinkling time (Leinauer & Smeal, 2018), and allowing for tiered rates/seasonal allotments (Sowby & South, 2023). These measures discourage overwatering and associated losses and can even further reduce depletion by underwatering turfgrass while retaining some of the functional properties. Depletion savings are less likely to be realized when full water right usage must be demonstrated to avoid water right forfeiture, and more likely to be realized when water rights are protected under a municipal future growth statute.

In 2022, the Utah state legislature passed HB 242, which requires all public water systems, with some exemptions, to install meters on all their pressurized irrigation (PI) connections. The deadline for installation is January 1, 2030.

This study reviewed the effectiveness of secondary metering and tiered rates in reducing outdoor water demands. Data from the Division of Water Rights (DWRi) was used to identify trends from 2019 to 2023. Following a review of the DWRi data, several case studies were examined to draw conclusions for basin-wide use.

Secondary Metering Methodology

The analysis was completed in two parts:

1. A high-level analysis of secondary water systems on the DWRi Water Use Database comparing source production, number of connections, and number of metered connections by year.
2. A review of specific case study systems to understand the range of success with secondary meter installations.

An inherent problem with metering is that pre-meter usage is unknown and is therefore difficult to compare to post-meter usage. Also, most areas throughout the state have experienced population growth, which is conflated with the water use data. Therefore, there are two types of before/after metering data with their own limitations: total usage before and after metering, and metered usage after metering. The pros and cons of each type of data are shown in Table K-1.

Table K-1. Pros and Cons of Total Usage and Metered Usage Data

Usage Data	Pros	Cons
Total usage before and after metering	• Data before metering was implemented is usually available. • Dramatic shifts in water use can sometimes be observed when metering and tiered rates are implemented together.	• Population has increased in most areas, which could obscure total reductions. • If total usage is normalized to connection, the average lot size irrigated will affect the calculated number and will include system losses, which will make comparisons between systems less accurate. • System losses cannot be separated from actual usage.
Metered usage after metering	• System losses are not included in metered data. • Gradual decreases in response to years of metering and reporting can be seen.	• Population has increased in most areas, which could obscure total metered usage reductions. • If metered usage is normalized to connection, the average lot size irrigated will affect the calculated number and will make comparisons between systems less accurate. • No metered data before metering is available.

All available data from the Utah DWRi Water Use Program was downloaded in 2024 for use in this analysis. The database contains detailed secondary water system data for the year 2019 through 2023. Prior to 2019, less secondary water specific data is available. The data for systems within the Great Salt Lake basin were summarized by pivot tables for comparison. This analysis comprised the high-level analysis.

Following the high-level analysis, we examined specific case studies to determine if the case studies supported the high-level analysis and to glean additional details about the effectiveness of secondary meters in reducing use and depletion. Each water system is unique and has a different timeline and method of implementing secondary meters. The details of the systems and the timeline were recorded in each case study, and the water usage before metering (if applicable) and after metering were compared. Water use data were obtained from the DWRi or from the systems' own records. Case studies were selected from systems who were able and willing to share data. The selected case studies were Spanish Fork, Weber Basin Water Conservancy District, Salem, and Saratoga Springs.

Secondary Metering Results

The DWRi began to collect data about the numbers of secondary water meters and metered usage in 2019. Some systems have had meters installed for longer, but the data are not available before 2019 in the state database. The number of systems reporting has grown each year since 2019 from 97 in 2019 to 218 in 2023.

Figure K-1 shows that about 25% of secondary connections in the state were metered in 2019-2020, increasing to about 35% metered in 2023. When the metered usage is normalized by the number of connections, the average metered usage per connection has not shifted meaningfully up or down. This is probably due to the majority of users are still not metered or have tiered rates applied. We note that the estimated percentage of metered connections is probably artificially high in 2019 due to a lower number of systems reporting that year, and the systems reporting earlier were more likely to be metered.

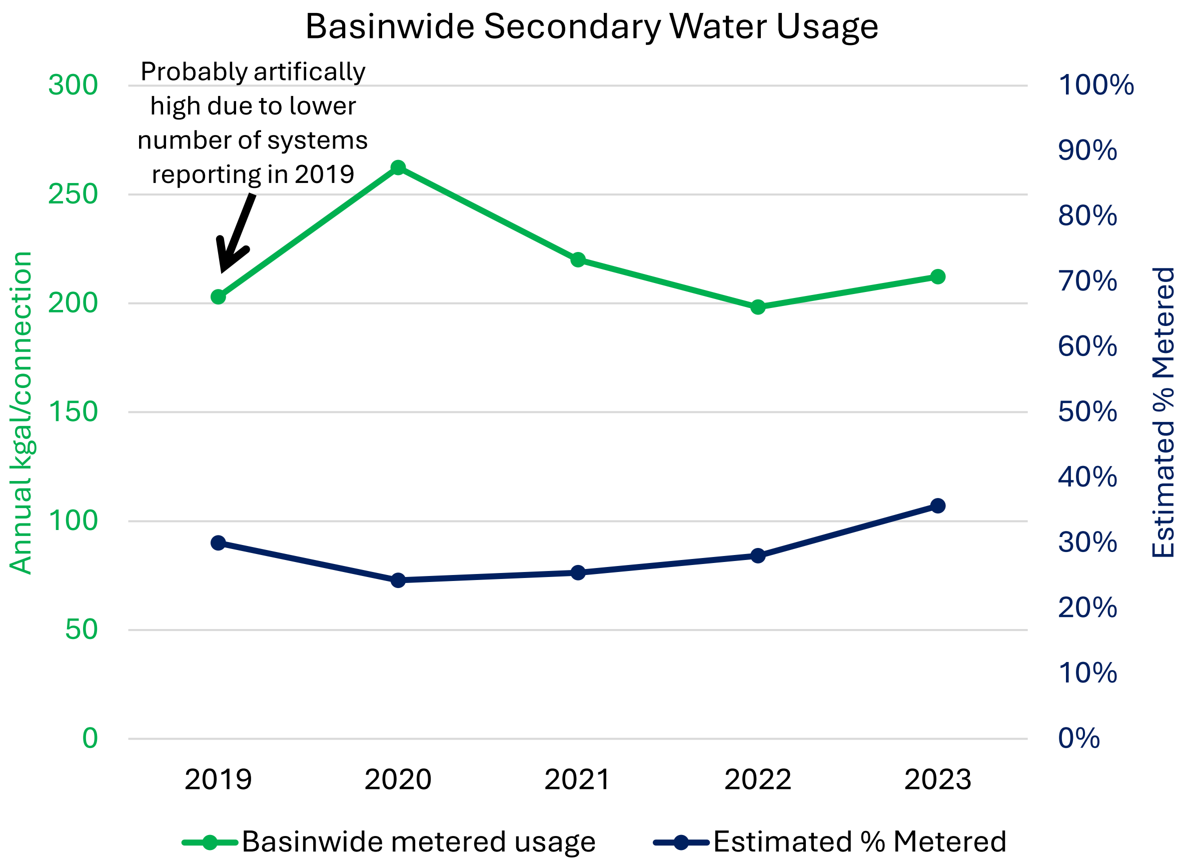

Figure K-1. Basin Wide Normalized Metered Usage and Estimated Percent of Connections Metered

Case Study – Spanish Fork

Spanish Fork appears to be the first city in Utah with full secondary metering achieved (in about 2001). This allowed Spanish Fork to implement a modest usage charge similar to the charges for drinking water.

Figure K-2, which includes only post-meter installation data seven years after meter installation, shows a slight uptrend in water use, or a neutral trend if the first three years are excluded (which may be lower quality data). Perhaps most importantly, Figure K-2 shows that the Spanish Fork per-connection usage (generally 126-193 kgal/connection) is lower than the basin wide averages (generally 198-220 kgal/connection, Figure K-1). It is unclear whether the Spanish Fork lower averages are due to smaller average lot sizes compared to the basin, or whether the effect is truly due to secondary metering and tiered rates. Also note that connection data for Spanish Fork is spotty and required interpolation in 2010-2019, and the quality of the reported metered data has probably improved with time.

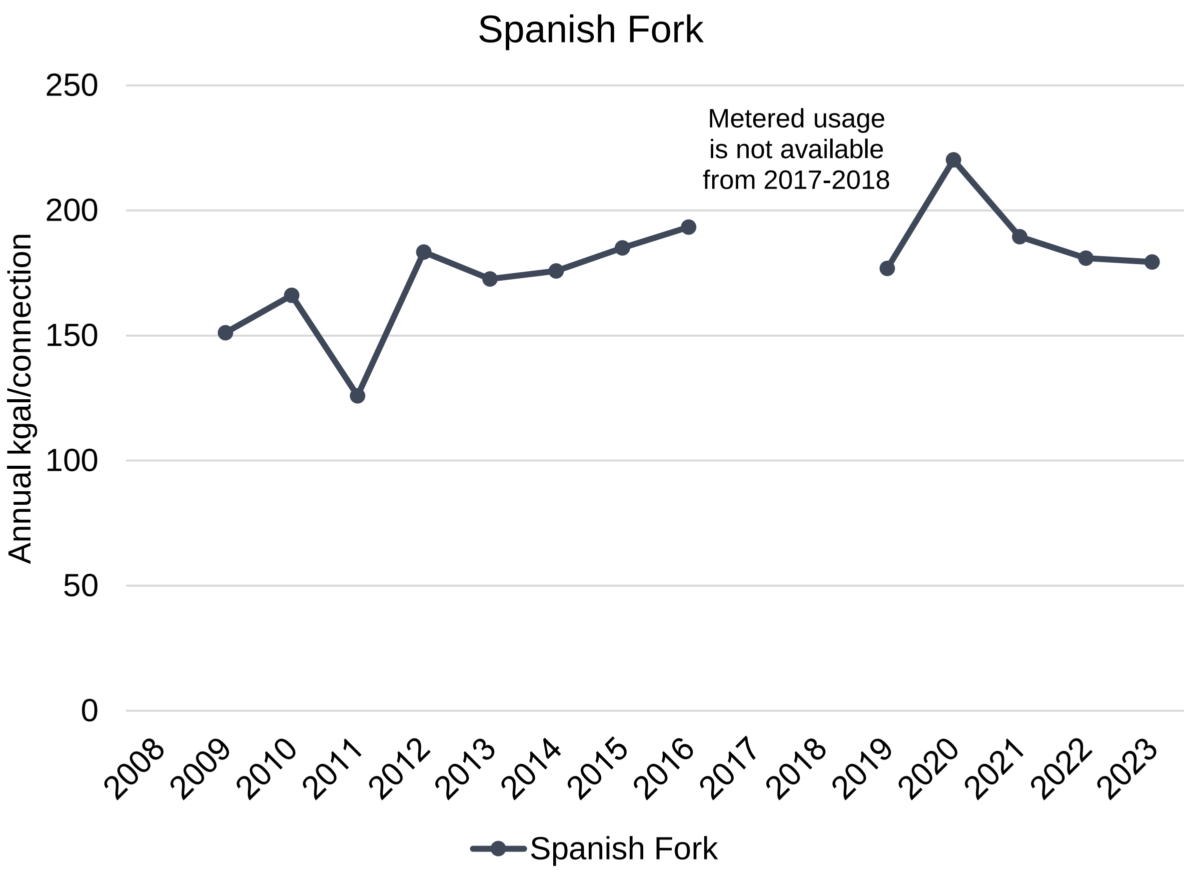

Figure K-2. Spanish Fork Normalized Metered Usage

In 2020, Spanish Fork implemented a stronger tiered rate for secondary water use (although still not as strong as other communities). This appears to coincide with the interruption of a slow uptrend in water use.

Case Study – Weber Basin Water Conservancy District

Weber Basin Water Conservancy District (WBWCD) has been installing secondary meters slowly since 2011, which is relatively early for the GSL Basin. In 2023, about 60% of WBWCD connections were metered. WBWCD conducted their own study of metered usage after meter installation in 2023. In 2022, some of the meters were 11 years old.

Figure K-3 (taken from the WBWCD study and annotated here) shows that on average, there has been a slow decrease in usage by connection of about 20% over the first nine years of meter installation. This reduction does not include any initial reduction which may have taken place immediately on meter installation, because the pre-meter usage is unknown.

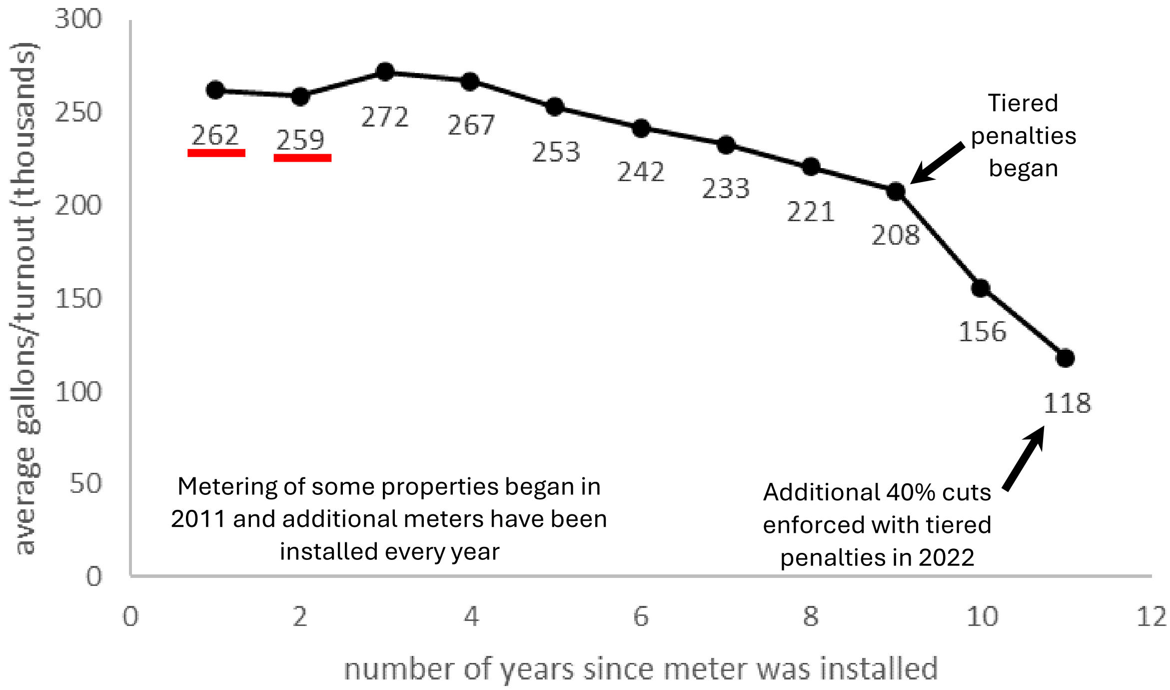

Figure K-3. Weber Basin Water Conservancy District Normalized Metered Usage

Figure K-3 also shows that when tiered penalties were introduced in 2020 (similar to tiered rates, but users were not charged beyond normal rates unless they exceeded a calculated allotment), an additional ~20% savings was realized the following year in 2021. Users were even able to use 15% less water on top of the 40% already-realized reduction in an extreme drought (2022) when 40% allotment cuts were imposed by tiered penalties.

It should be noted that Figure K-3 groups the data from users by the year after meter installation. Therefore, the first point on the graph contains data for the years 2021 and 2022 from some properties (those with meter installations in either 2020 and 2021), and the second point on the graph contains data for the year 2022 from some properties (those with meter installations in 2020). These years had intensive education campaigns and enforced water allotment cuts, which may be artificially decreasing these first two data points.

Case Study – Salem

Salem installed meters over the course of about three years starting in 2019. With the completion of installation, tiered rates took effect in 2022. Because water leaving the irrigation ponds is metered, water loss within the pipe network appears to be negligible (although water loss occurs in the ponds before water is delivered to the system). The low water loss makes evaluating the total water usage (before and after meters) feasible.

Figure K-4 shows that with the introduction of meters and tiered rates, total water use fell 27% in one year from the pre-meter average. Figure K-4 shows an even greater reduction of water use of 54% when water applied per irrigated acre is considered. The decrease in total water use between 2019 and 2023 occurred even though Salem gained 580 new connections (29% growth) over this same time frame. Salem was able to reduce its total water use while growing in irrigated acreage by watering much more efficiently and stretching the water supply much further. The year 2024 is on track for the same result as the previous two years. Time will tell if additional savings are realized for Salem similar to WBWCD (Figure K-3).

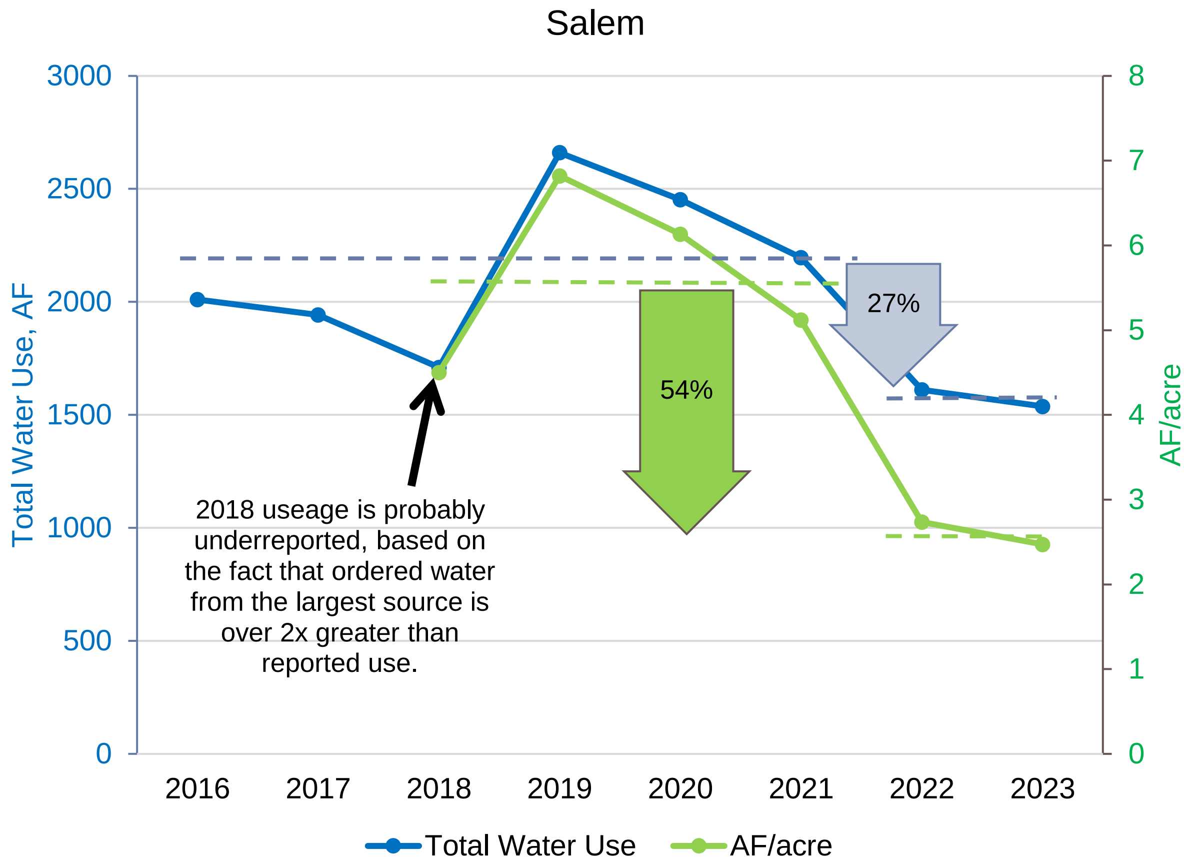

Figure K-4. Salem Total Secondary Water Use And Normalized Total Usage

For comparison to previous case studies, water use on a kgal/connection basis is 382 kgal/connection in 2019-2021 and 207 kgal/connection in 2022-2023.

Case Study - Saratoga Springs

Saratoga Springs began installing a small number of meters in 2008 or earlier (about 221 connections), but most secondary meters were installed in 2014 (about 5,800 connections). Tiered rates began in 2015. Figure K-5 shows that normalized metered usage per connection appeared to increase substantially between 2008 and 2014, but this is probably an artifact of the small number of metered properties not being representative of the whole city or poorer data quality. Figure K-5 also shows that after the meters and tiered rates were implemented in 2015, normalized metered usage has appeared to stabilize and is below the basin wide normalized metered usage averages.

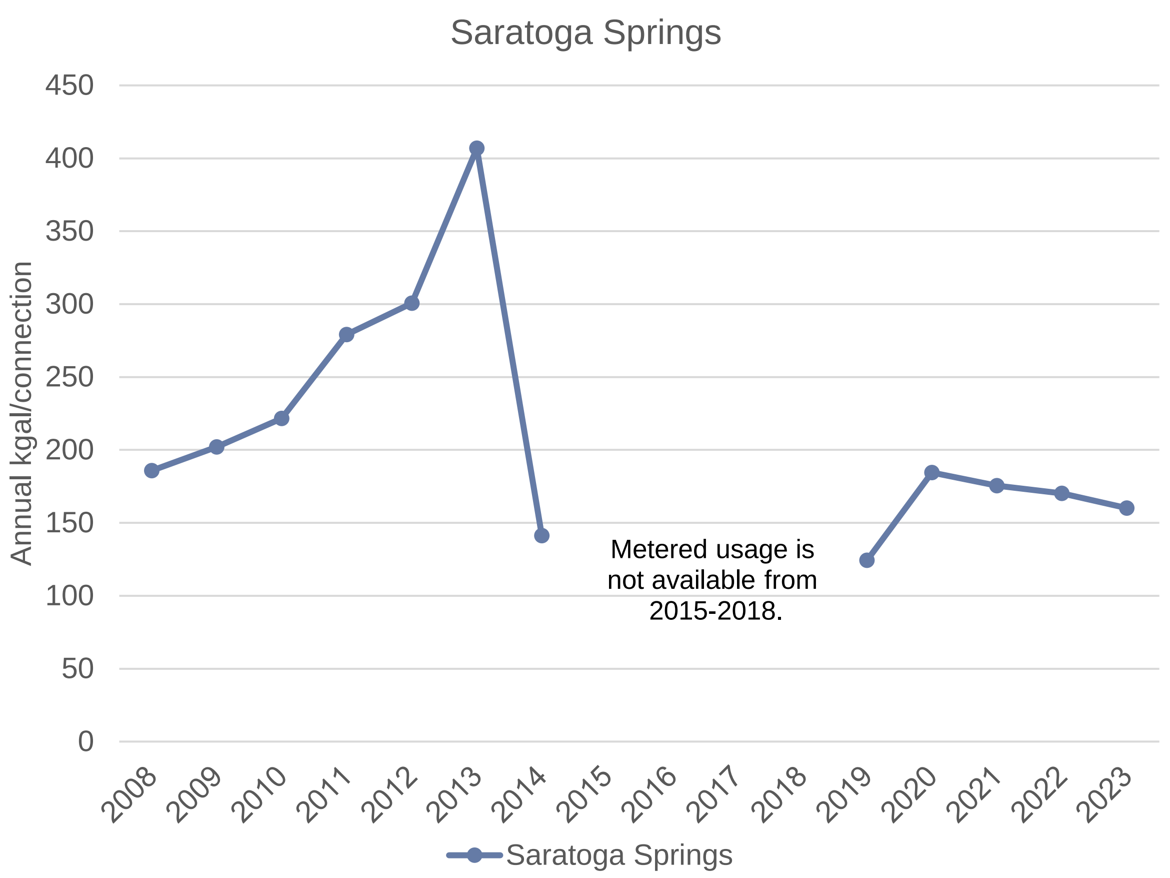

Figure K-5. Saratoga Springs Normalized Metered Usage

Secondary Metering and Tiered Rate Summary

Figure K-6 shows all case study cities and entities together with normalized meter usage (Spanish Fork, WBWCD, Saratoga Springs) or normalized total usage (Salem). All cities/entities converge on 150 kgal to 200 kgal per connection annually after metering.

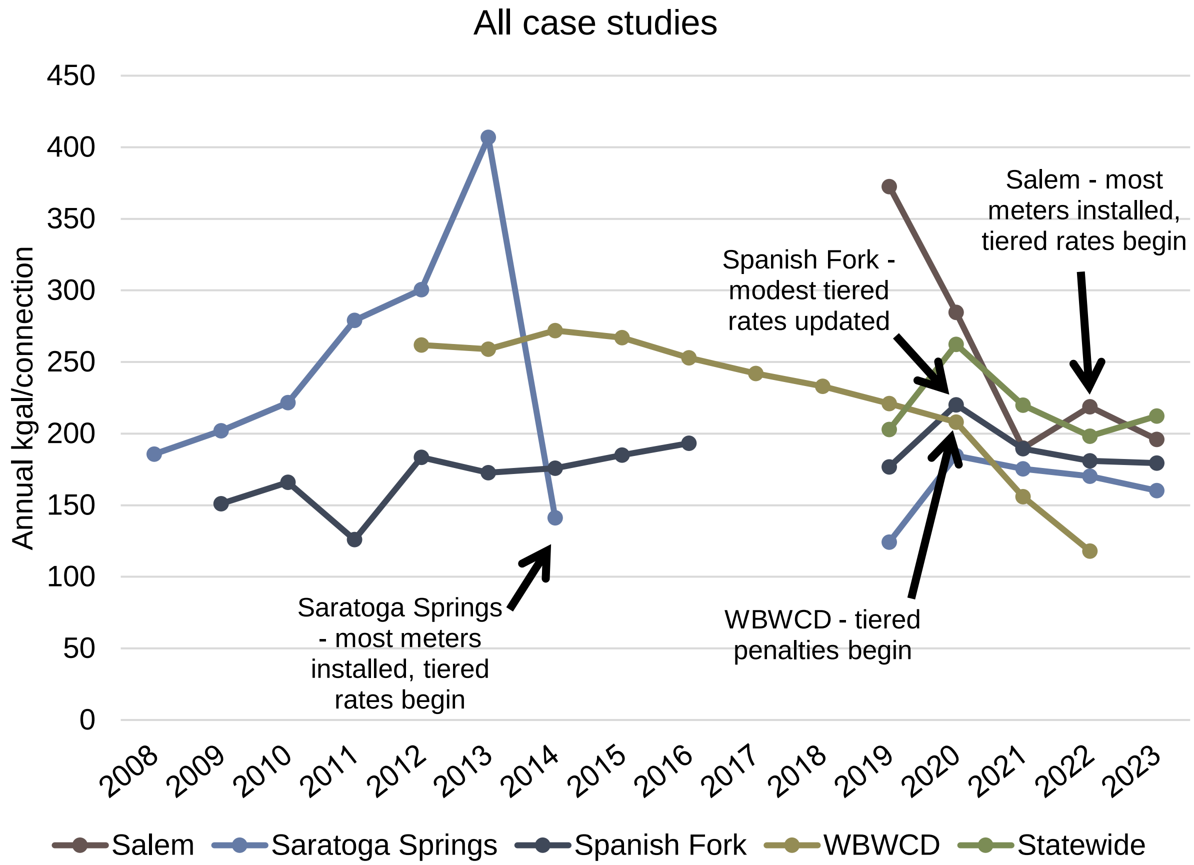

Figure K-6. All Case Studies Normalized Total Usage (Salem) or Normalized Metered Usage (All Other Entities)

Summary of Secondary Metering Findings

The following conclusions may be drawn from the high-level analysis and case studies:

- Early meter adopters with a usage charge (Spanish Fork since 2001) appear to have a lower water usage per connection than the statewide average (assuming equal average lot sizes), which supports the effectiveness of metering, reporting, and usage charges.
- Early meter adopters without a usage charge or tiered rate (Saratoga Springs 2008–2013, WBWCD 2011–2015) do not appear to have lower water usage per connection than the statewide average (assuming equal average lot sizes). In these systems, it is difficult to say whether there was an initial water savings with metering since pre-metered use could not be measured.
- There appear to be long-term benefits of metering and public education of about 20% even without charges or tiered rates (WBWCD in 2011–2019, Salem in 2022).
- Implementation of tiered rates or penalties (Saratoga Springs in 2015, WBWCD in 2020, Spanish Fork in 2020, Salem in 2023) appears to reduce water usage by up to 20% or at least interrupt an uptrend in the case of Spanish Fork in 2020.

Accordingly, we estimate that secondary metering with tiered rates could reduce outdoor demands by 5% to 27% (see Appendix M) relative to unmetered conditions, particularly in municipal systems. During droughts, higher penalties and reduced allotments could achieve savings up to 40%. Metering alone, however, appears unlikely to achieve significant savings without education or monetary consequences.

It is recommended to continue to fund metering projects. These initiatives have proven to be particularly effective in reducing outdoor water use across the state when water use data and customer education are coupled with incentivizing efficient water use. By expanding these programs, utilities can encourage conservation among their residents and aid in addressing the ongoing challenges of water scarcity in the GSL basin.

Introduction to Turfgrass Conversion

Landscape incentive programs provide incentives (rebates) to residents to replace their turfgrass with water-wise landscaping. JVWCD began offering turf conversion rebates in 2017 and programs have expanded to WBWCD, Central Utah Water Conservancy District (CUWCD), Washington County Water Conservancy District (WCWCD), and DWRe to offer incentives statewide (UWS, n.d.). Recent legislation has allowed DWRe to partner with the water districts and pay 50% of the rebate in eligible cities. These programs require plant coverage, mulch, and drip irrigation. The historical performance of the programs was reviewed to help determine the overall effectiveness and recent buy-in. The results provide a reference point for potential future savings and highlight the level of effort required for widespread implementation of turfgrass replacement.

Data encompassing the square footage of turfgrass replaced as well as the dollar amount that was reimbursed for said turfgrass removal was received from both CUWCD and WBWCD throughout their service areas. These values were categorized by city. It should be noted that this only covers turfgrass replacement that occurred through the UWS program.

Turfgrass Replacement Methods

Data was received on replacement volumes from CUWCD and WBWCD. Historical replacement volumes were reviewed to identify trends and patterns over time. The data were then categorized and compared across different cities and regions to assess variation in implementation and outcomes. This comparison helped evaluate the relative performance and effectiveness of replacement efforts.

Turfgrass Replacement Results

There were 26 participating cities serviced by the CUWCD that were included in this analysis. Results are shown in Figure K-7. The largest contributors were Salt Lake City and Sandy, with a total of 402,057 and 211,325 square footage of turfgrass replaced, respectively. These two cities accounted for 64% of the total grass replacements. On average, each city converted approximately 36,700 square feet of turfgrass. In all, 954,046 square feet of lawn was replaced by waterwise landscaping from 2021 to 2024.

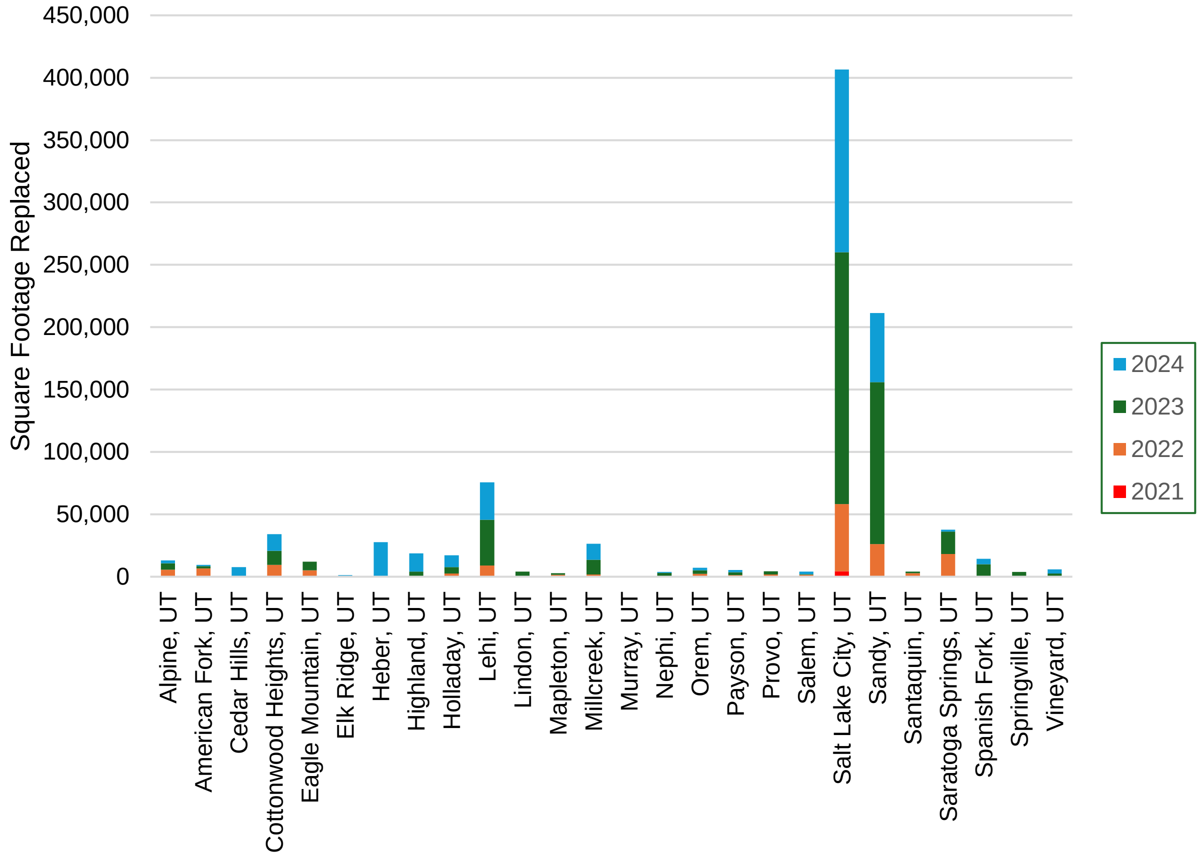

Figure K-7. Square Footage of Turfgrass Replaced with Water Wise Landscaping from 2021 – 2024 in the CUWCD

On average, each city converted about 36,700 square feet of turfgrass over this time period in the CUWCD service area.

In the WBWCD service area, 21 cities were included in the provided data. This includes 1,372 individual applicants whose combined grass replacement efforts resulted in $2,062,750 in rebates. This averages about $1.8 per square foot and $1,500 per applicant. Layton was the leader, shouldering 25 percent of the total lawn removals, while each city in this group averaged 53,000 square feet of grass. In all, over 1,100,000 square feet of grass was replaced by water-wise landscaping in the WBWCD service area.

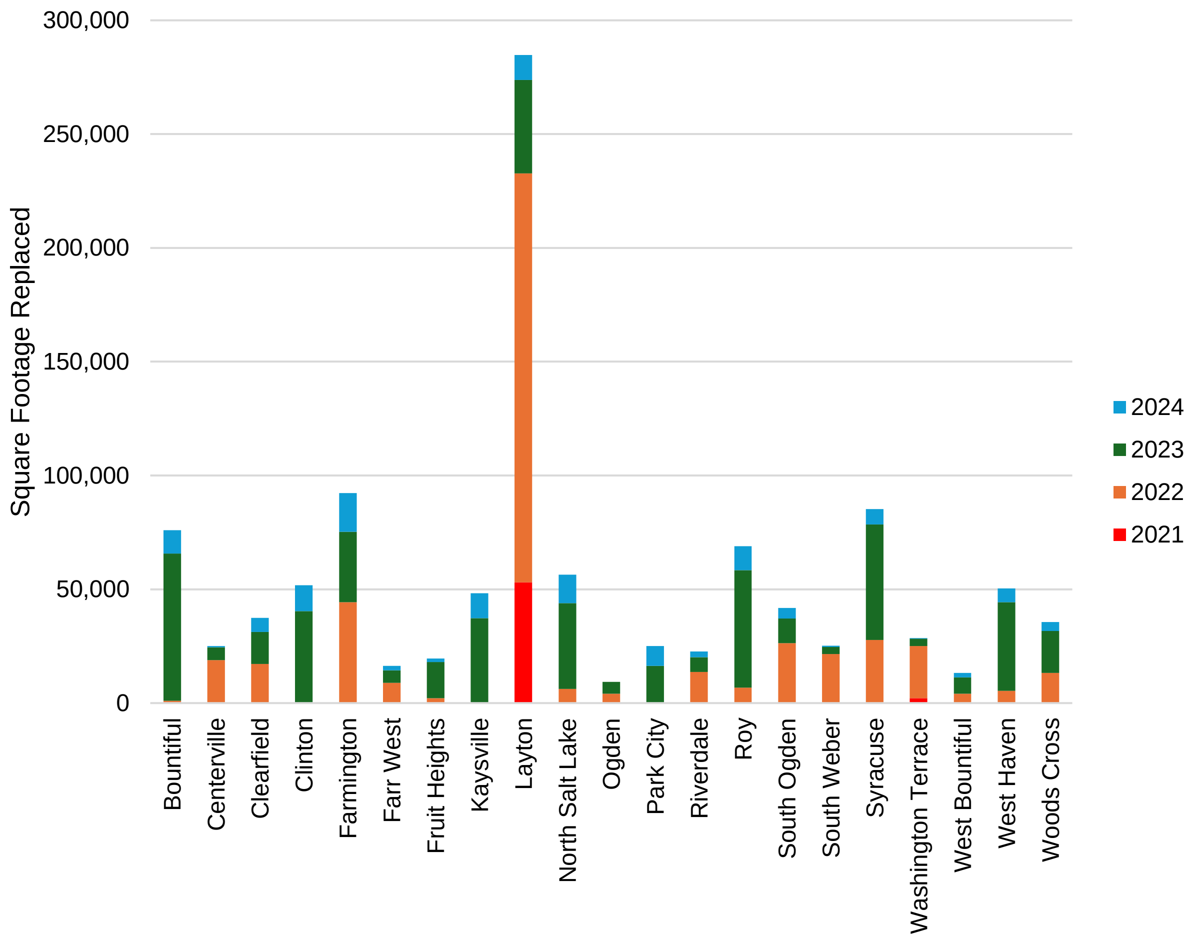

Figure K-8. Square Footage of Turfgrass Replaced with Water Wise Landscaping from 2021 – 2024 in the WBWCD

Between the two service areas, approximately 2,000,000 square feet (46 acres) of turfgrass have been replaced between 2021 and 2024. This equates to 0.033% of the total existing turfgrass area in the GSL basin.

Additional turfgrass replacement has likely occurred throughout the GSL basin. These volumes only represent the amount that has been completed through the UWS program. Additionally, the existing turfgrass that is replaced most likely gets moved to new areas in the city with development. Recommendations to bolster the programs are included in the following section.

Turfgrass Replacement Recommendations

Turfgrass replacement programs can provide a quick and immediate impact for depletion reduction. Converting turfgrass to water-efficient landscaping constitutes permanent water savings relative to the baseline condition. Replacement can occur on residential, commercial, and tax-exempt properties. However, the data above shows that adoption through UWS has been low.

One of the easiest targets for water conservation is non-functional turfgrass (NFT). Such highly irrigated but poorly used spaces consume water without providing much benefit. In a study of two Utah cities, Shurtz et al. (2022) found that small lots are less efficiently irrigated than large lots, likely due to the small, irregular shape of landscape features, including park strips and other NFT. Accordingly, NFT has a disproportionate effect on irrigation, much more than functional turfgrass. Performance data from NFT conversion programs in California and Nevada confirm that the savings are much higher than would be needed to sustain the consumptive use of turfgrass in their respective climates (AWE, 2018). Recommendations for the turfgrass replacement and tracking are outlined in Table K-2.

Table K-2. Turfgrass Replacement Recommendations

Recommendation	Description
Support Landscape Conversion Programs	Continue to support landscape conversion programs with a focus on NFT, including but not limited to park strips. This includes further efforts to increase voluntary participation in landscape conversion programs.
Future State Legislation	Develop state-level legislation that prohibits—or at least supports city staff in prohibiting—NFT in new construction, including but not limited to park strips. Additionally, prospective legislation could work to limit the amount of turfgrass that is installed for future developments, prioritizing waterwise landscaping. Cities are currently incentivized to adopt ordinances that limit turfgrass in new construction through the Landscape Incentive Program, but it could be expanded with additional legislation.
Prioritize State-Owned Lands	The state can make a significant impact on water depletion reductions by prioritizing the replacement of NFT that is owned by tax-exempt entities, such as governments (municipal, county, and state), schools, and churches. Replacing turfgrass on these properties does not require citizen action, unlike residential and commercial turfgrass replacement programs, which rely on public participation for effectiveness. Furthermore, a requirement could be established to have tax-exempt entities remove 15% of their turfgrass area, leaving the determination of NFT up to each system. Great opportunity exists and those volumes of turfgrass vary throughout the basin and may be a case-by-case situation. These efforts could build upon current efforts that aim to reduce turfgrass for new and reconstruction projects.
Statewide Turfgrass Mapping Program	One of the challenges of current turfgrass replacement programs across the state is the lack of accurate turfgrass mapping data. The data are crucial for the planning and implementation of water utility turfgrass replacement efforts, allowing for more efficient resource allocation and effective interventions. Accurate turfgrass mapping, especially when correlated with water use data, is essential for monitoring and evaluating program effectiveness. Updating the data annually ensures its accuracy. The state could purchase a commercially available product and provide it freely to the public and water utilities, thereby supporting conservation efforts.

Appendix K – References

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APPENDIX L STORM DRAIN OPTIMIZATION CASE STUDY

Many communities that have large undeveloped areas lack adequate storm drainage capacity. Historical farming practices resulted in natural drainageways being filled in, and infrequent flooding of these areas was generally overlooked due to not resulting in severe damage due to agricultural use. When development occurs in these areas, the developers are often required to retain all stormwater runoff generated by the site due to lack of downstream conveyance capacity. When retention is implemented (particularly in the groundwater discharge areas) evapotranspiration can increase.

An example of this situation is Beer Creek in Southern Utah County which drains from Salem. The creek's conveyance is too small for existing flows leaving a high likelihood that future development will be required to retain their runoff. Per Salem City standards, "If no place to discharge exists the retention volume required shall be designed with the following event. 100-year 24hr event." The other surrounding communities are likely to do the same if downstream capacity does not exist.

The fate of retained stormwater largely depends on whether the water is retained in an aquifer recharge or discharge zone (HAL, 2023). Stormwater retained in a recharge zone can infiltrate and reach the deep aquifer with an approximate 20% loss rate (HAL, 2023) where it continues its journey to the Great Salt Lake (GSL). Although some water is lost to evaporation before reaching GSL, the overall amount of water reaching GSL is higher than undeveloped land because little stormwater runs off from undeveloped land and is instead used by the pre-development vegetation. On the surface, it would appear that not retaining the stormwater and conveying it to surface channels would result in the most water reaching GSL without the infiltration losses. However, there would be unknown conveyance losses and necessary water quality treatment with its own unquantified evaporative losses, which could make the two methods of transport to GSL equivalent. There are also additional benefits to retaining stormwater near the site of generation and recharging depleted aquifers that treatment and conveyance cannot provide as easily.

Stormwater retained in an aquifer discharge zone, however, is often unable to infiltrate and therefore remains on the ground surface until it evaporates instead. Retention in this zone provides pollution control benefits, but no aquifer or GSL benefits. If this stormwater pollution is able to be controlled, the water could be released to benefit GSL.

Recently a master plan for Beer Creek in southern Utah County was completed. The re-establishment of the channel will provide adequate conveyance for a 100-year flood event. The cost for the re-establishment of the Beer Creek channel, with enough capacity for future development runoff, is approximately $30,000,000. The amount of additional water that would reach the GSL as a result of building this conveyance facility can be estimated by defining how much area remains to be developed in the discharge area and comparing the additional runoff as a result of development.

Discharge Zone Stormwater Estimation Methodology

The estimated area remaining to develop in the discharge area of Beer Creek is approximately 30 square miles. There are 24 square miles west of I-15 and 6 square miles east of I-15. The area east of I-15 is larger than 6 square miles but was reduced to account for some parcels in this area being already developed). It is unknown exactly how long it will take for this much area to develop, but it is likely that it will become fully developed.

Additional stormwater volumes as a result of development were estimated, and four scenarios of potential stormwater handling were considered for comparison. Per the HAL study on low impact development (LID) and impacts to the GSL, it was estimated that there is an increase in annual runoff of approximately 60 ac-ft per 100 acres of development from baseline undeveloped conditions. In the scenario of stormwater conveyance, losses are assumed to be about 10%. In three scenarios of stormwater retention, three sets of loss estimates are assumed due to the unknown variability across the discharge area of soil infiltration capacities and existing groundwater elevations. The three loss assumptions were 60%, 80%, and 90%, which are higher than the 20 to 40% losses which may occur for retained stormwater in the recharge zones during infiltration.

Discharge Zone Stormwater Estimation Results

In the conveyance scenario, an additional 54 ac-ft annually of stormwater would be conveyed to GSL per 100 acres of development. It is assumed that the water quality treatment ("flow through" best management practices) in this scenario which would happen before conveyance would provide minimal evaporative losses and equivalent pollution control to LID, which may not be true. Alternatively, attempting infiltration in the discharge zones may result in 24 ac-ft, 12 ac-ft, or 6 ac-ft annually of stormwater reaching GSL per 100 acres of development. The difference between the conveyance and infiltration scenarios results in an increase of 30 ac-ft, 42 ac-ft, and 48 ac-ft per 100 acres annually respectively through conveyance over infiltrating. Applying that difference over the entire 30 square miles or 19,200 acres yields 5,760 ac-ft, 8,064 ac-ft, and 9,216 ac-ft per year reaching GSL at fully developed conditions.

Discharge Zone Stormwater Conclusions

In the undeveloped Beer Creek drainage area within the aquifer discharge zone, it is estimated that treating and conveying excess stormwater resulting from development could deliver an extra 5,760 to 9,216 ac-ft annually to GSL at full development. This volume of stormwater would otherwise evaporate if traditional LID were used in the discharge zone. LID is far more effective in the recharge zones and provides local pollution control and aquifer recharge benefits. It is difficult to say whether LID or treatment and conveyance in the recharge zone leads to more stormwater volume delivered to GSL due to unknown losses during stormwater treatment and conveyance.

Considering the total cost of Beer Creek re-establishment and dividing it by the increased volume of water produces a cost per ac-ft of water to the GSL: $5,208/annual ac-ft, $3,720/annual ac-ft, and $3,255/annual ac-ft. These costs may be useful when comparing options to help improve the volume of water getting to GSL. As noted in the HAL LID study, the surface flow path is much quicker and would result in getting more water to the GSL sooner than the groundwater flow path.

Appendix L - References

HAL (Hansen, Allen, and Luce) and LimnoTech. 2023. *Great Salt Lake Stormwater Study Report.* Utah Department of Natural Resources. https://water.utah.gov/wp-content/uploads/2024/02/GSL-Stormwater-Study-Report.pdf

APPENDIX M WATER CONSERVATION PROGRAM METHODOLOGY AND ANALYIS

This appendix outlines the methodologies for estimating total potential depletion reduction for the M&I conservation programs evaluated and the costs and savings of implementing these programs. Low and high bookend estimates were developed to capture the variability and range in uncertainty in these estimates.

Depletion Savings & Uncertainty Estimate Methodology

This section outlines the methodologies for estimating depletion reduction potential for the M&I conservation programs evaluated and capturing uncertainty in these depletion saving estimates. The methodologies are explained by program.

For all programs, conservations savings (i.e. reduced water use) were estimated in order to quantify the corresponding reduction in depletion. The parameters used to estimate water conservation savings for each program are summarized in Table M-1, with detailed descriptions provided in the following subsections. It is important to note that for all outdoor water use—excluding turf replacement programs—depletion was assumed to range between 72% and 86% of the conservation savings, as detailed in Appendix A.

Table M-1. Parameters for Evaluating Conservation Program Savings

Program Parameter	Low Estimate	High Estimate
Weather-Based Irrigation Controller Savings (%)	15.0%	40.0%
Irrigation Audit Savings (%) – Low	10.9%	NA
Irrigation Audit Savings (%) – High Year 1	NA	20.6%
Irrigation Audit Savings (%) – High Year 2	NA	7.7%
Irrigation Audit Savings (%) – High Year 3	NA	6.5%
HE Car Wash - Gallons Saved / Wash	30	30
HE Car Wash - People/Household	3.04	3.04
HE Car Wash - Cars/Household	1.0	2.00
HE Car Wash - Washes/Year	1.0	26
Indoor Residential Water Use Efficiency Target (gpcd)	60	40
Cooling Tower Savings (AF/Year/Unit)	0.26	0.26
Landscape Water Budget Savings (%)	5.0%	30.0%
Allotment Based Tiered Rate Savings (%)	5.0%	30.0%
Conservation Tiered Rate Structure Savings (%)	5.0%	27.0%
Portion of Culinary Water used for Outdoors (%)	40.0%	40.0%
Universal Metering (%)	5.0%	20.0%
Indoor Depletion	5.0%	5.0%
Outdoor Depletion	72.0%	86.0%

Turf Replacement

Turf irrigation demand by sub-basin was first estimated to quantify potential water conservation volume savings associated with turf replacement programs. This analysis utilized the Utah Department of Natural Resources' Water Savings Estimator tool. This tool compares water requirements between traditional lawn maintenance practices and “Water Wise” landscaping alternatives. For the high uncertainty range depletion estimate, the state program's minimum plant coverage requirement of 50% was used, meaning half the converted area would be planted with water-efficient vegetation and the remainder would be hardscape. For the low estimate, a 100% plant coverage with water-efficient vegetation assumption was utilized which would require more irrigation. Both approaches assume complete implementation across all eligible properties in the Great Salt Lake basin, allowing for a comprehensive assessment of potential water savings across different landscaping configurations.

Depletion reduction potential estimates for turf replacement were then determined from the water conservation volume estimates. This captures the portion of the irrigated water that would have been evaporated (i.e., depleted) by the turf grass. To estimate depletion, *The Crop and Wetland Consumptive Use and Open Water Surface Evaporation, Appendix I* was utilized to find average net irrigation rates of turfgrass across each of the Great Salt Lake sub-basins. These net irrigation values represent the volume of water required to meet the consumptive use of turfgrass, excluding contributions from effective precipitation, and thus provide a direct basis for estimating the associated depletion reductions. The averaged values were multiplied by the area of turf grass removed from each of the sub-basins to provide a total volume of depletion avoided by turf grass removal. Important inputs for estimating turf grass conservation savings and associated depletion impacts are summarized in Table M-2.

Specific turf grass areas were also evaluated, including the replacement of turf on tax-exempt properties and park strips. Analyses conducted by Hansen, Allen & Luce (HAL) found that tax-exempt parcels accounted for between 9.22% and 10.96% of total urban turf across the sub-basins (Appendix A). The proportion of turf located in park strips varies by sub-basin and is influenced by factors such as urban density and development patterns. Based on data collected from eight municipalities within the basin, park strip coverage was estimated to range from 8.8% in less developed sub-basins to 18.2% in more urbanized sub-basins.

There is significant uncertainty in estimating depletion reduction from turf grass replacement programs. Variation in the type and coverage of landscape replacing turfgrass significantly impacts outcomes. Specific location considerations and the preferences of households or municipal managers also play an important role in determining actual water savings. Additionally, fluctuations in weather patterns and evapotranspiration rates across time and sub-basins add another layer of variability. Despite these uncertainties, turf grass replacement consistently offers the largest potential savings, though with a considerable range in estimated depletion reductions.

Table M-2. Turfgrass Replacement Variables

Parameter	Lawn	WaterWise
Turf Area (acres)	136,195	
Average ET_0 (inches)	33.79	
Average Net Irrigation (inches)	17.14	
Net Irrigation St. Dev.	1.60	
Crop Coefficient (K)	0.80	0.30
Residential Irrigation Efficiency (IE)	0.55	0.90
Inches/Gallons Conversion	0.62	0.62
WaterWise Plant Coverage Low		1.0
WaterWise Plant Coverage High		0.5

Weather Based Irrigation Controllers

This estimate quantifies water savings based on documented efficiency improvements following the implementation of smart irrigation controllers. Research indicates these devices reduce water use by approximately 15% for users practicing average irrigation, while users who historically over-irrigate may achieve reductions up to 40% (Lunstad & Sowby, 2023). This information indicates that historically high water users should be prioritized for this program. The high-end estimate assumes all users fall into the over-irrigation category, reflecting a maximum savings potential under universal adoption among high-water-use households. This framework accounts for the spectrum of existing irrigation behaviors and their influence on potential conservation outcomes.

Estimating depletion reduction from the implementation of weather-based irrigation controllers involves substantial uncertainty. One primary source of variability lies in the behavioral response to increased irrigation efficiency. As observed in other irrigation efficiency programs, there is a tendency for some users to use the efficiency gains to irrigate additional acreage rather than reduce overall water use. Furthermore, outcomes vary based on existing irrigation methods, newly adopted watering techniques, and the types of vegetation being irrigated. These interacting factors introduce significant uncertainty in predicting actual water depletion reductions, making it necessary to express potential outcomes as a range rather than a fixed value.

Landscape and/or Irrigation Audits

The effectiveness of this program, where irrigation systems are professionally assessed to detect inefficiencies, leaks, and scheduling issues, is modeled to decrease over time. Research shows the greatest water savings occur in the first-year post-audit (20.6%), followed by a decline to 7.7% in year two, and 6.5% in year three (AWE, 2015). These diminishing returns are attributed to system degradation and user reversion to pre-audit practices. The high-end estimate incorporates the year-by-year decline, while the low-end estimate utilizes a single overall reduction of 10.9% as reported by The California Urban Water Conservation Council (California Urban Water Conservation Council, 2005). This approach captures short-term effectiveness while acknowledging the need for sustained user engagement and ongoing maintenance to retain benefits.

Estimating depletion savings from irrigation audits involves multiple layers of uncertainty. Similar to other efficiency programs, users may respond to increased irrigation capacity by expanding watering rather than reducing consumption. Results also vary with system age, design quality, vegetation type, and maintenance practices. Some systems may have minimal inefficiencies to begin with, limiting the potential for savings, while others may reveal substantial conservation opportunities. These context-specific variables, along with fluctuating weather and evapotranspiration conditions, create a wide range of possible depletion outcomes, necessitating high and low estimates to adequately reflect this variability.

Utah State University currently administers an irrigation efficiency audit program known as Water Check, which offers residential and commercial irrigation evaluations at no cost from May through the end of August. The program is available within the Salt Lake City Department of Public Utilities and Sandy City service areas, as well as through Extension offices in Iron County and Washington County. Expanding this program to additional communities throughout the Great Salt Lake watershed could further enhance regional water savings and management outcomes. For more information on the Water Check Program, please visit: https://extension.usu.edu/cwel/watercheck

Statewide Turf Mapping

This program does not directly generate depletion reductions but instead provides critical data infrastructure to enhance targeted water conservation efforts. Through aerial imagery and remote sensing, it maps existing turf areas and associated characteristics, enabling water managers to identify highly irrigated turf areas, track landscape changes, and evaluate turf-related conservation program outcomes. These datasets increase planning precision and support more effective allocation of resources.

While the program itself does not produce quantifiable savings, it plays a foundational role in improving the accuracy and reliability of depletion estimates in related initiatives. By establishing baseline landscape conditions and enabling before-and-after comparisons, it helps reduce uncertainty of turf conversion and other outdoor efficiency strategies. Developing and monitoring current and future turf area estimates is essential for this effort. Additionally, tracking historical turf areas using the same technology can aid in estimating historical depletions from turf irrigation.

Water Conservation and Efficiency Plans

These plans serve as strategic frameworks that enable the design and coordination of conservation activities but do not directly produce water savings. Instead, their effectiveness lies in their capacity to identify high-impact opportunities, establish measurable goals, align conservation actions with system needs, and increase participation across programs. Success is evaluated based on the plan’s ability to guide, integrate, and monitor multiple initiatives rather than its direct influence on water use.

While no specific depletion reductions are attributed to these plans, they help reduce the uncertainty of other conservation actions by ensuring coordinated implementation. By improving program alignment and targeting, these strategies increase the likelihood that conservation investments will be made in areas with the highest potential impact, thereby indirectly narrowing the range of estimated depletion savings.

This program and its associated impact does not quantify direct water savings but instead focuses on the plan's role as a strategy that enables other conservation activities. Comprehensive planning can lead to the identification of high-value opportunities, the establishment of measurable goals, alignment with system needs, and increased participation in conservation programs. Success would be measured by the plan's ability to coordinate multiple conservation efforts and achieve established conservation targets.

End Use Water Conservation and Efficiency Analyses

This approach focuses on detailed water use assessments to identify savings opportunities at the customer level, particularly among high-use or non-revenue water accounts. The effectiveness is not measured by direct reductions but by the volume and quality of conservation opportunities identified and acted upon. Success depends on how many targeted users adopt recommended practices or retrofits following the analysis.

Uncertainty in this program lies in the variability of customer responses and the effectiveness of follow-up implementation. Not all identified opportunities lead to action, and actual depletion savings can vary based on the adoption rate, scale of intervention, and water use behaviors. The analyses themselves reduce some uncertainty by revealing hidden inefficiencies, but realized savings remain contingent on subsequent steps, which introduces variability in final outcomes.

The State of Utah currently supports the implementation of such practices through the Transparent Water Billing Grant Program, which assists water providers in adopting billing formats that clearly communicate customer water use in an easy-to-understand manner. By increasing transparency and awareness, the program encourages customer adoption of conservation practices while helping households better understand the link between water efficiency and potential cost savings. More information, please visit: https://conservewater.utah.gov/transparent-water-billing/

Cooling System Retrofits

The water savings potential from upgrading cooling towers was estimated using geospatial data for building size assumptions as well as assumed water savings that can be achieved through system optimization strategies. Under optimized conditions, a standard 350-ton cooling tower serving a 100,000-square-foot building can save approximately 0.26 ac-ft per year (California Utilities Statewide Codes and Standards Team, 2011). High-end estimates include buildings of 100,000 square feet or larger, while the low-end estimate includes smaller 24,000-square-foot buildings, which aimed to include mid-sized residential or commercial high-rises.

Variability in depletion savings for this program stems from multiple building-specific factors. Cooling system type, usage frequency, retrofit quality, and operational practices all influence the magnitude of actual water reductions. Moreover, variations in local climate, occupancy patterns, and equipment maintenance add additional uncertainty. Consequently, while retrofit potential can be reasonably estimated using building data, depletion outcomes remain variable and require range-based estimation.

Vehicle Washing/Car Wash Rebates

This program provides incentives for commercial car washes to install water-efficient technologies, with research showing average savings of 30 gallons per vehicle washed (U.S. EPA, 2017). The high estimate assumes bi-weekly washes for two vehicles per household, while the low estimate assumes just one wash annually per household. Household size assumptions are based on an average of 3.04 people per residence.

Depletion savings from this program vary considerably due to uncertainties in actual car washing frequency and participation rates. While average gallons saved per wash are reasonably well documented, household-level behaviors are highly variable and difficult to quantify. Factors such as seasonal variation, access to participating car washes, and household vehicle ownership all influence the overall savings achieved, resulting in a broad potential range of depletion outcomes.

Indoor Residential Water Use Efficiency Audits and Retrofits

This program estimates potential depletion reductions by conducting residential audits to identify indoor water conservation opportunities. Drawing on Utah's *Regional M&I Water Conservation Goals*, the high-end scenario assumes indoor use can be reduced to 40 gallons per capita per day (gpcd) through the adoption of high-efficiency fixtures, appliances, and behavior changes. The low-end scenario targets 60 gpcd (DWR, 2019). These benchmarks reflect the expected outcomes of audit-driven retrofits and voluntary or incentivized participation.

Depletion savings from indoor efficiency improvements are inherently variable, influenced by a combination of behavioral, structural, and demographic factors. Realized savings depend on household participation, the degree of implementation of recommended measures, and the consistency of water-efficient practices over time. Additionally, variations in household size, plumbing system efficiency, and occupancy patterns affect both baseline demand and conservation potential. Given these uncertainties, a range-based estimation approach is essential to represent the full spectrum of possible outcomes.

Universal Metering

Universal metering involves installation of meters on all water connections—both potable and secondary—to enable accurate measurement and management of water use. While the program's effectiveness varies widely, some districts, such as the Weber Water Conservation District, report usage reductions as high as 20%. Other areas, however, have seen little to no change in consumption without complementary policies or education programs.

The variability in depletion savings from metering stems largely from its dependence on user awareness and behavior. While metering enables water tracking, it does not inherently change consumption patterns unless coupled with other conservation strategies. Users may alter behaviors once they become aware of their usage, but this effect is not guaranteed. The inconsistency in response and the difficulty of isolating the metering effect from other interventions contribute to substantial uncertainty in estimating actual depletion reductions.

Allotment Based Tiered Rate Structure

This approach is based on data from the City of Saratoga Springs, where implementation of an allotment-based rate structure led to a 30% reduction in average annual water demand per irrigated acre for secondary water. Under this model, each property receives a water allotment based on its rights and irrigated acreage, and water use above the allotment incurs higher charges. The high-end estimate reflects this 30% reduction.

Depletion savings from tiered rate structures exhibit significant variability due to inconsistent user sensitivity to pricing signals. Some individuals respond strongly to higher prices, while others continue high water use despite increased costs. Furthermore, changes in behavior following the implementation of pricing reforms are difficult to predict and measure, especially without supporting education or enforcement. These behavioral factors introduce uncertainty into both participation rates and the magnitude of actual water use reductions, making it necessary to use a wide estimate range when projecting depletion savings. For these reasons, a 5% reduction was assumed for low end estimates.

Tiered Pricing for Residential Water Use

The pricing strategy draws on data indicating that a 10% increase in water rates typically results in a 5% reduction in consumption. Applying tiered rates from the Great Salt Lake Water Conservation Tool Box—ranging from 33% to 80% increases per tier—expected decreases in water use for each tier led to an average of 27% use reduction, for the high end scenario (SWCA, 2024). This approach accounts for price elasticity and measures effectiveness by comparing water usage before and after rate implementation. However, achieving these reductions depends on proper implementation, including the development of informed tiers and rate levels that reflect local water use patterns, climate, and customer behavior.

As with other pricing strategies, depletion savings from tiered residential rates vary due to inconsistent user responses. Some consumers may significantly reduce water use in response to higher costs, while others may remain relatively unaffected. Properly formatted tiers—those that align charges with realistic budgets and clear usage thresholds—can be more effective in influencing user behavior and encouraging conservation. The behavioral aspect of conservation introduces unpredictability into program outcomes. Additionally, measuring the long-term impact of price increases—especially when not paired with metering, education, or enforcement—poses methodological challenges that compound the uncertainty in projected savings. To reflect these uncertainties, a conservative 5% reduction was used for the low-end estimate.

Aggregated Depletion Strategies

Because many of these programs are likely to be implemented concurrently and at varying levels of intensity, it is important to recognize that their combined impact on depletion will not be simply additive. Interactions between strategies can significantly influence overall effectiveness. For instance, universal metering enables tiered rate structures to function more effectively by providing accurate consumption data, while turfgrass replacement may reduce baseline outdoor use, thereby altering the magnitude of savings achieved through pricing incentives. A summary table of aggregated strategy outcomes is provided below to illustrate these interdependencies.

Table M-3. Aggregated High Priority Depletion Reduction Strategies

Program	Program Description	Low Reduction in Depletion Estimate	High Reduction in Depletion Estimate
		(ac-ft/yr)	*(ac-ft/yr)*
Universal Metering	Installation of secondary meters on all homes without meters within the basin.	6,000	28,500
Conservation Focused Tiered Rate Structures for both Newly Installed and Existing Meters without Tiered Rates	Implementation of conservation focused tiered rate structures on both newly installed meters and previously installed meters that do not currently have tiered rates structures.	10,100	65,100
Tax-Exempt Park Strip Turfgrass Replacement	Replacement of non-functional turfgrass, such as park strips, owned by tax-exempt entities with native or low-water-use plants and hardscapes.	3,400	4,600
Tax-Exempt Park Strip Turfgrass Replacement/ Conservation Tiered Rate Structure Aggregate	The simultaneous implementation of the three programs—Tax-Exempt Park Strip Turfgrass Replacement, Universal Metering, and Conservation Tiered Rate Structures for all connections.	13,300	68,800

Benefit-Cost Analysis Methodology

This appendix describes the process to estimate costs and benefits of the conservation programs evaluated. The Benefit-Cost Analysis methodology outlined by the American Water Works Association (2017) was adapted for the purposes of this report. This benefit-cost analysis was utilized to evaluate and select conservation programs that are best suited for reducing depletion from M&I use across the Great Salt Lake Basin.

The detailed methodology for benefit-cost analysis may be described by the numbered steps listed below. This type of analysis required locale-specific data on water use and demographics, described in Appendices A and B of this report. The best sources of conservation program costs are from other utilities that have conducted similar programs.

1. Develop estimates of water use without any additional conservation: Water use data was utilized between 2019 and 2023. This establishes the current consumption patterns across residential, commercial, institutional, and industrial sectors in the Great Salt Lake Basin, serving as the foundation for all subsequent conservation projections.
2. Prepare a baseline projection of water use including effects of applicable federal, state, and local codes and standards (i.e., passive conservation): This involves projecting water use trends forward with consideration only for conservation that would occur without interventions through regulatory compliance and fixture replacements at the end of useful life. Utah's recent water efficiency standards for appliances and plumbing fixtures were incorporated, along with demographic and development projections through 2050.

However, this study did not include analyses of future water use projections and thus, this step was not included in the analyses for this report.

3. Based on the profile of use by different customer groups, identify all potentially applicable water conservation measures: A list of M&I conservation programs was compiled from various references. This included technological measures (cooling tower retrofits, universal metering) behavioral programs (education campaigns), financial incentives (turf replacement rebates and tiered rate programs), and regulatory approaches (mandated irrigation audits).

4. Screen the measures to select a short list of measures that warrant a benefit-cost analysis: The comprehensive list compiled in step three was reviewed to filter and prioritize programs that would be most effective in reducing outdoor depletion and increase potential for savings to return to the Great Salt Lake.

5. For each measure, estimate the market penetration (the percent of customers that will participate in the measure): The goal of this report is to identify the full potential M&I conservation savings that is possible in the Great Salt Lake basin. Thus, the assumption for this analysis is 100 percent market penetration. In practice, this represents the theoretical maximum savings potential, with actual participation likely requiring significant policy, regulatory, and financial mechanisms.

6. Estimate the average annual savings by multiplying the number of participants by the measure's unit water savings: For each conservation measure, unit water savings were developed based on data from previously implemented programs, industry literature, and calculated depletion saving estimates. These per-unit savings (gallons per household, acre-feet per acre, etc.) were multiplied by the estimated number of eligible accounts to determine the total potential water savings per program.

7. Estimate the measure costs by multiplying the number of participants by the measure's unit cost. Convert to the equivalent present value in today's dollars: Comprehensive cost estimates were developed for each conservation measure, including upfront implementation costs, ongoing maintenance requirements, and administrative overhead. All costs were converted to 2024 dollars using a discount rate of 3% to facilitate accurate comparison between programs with different implementation timelines.

8. Determine the operation and maintenance (O&M) cost savings associated with reduced water use and wastewater flows: Conservation reduces variable costs including pumping energy, chemical treatment, distribution system maintenance, and wastewater processing. This step calculated the annual O&M savings for both water and wastewater systems based on current utility expenditure data and projected conservation outcomes.

The present value of costs associated with each conservation program was used to determine an annualized cost per acre-foot of water conserved and an estimated cost per acre-foot of depletion reduction, as shown in Table M-4.

Table M-4. Cost Estimates of Water Conserved and Depletion Reductions

Name of Program	Reference Cost		Reference Unit *($/X)*	Year	CCI Adjustment	2025 Cost		Citation
	Low	High				Low	High	
Landscape/Turf Replacement Program	$3.25	$7.50	Square foot	2019	1.27	$4.13	$9.53	DWRe, 2019
Weather-Based Irrigation Controllers[1]	$175	$909	Controller	2025	1	$175	$909	HomeWyse, n.d.
Landscape/Irrigation Audits	$50	-	Site Audit	2008	1.52	$76		A&N Technical Services, 2005
	-	$310	Site Audit	1994	2.19		$679	HomeWyse, n.d.
Toilet Replacement[1]	$320	$1,236	Toilet	2025	1	$320	$1,236	HomeWyse, n.d.
Washing Machine Replacement[1]	$577	$1,860	Washing Machine	2025	1	$577	$1,860	HomeWyse, n.d.
Dishwasher Replacement[1]	$805	$2,100	Dishwasher	2025	1	$805	$2,100	HomeWyse, n.d.
Plumbing Leak Detection	$210	$255	Leak Detection Service	2025	1	$210	$255	HomeWyse, n.d.
Cooling Tower Retrofit Rebates	$3,624		Cooling Tower	2011	1.45	$5,255	$10,510	California Utilities Statewide Codes and Standards Team, 2011
Allotment Based Tiered Rate Structure[2]	$0.91	$7.58	Rate Study / Household	2025	1	$0.91	$7.58	Jacobs, 2025
Conservation Focused Tiered Rate Structure[2]	$0.91	$7.58	Rate Study / Household	2025	1	$0.91	$7.58	Jacobs, 2025
Universal Metering[1]	$1,300	$2,000	Meter	2019	1.27	$1,651	$2,540	UDWR, 2019

1. Cost includes installation.
2. 2. Cost estimates were developed in-house using industry expertise and AWWA M1 system sizing for small, medium, and large systems.

Appendix M - References

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APPENDIX N WATER DEMAND MODEL

The purpose of this analysis is to perform a high-level review of the Utah Division of Water Resources (DWRe) Water Demand Model (WDM). The model estimates current and future outdoor residential water use across public water supplier service areas. The model is structured around a core equation that multiplies three main components: the average irrigated area per home, the average depth of water applied, and the total number of homes. This is further refined by accounting for differences between single-family and multi-family housing types. The model incorporates multiple geospatial and demographic datasets to inform each parameter and projects future demand based on population growth, housing trends, and climate-adjusted evapotranspiration.

This analysis outlines assumptions used, reviews results, and provides recommendations on potential upgrades, including findings from this study.

Model Summary

The WDM model does a sufficient job at capturing the extensive list of variables that should be considered when estimating future demands. This section evaluates the parameters used in the model by discussing what each represents, and how it was derived. An outline of assumptions used for indoor and outdoor demand estimation are summarized in the following sections.

Indoor Demand Model Assumptions

The indoor demands are determined from the following equations in Figure N-1:

$$GPD_{Indoor} = 32.1 * PPH + 88.4$$ Correlation Coefficient R^2=0.67 Equation (4)

$$GPCD_{Indoor} = \frac{88.4}{PPH} + 32.1$$ (Derived from equation 4) Equation (5)

where:

gpd_{Indoor} = Gallons per Household per Day
pph = Persons per Household
$gpcd_{Indoor}$ = Gallons per Capita per Day Water Use

Utah Division of Water Resources (2009). "2009 Residential Water Use" *Utah Division of Water Resources*, Salt Lake City, Utah.

Figure N-1. Summary of equation for indoor demand (Utah DNR Presentation)

The following is a summary of each parameter, including data sets used to determine the information.

Population (Pop)

Population data originates from the Kem C. Gardner Policy Institute and is initially represented at the TAZ (Traffic Analysis Zone) or Census block level. For the model, this data is disaggregated into public water supplier boundaries. Adjustments were made in some counties to account for traveler populations (e.g., tourists), which can significantly affect seasonal demand.

Persons Per Household (PPH)

PPH is also obtained from the Kem C. Gardner Policy Institute and is used to convert population into estimated household counts. The model uses 2015 data at the county level and applies it uniformly within each county's supplier areas. No further adjustments were made at the supplier boundaries. The lack of adjustment below county level data could introduce some error as population demographics could vary between water suppliers even within the same county. Furthermore, persons per household has and will change with time. Both the US and the Utah average PPH has decreased over the last 50 years, and the US average PPH has decreased more than the Utah average PPH in this time period (Bateman, 2021). The Utah average PPH could decrease to the US average PPH in the future, which would increase per capita use somewhat.

Single-Family Home Percentage (SFH%)

The percentage of homes that are single-family residences is critical to splitting the model into SFH and MFH components. The baseline SFH% is derived from the American Community Survey (ACS) data from around 2013, and disaggregated from census boundaries into public supplier boundaries. For projections, SFH% is estimated from a spreadsheet model using county building permit trends and the projected number of homes at the basin level. These values are then distributed to suppliers. One key challenge is that changes in housing type (e.g., increased multi-family development) may not be fully captured if building trends shift rapidly or diverge from historical patterns. Model users should recognize that existing households skew heavily towards single family homes, so newer builds (which lean towards majority multi-family developments) are only slowly shifting the balance between single-family and multi-family homes to more equal proportions.

Outdoor Demand Model Assumptions

The model utilizes several of the variables used for the indoor demand, including the addition of several more to determine anticipated outdoor water usage. The equation shown in Figure N-2 summarizes the assumptions for outdoor demand estimation.

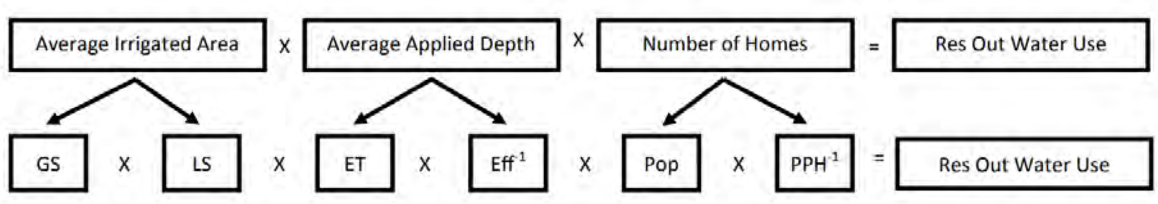

Figure N-2. Outdoor water use calculation equation

In addition to the equation shown in N-2, a methodology was developed to further account for Multi-Family Housing (MFH) and Single-Family Housing (SFH). This is done by assuming a coefficient for average irrigated area in MFHs. The total residential outside water use can be found by finding the percentage of SFHs in an area. The equations are shown below.

MFH Equation:

$$A \times ET \times Eff^{-1} \times Pop \times PPH^{-1} \times (1\text{-}SFH) = \text{MFH Water Use}$$

SFH Equation:

$$GS \times LS \times ET \times Eff^{-1} \times Pop \times PPH^{-1} \times SFH = \text{SFH Water Use}$$

Figure N-3. MFH vs. SFH Water Use

The following sections outline details on the various assumptions used for the equation inputs.

Green Space Percentage (GS)

Green space percentage represents the proportion of a residential lot that is irrigated or vegetated. This is estimated using four-band aerial imagery analyzed via NDVI (Normalized Difference Vegetation Index), which identifies live vegetation by comparing visible and infrared light reflectance. NDVI is processed over public water supplier boundaries, and results are summarized to provide an average green space value per supplier. This metric is critical in estimating irrigated area, but it comes with several challenges. Non-irrigated vegetation (like natural shrubland) may be mistakenly classified as irrigated. In addition, shadows from buildings or trees can obscure true ground conditions. The model can overestimate green space in upper elevation areas where vegetation may not be irrigated at all. During projection calibration, GS values are iteratively adjusted until the model output aligns with Regional Conservation Goal (RCG) targets.

Lot Size (LS)

Lot size refers to the average parcel size for residential properties and is sourced from county recorder data. Parcels within each public water supplier boundary are filtered, and data quality is assessed to select the most reliable source. These parcel-level values are then averaged to define a representative lot size per supplier. One key limitation is inconsistency in county datasets — not all parcels are well-categorized, and some linework may be outdated or poorly aligned. Also, certain areas like park strips (narrow grassy areas between sidewalks and roads) are often omitted, which can lead to underestimation of irrigated area. Like green space percentage, lot size values were iteratively tuned to align with RCG targets during the projection process.

Standard Irrigated Area for Multi-Family Housing (A)

For multi-family housing units (MFH), the model assumes a fixed irrigated area per unit, rather than calculating based on parcel-level lot sizes. This constant, derived from Water Resources (WRe) research, varies only in the Kanab/Virgin Basin, where a unique value is applied. For all other areas, the same value is used. This simplification is useful for modeling but introduces limitations, especially in projections. The irrigated area per MFH unit does not evolve over time, which may overlook future landscape changes such as increased landscape conservation. If this standard irrigated area is used, it should be frequently updated for the present and allowed to evolve in projections.

Evapotranspiration (ET)

Evapotranspiration represents the total water loss from soil and plant surfaces due to evaporation and plant transpiration. The model uses GridET, a gridded climate dataset, averaged over turf grass areas within each water supplier boundary. This parameter is fundamental in determining the water needed to sustain existing vegetation. While this approach provides spatially detailed climate data, projections depend on future climate assumptions. For long-term estimates, adjustments were made based on recommendations from Utah State University (USU) to account for the potential impacts of climate change, introducing uncertainty in how ET will trend regionally.

Irrigation Efficiency (Eff)

Irrigation efficiency accounts for the effectiveness of watering practices. The model uses historical efficiency values at the basin level for its baseline, which are calibrated to match observed water use. For projections, these values are iteratively adjusted until the model aligns with RCG output. Challenges with this parameter include the variability in real-world irrigation systems and user behavior, which makes it difficult to define a universally applicable efficiency value. This parameter also appears to include other losses, such as losses in the distribution system before reaching the end user. These system losses are important to consider in a demand model and should be explicitly included in the equation or the irrigation efficiency variable should be renamed to acknowledge this loss. The Division of Water Rights has estimated system losses for each system which could easily be incorporated.

Model Results

Outputs for the model were provided for the Salt Lake County region. Results were analyzed to determine the validity of the results.

- **Water Systems at Buildout Increase Over Time:** There was increased water use across different buildout types. Cities that are growing or being redeveloped should be expected to see an increase in water use; however, cities that are near full buildout capacity should show a decline in water use with conservation practices, unless zoning changes to allow higher density redevelopment are expected.

- **Increasing Indoor GPCD Over Time:** The model shows a consistent increase in indoor residential gallons per capita per day (GPCD) across each 10-year interval until the buildout year of 2070. The model currently estimates indoor water demand using a formula dependent on PPF which has been in a long-term decline. However, this result challenges expectations based on technological improvements and long-term conservation behaviors, which should result in declining or stabilizing indoor water use over time. Future indoor GPCD projections appear unrealistic and may not be statistically significant based on the range of data presented, especially in fully built-out communities where we expect water use efficiency to improve due to factors like appliance upgrades, building code updates, and growing public awareness. This raises concerns about the validity of the PPH-based equation when applied to long-range forecasting.

- **Inaccurate Indoor Water Use**: Model estimates for demands in 2020 don’t match data that was recorded on the Utah Division of Water Rights water use portal for several communities.

Recommendations

It is recommended that the following be added to the model to help ensure that it is compatible with future anticipated water usage.

Overall

- Should not be solely calibrated on RCG and should consider findings from this report.
- Includes better accounting of future depletion estimates to better track impacts to Great Salt Lake, such as depletion budgets.
- Consider conservation, including policy changes within cities (turfgrass reduction factor or conservation incentives).
- Consider the buildout possibilities of the system (if the city is growing, buildout, or in the process of redevelopment).
- **Updating SFH% estimation:** Given the constant evolving housing trends it is recommended that the model revise its methodology for estimating the Single-Family Home Percentage (SFH%) for both baseline and future years. Specific improvements include:
  - Utilize housing type projections from current municipal or county general plans, which often include future land use maps and zoning designations. These documents can provide insight into where single-family and multi-family development is expected, allowing the model to align more closely with planned growth patterns and local policy direction.
  - Incorporate Local Permit datasets at the municipal or county level, such as from the U.S. Census Building Permits Survey or local planning departments. This allows the model to capture rapid shifts in housing composition.

Indoor

- **Revise future indoor use methodology:** The current equation, which relates indoor use to PPH, may need refinement or replacement. Future projections should account for increased indoor water efficiency over time. Analyses should evaluate if increases in water use at lower PPH are statistically significant. A static or increasing GPCD assumption may misrepresent future indoor demand.

Outdoor

- **Introducing Depletion:** Depletion should be added into the outdoor calculations to expand the utility of the model beyond water demand only.
- **Including Turfgrass Reduction Factor:** A factor should be included that accounts for a reduction in existing turfgrass, based on historical trends, as well as irrigation system efficiency upgrades.
- **Introducing a Variable Irrigated Area parameter for MFH:** The current model applies a fixed irrigated area per multi-family housing (MFH) unit, which does not account for evolving landscaping trends or urban design changes over time. To improve the model’s accuracy, we recommend implementing a variable MFH irrigated area that changes over time or across scenarios. This parameter could be informed by case studies, analysis of zoning regulations and laws.
- **Consider non-turfgrass irrigation factor:** Include future parameters that account for future development using natural or non-turfgrass landscaping.
- **Separate System Losses from Irrigation Efficiency:** Use available estimated system loss data from the Utah Division of Water Rights as a separate parameter from irrigation efficiency to clarify and better define each type of loss and recognize differences between systems.

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