# Central Basin and Range Ecoregion Wetland Assessment and Landscape Analysis

*by*

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# EXECUTIVE SUMMARY

Wetlands in the arid Central Basin and Range ("Central Basin") ecoregion of Utah are scarce but provide important functions including critical habitat for wildlife including Species of Greatest Conservation Need and migratory birds, water quality improvement, and recreational and aesthetic values. The Utah Geological Survey (UGS) conducted a study in 2019 and 2020 to better understand the location, type, condition, and potential function of wetlands in the ecoregion. This study focused on areas in the Great Salt Lake and Escalante Desert-Sevier Lake ("Sevier Basin") HUC6 watersheds within the Central Basin to complement previous work by the UGS that focused on other watersheds in the ecoregion. The Great Salt Lake HUC6 is composed of two distinct areas that differ in the abundance, type, and common stressors of wetlands, and it was split into two strata—Great Salt Lake for wetlands within the Great Salt Lake HUC8 (mostly wetlands along the east shore of the lake) and the West Desert for the remainder of the area. The Sevier Basin was not divided and served as the third stratum. Our study consisted of three objectives: 1) obtaining baseline data on wetland condition, stressors, and potential function by conducting a field survey, 2) identifying and describing high quality or least disturbed wetlands for different wetland types, and 3) conducting a two-part landscape analysis to use spatial data to understand the intersection of land use, ownership, and wetland distribution and then summarize trends in surface and ground water over the last 30 to 60 years.

We defined the target population as all vegetated wetlands (e.g., marshes, meadows, aquatic bed) and sparsely or unvegetated wetlands that were less than 8 ha in size. We used a random stratified design to select survey sites from a sample frame derived from National Wetlands Inventory data, though the majority of wetland mapping in the Sevier Basin and West Desert (>89%) is out of date. We evaluated 210 randomly selected sites, but only conducted surveys at 81 of the sites due to lack of target wetland or no landowner access; we also surveyed six subjectively selected sites. More than 70% of randomly selected wetland sites in the Sevier Basin were not sampleable wetlands. Playas and saline meadows accounted for over 60% of the surveyed features, followed in descending order by marsh, aquatic bed, mudflat, fresh meadow, forested-shrubland, and shallow water sites. Marsh and mudflat wetlands were most common in the Great Salt Lake stratum, and playa and saline meadow wetlands were most common in the Sevier Basin and West Desert. Forested-shrubland wetlands were rare overall but were the third most common wetland type in the Sevier Basin, the only stratum where they were found.

Wetland condition varied by strata and was generally best in the West Desert stratum and worst in the Great Salt Lake stratum. Condition also varied by wetland type. Playas were typically in the best condition, likely due to their often remote location and saline soils which limit their degree of disturbance from grazing, non-native species, and other stressors. Marshes and mudflats were typically in the poorest condition, often due to high cover of noxious weeds and other non-native species, as well as poor hydrologic condition due to upgradient management activities and water quality stressors. The most prevalent stressors across the study area were non-native or invasive plants in both the buffer and plot, agricultural runoff or direct manure contributions from livestock, and buffer soil disturbance by animals, though the severity of the stressors varied by strata. Variation in overall condition across the strata was mostly driven by differences in vegetation composition and hydrologic stress. Noxious weeds were most prevalent in the Great Salt Lake stratum, where the noxious weed *Phragmites australis* ssp. *australis* (Phragmites) is estimated to occupy about 28% of the area, a conservative estimate because two sites in the stratum were deemed inaccessible due to excessive Phragmites cover and not surveyed. The occurrence of Phragmites in Great Salt Lake wetlands is well known, and researchers and managers continue to develop treatments and target management activities to control its spread. Noxious and non-native species were a much smaller issue in the West Desert and Sevier Basin. Other noxious weeds encountered in the study include white top (*Cardaria draba*), Canada thistle (*Cirsium arvense*), Russian olive (*Elaeagnus angustifolia*), quack-grass (*Elymus repens*), broadleaf pepperweed (*Lepidium latifolium*), and tamarisk (*Tamarix* spp.). Of these, tamarisk was most prevalent, estimated to occupy 2.5% of wetlands in the Sevier Basin. The species was also frequently found at sites that were no longer wetlands in the stratum.

Water management and water quality in Great Salt Lake and groundwater withdrawal in the Sevier Basin were drivers of poor hydrologic condition or wetland loss in those strata. Great Salt Lake wetlands were typically within or adjacent to artificial impoundments where management focuses on waterfowl production. Little if any water reaches these wetlands without passing through anthropogenic control via canals, levees, and control structures, though Great Salt Lake itself would flood these sites in higher water years. Additionally, most of the water reaching these wetlands passes through dense urban and agricultural areas before reaching Great Salt Lake, accumulating water quality stressors and often listed as impaired. Nearly one-half of surveyed wetlands in the Sevier Basin had evidence of impacts of groundwater withdrawal, such as stressed or dying vegetation.

We investigated two wetland functions in the study area: capacity to improve water quality and hydrologic function (capacity to reduce flooding and erosion). Great Salt Lake wetlands were estimated to have "medium" capacity to improve water quality, whereas those in the Sevier Basin and West Desert were frequently rated "low." Great Salt Lake wetlands had more landscape

potential for receiving water quality stressors since they are in much closer proximity to large urban areas and associated pollution and more frequently receive surface water. Wetlands across the study area were estimated to provide low overall hydrologic function, with the exception of riverine wetlands in the Sevier Basin. Wetlands in the study area tended to not receive significant surface water inputs, were in remote locations, and were not in areas with historical flooding issues.

We used the data from the current study along with data from previous UGS surveys in the ecoregion to identify least and most disturbed sites for each wetland type. We calculated overall impact scores for each site using stressor data and identified sites as least and most disturbed if they fell towards the bottom or top of the impact score range for a given wetland type, respectively. We were only able to assign sites to least and most disturbed condition for four wetland types—fresh meadow, marsh, saline meadow, and playa—due to low sample size and lack of range of condition in other wetland types. Overall wetland condition scores and several vegetation metrics, including mean C, cover-weighted mean C, and percent relative native cover, differed significantly between least and most disturbed sites for each wetland type. These least disturbed sites can provide information on reference conditions for restoration and mitigation efforts.

For the landscape analysis, we investigated all features mapped by the National Wetlands Inventory, not just features that were part of the target population, resulting in 11,449 $km^2$ of aquatic features investigated, versus just 541 $km^2$ included in the target sample frame. Nearly all the aquatic features in the Great Salt Lake stratum are state-owned and mapped as open water or barren land cover (exposed lakebed). The majority of aquatic features in the Sevier Basin and West Desert are federally owned and mapped as playa or other barren land cover, though private landowners own a disproportionate share of all wetland types except playa. We assessed 30-year trends in surface water extent using remotely sensed data and 60-year trends in groundwater well levels. Both largely showed declining trends across the study area and are likely a major cause of wetland loss and degradation. Evidence from groundwater wells in the Lower Sevier watershed is especially noteworthy for the large number of wells showing long-term declines in groundwater levels.

Wetlands and other water resources in the Central Basin are both critical and scarce. Wetlands in our study area are very vulnerable to the impacts of water diversion, from direct wetland loss in the Sevier Basin to increased invasion by introduced plant species on Great Salt Lake's drying lakebed. While wetlands in the West Desert have not experienced widespread hydrologic impacts like those seen in other parts of the study area, impacts seen elsewhere should serve as a bellwether to what could happen if large amounts of new diversions are allowed without accounting for ecological impacts. Importantly, wetlands that are lost or severely impacted are unlikely to convert to intact upland communities. Instead, they might convert to systems such as cheatgrass-dominated annual grasslands that provide little ecological benefit and lead to altered fire regimes and increased dust production. Periodic assessment of wetlands in the Central Basin, whether through field assessments or remote sensing or a combination of the two, is critical for understanding trends in aquatic resources over time and identifying potential drivers of change.

# INTRODUCTION

## Project Background

Wetlands in the Central Basin and Range ("Central Basin") ecoregion of Utah represent a small percentage of the landscape but provide outsized ecological services in this arid region including wildlife habitat, water quality improvement, and flood attenuation. Much of the wetland area is concentrated around Great Salt Lake but also includes riverine wetlands along the Sevier River and isolated spring-fed wetland complexes and areas of shallow groundwater in remote areas that represent important wildlife habitat and critical stopovers for migrating birds, such as Fish Springs National Wildlife Refuge (NWR). Wetlands in the region also provide crucial habitat for Utah Species of Greatest Conservation Need (SGCN), including Columbia spotted frog (*Rana luteiventris*), Utah least chub (*Iotichthys phlegethontis*), and several endemic springsnail species. Considering estimates of increased future large-scale water withdrawals and continued population increases in the area, understanding wetland extent and condition will be essential to the conservation of wetlands and hydrologic resources in the region.

Wetlands in the Central Basin face numerous threats including hydrologic alteration, water quality stressors, and non-native plant invasion (Menuz and Sempler, 2018). Additionally, National Wetlands Inventory (NWI) mapping in most of the region last occurred in the early 1980s, an abnormally wet period, and little work has been done to assess mapping accuracy and current wetland conditions in the area. Overarching these threats is the fact that basic information on Utah's wetlands is lacking (Utah Wildlife Action Plan Joint Team, 2015), which is problematic because monitoring and assessment data are needed for such crucial activities as evaluating the results of restoration, determining appropriate mitigation, planning management actions, and identifying conservation targets.

The UGS, funded by a grant from the U.S. Environmental Protection Agency, conducted an assessment of wetlands in the Central Basin ecoregion to provide data on the type, condition, and potential function of wetlands in the watershed. Our project had three major objectives, including obtaining baseline data on wetlands in the study area, identifying and describing least disturbed sites, and creating a landscape profile using mapped wetland data and ancillary information to better understand the landscape setting and hydrologic conditions of wetlands in the ecoregion.

The Central Basin spans a large part of Utah and includes a diversity of land use patterns and wetland types. This project focuses on two level 6 hydrologic unit code areas (HUC6s) within the ecoregion: Great Salt Lake (HUC 160203) and Escalante Desert-Sevier Lake (HUC 160300, "Sevier Basin"), and excludes parts of the ecoregion that the UGS has previously surveyed (Menuz and others, 2014, 2016; Menuz and Sempler, 2018; Menuz and McCoy-Sulentic, 2019). Hydrologic units represent the area of the landscape that drains to a single point in a stream network and are organized in a hierarchical system ranging from large HUC2 units to the smallest HUC12 units. The Great Salt Lake HUC6 was further divided into two strata due to differences in hydrology and proximity to urban centers—Great Salt Lake stratum using the Great Salt Lake HUC8 (16020310, "Great Salt Lake") and the remaining area within the Great Salt Lake HUC6 as the "West Desert."

## Utah Rapid Assessment Procedure

The UGS began developing the Utah Rapid Assessment Procedure (URAP) in 2014 as a tool to rapidly assess the condition of Utah's wetland resources. The initial protocol was largely based on one used by the Colorado Natural Heritage Program (Lemly and Gilligan, 2013) modeled on the Ecological Integrity Assessment developed by NatureServe (Faber-Langendoen and others, 2008). Wetland condition data are collected using a series of qualitative or semi-quantitative metrics. Each metric is composed of a series of potential states, ranked from A through D, to denote a range of conditions from pristine unaltered wetlands to severely altered wetlands. The UGS added metrics to assess habitat for sensitive amphibian species to the protocol in 2015 and 2016 (Menuz and Sempler, 2018), developed draft methods for wildlife habitat functionality in 2017 (Menuz, 2017), and tested methods for collecting data on flood attenuation as part of this study. The UGS conducted a validation study in 2017 and made some changes to the protocol based on those findings (McCoy-Sulentic and Menuz, 2019; Menuz and McCoy-Sulentic, 2019). Data for this project were collected using the most recent version of the protocol and associated field forms (appendices A and B). The work described in this report follows the EPA's three-tiered framework to assess wetlands at varying spatial scales and levels of intensity (U.S. Environmental Protection Agency, 2006). For this project, we created a Level I landscape profile and hydrology analysis, collected primarily qualitative Level II wetland condition and function data, and collected more intensive Level III plant community composition data.

## Condition Versus Function Assessments

The assessments conducted for this project evaluate wetland condition and some aspects of wetland function. Wetlands in good condition exhibit species composition, physical structure, and ecological processing within the bounds of states expected for systems operating under natural disturbance regimes (Lemly and others, 2016). Direct or indirect anthropogenic alteration may lead to a change in these states and a concomitant lowering of the overall condition of the wetland. For the condition assessment, wetlands are evaluated to determine the degree to which they deviate from a reference standard, or anthropogenically unaltered, wetland. In contrast, functional assessments evaluate services provided by wetlands that are deemed important to society, such as the ability to attenuate flood waters or provide wildlife habitat (Fennessy and others, 2007). Many severely altered (i.e., low condition) wetlands still provide functional services; for example, a wetland adjacent to a wastewater treatment plant can improve water quality, and an artificially impounded reservoir can provide amphibian habitat.

Reference standards are an important component of condition assessments. The reference standard condition is the condition that corresponds with the greatest ecological integrity within the continuum of possible site conditions (Sutula and others, 2006) and is usually specific to a particular class of wetland (e.g., montane meadow, playa, etc.). The reference standard condition can refer to the expected state prior to any anthropogenic disturbance or at a specified historical point in time, or it can refer to the condition of the least disturbed sites within the survey area or wetland type (Stoddard and others, 2006). For the condition assessment, we used a reference standard adopted from Colorado Natural Heritage Program's Ecological Integrity Assessment, which sets a standard based on "deviation from the natural range of variability expressed in wetlands over the past ~200–300 years (prior to European settlement)" (Lemly and others, 2016). Although reference standard condition is ideally determined from field observations of undisturbed or minimally disturbed wetlands (i.e., reference standard sites), there can be too few undisturbed sites in some highly altered landscapes to determine the natural range of variability. Because of this, reference standards for the condition assessment were developed based on a combination of field observations from minimally disturbed wetlands, review of relevant literature, and evaluation of conditions described in rapid assessment protocols from other states. In contrast, we used the least disturbed condition as the reference standard when we compared attributes of least disturbed wetlands to other wetlands within each wetland class.

## Wetland Classification

We applied three classification systems to wetlands in our study. We used the Cowardin classification system to select wetlands for our survey sample frame and to conduct the landscape analysis, and we classified wetlands in the field using Cowardin, hydrogeomorphic (HGM), and the Utah wetland type classification.

The NWI classifies wetlands using the U.S. Fish and Wildlife Service's Cowardin classification system, which separates wetlands and deepwater habitat into three systems in Utah (riverine, lacustrine, and palustrine) that are further divided based on substrate material, predominant overstory life form, water regime, and other modifiers (Cowardin and others, 1979). This classification represents the only available spatial data for wetlands in Utah. Unfortunately, much of this spatial data is out-of-date and mapped using older technologies and lower resolution.

The HGM system classifies wetlands as one of seven types based on water source, hydrodynamics, and geomorphology (Brinson, 1993). For this study, wetlands were either classified as lacustrine fringe, riverine, slope, or depressional (four of the original HGM classes) or as one of three novel classes developed to improve description of highly managed wetlands around Great Salt Lake. *Impoundment release* wetlands receive horizontally spreading water when water is released from an upgradient impoundment, typically occur on mudflats around Great Salt Lake, and lack major channels. *Depressional impoundments* are wetlands that occur within artificial impoundments greater than 8 ha in size and less than 2 m deep and have primary water fluctuations that are vertical with rising and falling water levels due to steep impoundment sides. *Depressional impoundment fringe* wetlands occur on the edge of depressional impoundments and receive water that spreads and recedes horizontally with changing water levels.

Menuz and McCoy-Sulentic (2019) described six major wetland types known from the Central Basin, based on analysis of vegetation data from previous UGS surveys (Jones and others, 2014; Menuz and others, 2014, 2016; Menuz and Sempler, 2018; Menuz and McCoy-Sulentic, 2019) and Utah wetland data from partner organizations. Data from partner organizations came from Utah Division of Water Quality wetland surveys (Utah Division of Water Quality, 2016a, 2018) and unpublished data from the EPA's 2016 National Wetland Condition Assessment, the BLM's 2019 lentic AIM data, and research from a graduate student at Utah State University. Differentiation between wetland types was largely driven by plant community composition as well as factors related to water regime and salinity tolerance. This classification system has been named the "Utah wetland type" classification (hereafter "wetland type") and originally included forested-shrubland, emergent marsh (now "marsh"), submergent marsh (now "aquatic bed"), meadow, playa, and mudflat. Since the original classification, we separated meadows into saline meadow and fresh meadow and narrowed our definition of mudflats. We used the wetland type classification for the majority of our analyses.

## Project Objectives

### Objective 1: Obtain Baseline Data for Study Area

Our first objective was to obtain baseline data on wetlands in the Central Basin ecoregion, including estimates of the types, range of conditions, potential functions, and common stressors. These data can provide information for conservation and management planning and serve as a baseline for future studies. We used URAP to collect field data at more than 80 wetlands in the Central Basin and analyzed results for three strata—Great Salt Lake, West Desert, and Sevier Basin.

### Objective 2: Describe High Quality Wetland Condition

Our second objective was to identify least disturbed reference sites for each wetland type and describe least disturbed conditions. This information can be used to help set restoration or mitigation standards, better understand the conditions of wetlands that may be impacted and help guide qualitative wetland evaluations. We combined data from this study with data from previous UGS surveys in the Central Basin to select sites that were "least disturbed" and "most disturbed" based on stressor information recorded in the field. We then compared floristic metrics, water quality parameters, and URAP scores between least and most disturbed sites to identify attributes that differed between site types. Last, we summarized a variety of attributes for each wetland type and developed wetland type descriptions.

### Objective 3: Landscape Analysis

Our third objective was to conduct a GIS-based landscape analysis to describe and evaluate wetlands across the study area. The first component of the landscape analysis was using streamflow, lake elevation, and groundwater data and remotely sensed estimates of surface water to evaluate hydrologic changes over a longer time scale. The second component involved using NWI data to look at patterns of wetland ownership and local stress by wetland type and strata across the study area. These two components together help us to understand current wetland conditions in relation to how conditions have changed over time and to identify areas and wetland types most in need of restoration, protection, or creation.

## STUDY AREA

### Ecoregional and Geographic Setting

The Central Basin extends across western Utah, much of Nevada, and small parts of California, Idaho, and Oregon (U.S. Environmental Protection Agency, 2013). The ecoregion is internally drained and composed of a series of dry desert basins separated by northerly trending parallel mountain ranges. Precipitation and temperature vary with altitude, with mountain ranges experiencing cooler and wetter conditions, whereas valley bottoms experience hotter and drier conditions. Mean annual temperature across the study area is ~10°C, with precipitation ranging from 101 to 1113 mm, and a mean of 292 mm per year (30-yr mean; PRISM Climate Group, undated). Lower elevations tend to be dominated by shrubs and grass or are barren, and woodland, mountain brush, and scattered open forests are found at higher elevations. The highest concentration of wetlands in the ecoregion is found along the east shore of Great Salt Lake, where inputs from several perennial rivers and streams are heavily managed with an extensive network of canals and impoundments. Other wetlands in the ecoregion include spring complexes, areas of shallow groundwater, and wetlands along streams and lakes.

Wetland plant communities vary depending on water regime, management, and the availability and duration of fresh water. Bulrush (*Schoenoplectus* spp.), cattails (*Typha* spp.), common reed (*Phragmites australis*), and submerged aquatic vegetation (primarily *Stuckenia* spp.) are common in emergent marshes and artificial impoundments. Mountain rush (*Juncus arcticus* ssp. *littoralis*) and spikerushes (*Eleocharis* spp.) are common in seasonally flooded areas. Barren and sparsely vegetated playas, salt flats, and mudflats also occur throughout the area and have salt-tolerant plant species including iodinebush (*Allenrolfea occidentalis*), pickleweed (*Salicornia rubra*), and saltgrass (*Distichlis spicata*).

In Utah, six HUC6 watersheds are partially within the Central Basin. The study area for this project only includes two of these—Great Salt Lake and Escalante Desert-Sevier Lake. About two-thirds of the Escalante Desert-Sevier Lake and 90% of the Great Salt Lake HUC6 watershed is located within the Central Basin ecoregion. The study area is bounded by the Utah-Nevada border to the west, the Raft River and Grouse Creek Mountains to the northwest, the Utah-Idaho border to the north and several low mountain ranges in northern Washington County to the south (figure 1). The eastern boundary is created by the Lower Bear, Weber and Jordan watershed boundaries to the northeast and the edge of the Wasatch and Uinta Mountains ecoregion to the southeast.

In this study, the Great Salt Lake HUC6 is divided into two strata: Great Salt Lake, composed of the namesake lake and parts of the surrounding lakeshore, and West Desert for the remainder of the watershed (figure 1). The third stratum in the study is the part of the Escalante Desert-Sevier Lake HUC6 watershed that lies within the Central Basin. The West Desert is somewhat drier than the Sevier Basin, receiving a mean of 277 mm versus 310 mm in the Sevier Basin (30-year mean; PRISM Climate Group, undated). The Sevier Basin is located closer to the taller Wasatch Range and closer to the transition zone between the Basin and Range region and the Rocky Mountain region (Utah Division of Water Resources, 1999). Temperatures in both the West Desert and Sevier Basin are similar with a yearly mean of about 10°C.

The other HUC6 watersheds in the Central Basin in Utah include the Lower Bear, Jordan, Weber, and Lower Colorado-Lake Mead. The Lower Bear, Jordan, and Weber watersheds together contain the majority of Utah's population, are located along the east shore of and discharge to Great Salt Lake and were the focus of previous UGS studies (Menuz and others, 2014, 2016; Menuz and Sempler, 2018; Menuz and McCoy-Sulentic, 2019). The small part of the Central Basin ecoregion found in the Lower Colorado-Lake Mead HUC6 drains to the Virgin River and then ultimately the Colorado River.

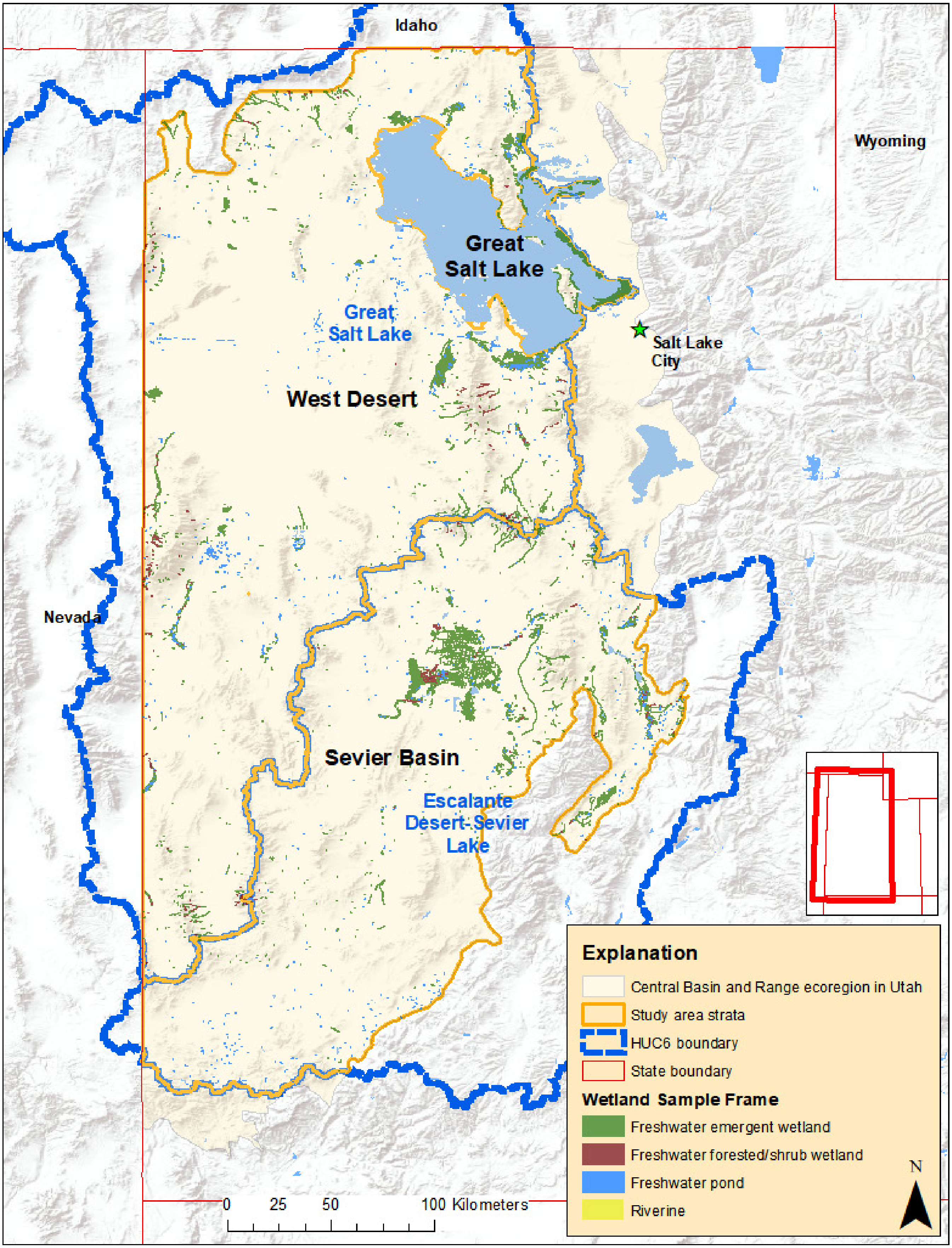


***Figure 1.*** *Overview of the Central Basin study area. Strata names are labeled in black text in the center of each stratum polygon and HUC6 watersheds are labeled in blue text.*

# Hydrology

## Great Salt Lake Hydrology

Great Salt Lake is a high-salinity terminal lake located in northern Utah on the eastern edge of the Central Basin ecoregion. Large lake surface area and shallow bathymetric relief create a highly transitory shoreline along present-day Great Salt Lake. In a typical year, the shoreline can migrate up to 800 m in some locations, and it has been estimated that with a change of 0.3 m in the lake's water level, approximately 178 $km^2$ of ground surface is inundated or exposed lake-wide (estimated as 1 foot and 44,000 acres by Aldrich and Paul [2002]).

The hydrology of Great Salt Lake is largely dependent on water supplied by the Bear, Weber, and Jordan Rivers that emerge from the Wasatch Range on the east side of the lake; the rivers supply about 40.5%, 18%, and 12% of the inflow, respectively (Utah Division of Water Resources, 2001). Direct precipitation contributes about 28% of the inflow to the lake, and the West Desert basin contributes approximately 1.5% of the annual inflow, mostly via subsurface flow. Historically, the Bear, Jordan, and Weber Rivers ended in deltas along the eastern shore of Great Salt Lake, creating extensive complexes of wetlands. Upon settlement of Salt Lake Valley and surrounding areas, agricultural development and associated water use beginning in the mid- to late 1800s (Jackson, 1978) and subsequent groundwater pumping led to drastic reductions in the amount of water reaching Great Salt Lake and dewatering of associated wetlands. Net river inflows to the lake have declined by 39% over the past 150 years due to consumptive water use, resulting in reductions in lake water levels of 11 feet and in lake volume of 48% compared to an unaltered state (Wurtsbaugh and others, 2016).

Impoundments for wetland maintenance and waterfowl habitat conservation were built along the lake beginning in the early 1900s, and currently very little surface flow enters Great Salt Lake without first passing through ditches or impoundments. While wetland hydrology in the region is still influenced by natural processes including spring run-off in headwater streams, groundwater discharge from springs, and natural climate fluctuations, the timing, duration, and amount of water reaching Great Salt Lake wetlands are strongly influenced by upstream and adjacent impoundments, agricultural withdrawals and return flows, urban runoff, and management decisions related to the movement of water through impoundment systems.

The Utah Division of Water Quality (UDWQ) divides the lake into five water quality assessment units, including Gunnison Bay, Gilbert Bay, Farmington Bay, Bear River Bay, and transitional waters (Utah Division of Water Quality, 2020). However, water quality standards have not been developed for the lake with the exception of a selenium standard for Gilbert Bay, which had no evidence of impairment in the latest UDWQ assessment report. The unique characteristics of the lake, including its hypersalinity, lack of baseline water-quality data, and presence of unique organisms, make development of water quality standards difficult (Utah Division of Water Quality, 2021). The three major rivers contributing to the Great Salt Lake (Bear, Weber, Jordan) are all impaired.

## West Desert Hydrology

The hydrology of the West Desert consists largely of groundwater resources with some perennial streams in higher elevation mountain canyons that generally disappear into the alluvial and colluvial fans as they reach valley bottoms. Although some surface water flows from the West Desert to Great Salt Lake, much of the area is composed of several internally drained basins. The U.S. Geological Survey (USGS) currently maintains only five streamflow gaging stations throughout the area including Vernon Creek, Faust Creek, Clover Creek, South Willow Creek, and Dunn Creek, which are all smaller streams with average annual flow less than 5,000 acre-feet (Utah Division of Water Resources, 2001). Blue Creek near Howell in Box Elder County is one of the rare examples of a perennial stream in a valley bottom setting and flows toward but does not reach the Great Salt Lake. Vegetated wetlands represent less than one percent of the West Desert (table 1) and are largely supported by groundwater. Much of the wetland area is located around a number of large spring complexes, including areas on the northern side of Great Salt Lake around Gunnison Bay and the east side of the Promontory Mountains, on the southern side of Great Salt Lake in northern Tooele and Skull Valleys, near the Nevada-Utah border at Blue Lake Wildlife Management Area and in areas of Snake Valley, and at Fish Springs Wildlife Refuge near the center of the study area. These spring complexes are generally characterized by relatively large discharge, low variability of discharge, and temperatures of 20°C or higher (Utah Division of Water Resources, 2001).

The West Desert is sparsely populated and pressure on water supply is lower than in other parts of Utah. Agriculture accounts for the largest amount of water use and relies on a combination of usually intermittent surface water flow, water storage in small reservoirs, and groundwater supplies (Utah Division of Water Resources, 2001). All the municipalities in the West Desert

*Table 1. Characteristics of study area strata, including extent and abundance of wetlands in the sample frame and time period of wetland mapping (U.S. Fish and Wildlife Service, 2019), land ownership (SITLA, BLM, and partners, undated), and land cover (Multi-Resolution Land Characteristics Consortium, 2019).*

| Stratum | | Great Salt Lake | West Desert | Sevier Basin |
|---|---|---|---|---|
| Area ($km^2$) (% of total in study area) | | 4527.1 (6.2) | 40,069.4 (55.2) | 27,927.6 (38.5) |
| Number of wetlands (% of total in study area) | | 595 (2.9) | 10,559 (52.2) | 9087 (44.9) |
| Wetland area ($km^2$) (% of total in study area) | | 92.1 (17.0) | 257.8 (47.6) | 191.4 (35.4) |
| Percent outdated wetland mapping | | 35.0% | 89.4% | 99.4% |
| Percent wetland mapping 2000–2009 | | 32.6% | 6.7% | 0.0% |
| Percent wetland mapping 2010–2019 | | 32.4% | 3.9% | 0.6% |
| Land ownership, by percentage | Federal | 0.6% | 73.5% | 64.8% |
| | Private | 0.5% | 17.7% | 26.2% |
| | State | 98.9% | 8.1% | 9.0% |
| | Tribal | 0.0% | 0.7% | <0.1% |
| Land cover, by percentage | Developed | 0.0% | 0.7% | 1.6% |
| | Agricultural | 0.0% | 1.6% | 4.6% |
| | Forested | 0.0% | 5.9% | 13.8% |
| | Shrubland | 1.0% | 55.9% | 62.3% |
| | Grassland/herbaceous | 4.6% | 8.9% | 13.7% |
| | Barren | 33.3% | 26.1% | 3.2% |
| | Open water | 59.5% | 0.3% | 0.1% |
| | Wetlands | 1.5% | 0.6% | 0.6% |

rely on groundwater for water supply from wells and spring flow. The USGS identifies two areas of significant groundwater development in the West Desert—Curlew Valley and Tooele Valley—and most measured wells in both valleys show long-term declining water-level trends (Smith and others, 2019). Snake Valley became the focus of concern in recent years for residents and wildlife managers due to a proposal to withdraw water from the valley and adjacent valleys in Nevada to deliver to Las Vegas. Although that plan appears indefinitely delayed, local applications for groundwater pumping continue and some areas of the valley show declining water levels (Goodwin and others, 2021).

Most of the West Desert is not assessed for water quality standards by the UDWQ due to the lack of perennial surface water, and most of the areas that are assessed have insufficient data to determine whether waters are impaired (Utah Division of Water Quality, 2021). Four UDWQ assessment units for streams are impaired, including Vernon Creek and Faust Creek near Vernon in Tooele County, which are impaired for pH and temperature, respectively; Blue Creek, impaired for pH, boron, total dissolved solids, selenium, and *E. coli*; and Lake Creek in the southern part of Snake Valley, impaired for macroinvertebrates. Three reservoirs in the stratum, all in Tooele Valley, are also impaired. Groundwater tends to be fresher near recharge areas along the margins of mountain ranges and becomes more saline toward valley bottoms (Utah Division of Water Resources, 2001).

## Sevier Basin Hydrology

The Sevier Basin stratum can be divided into three major hydrologic units—the Sevier River drainage, which accounts for about 53.6% of the area in the stratum; Beaver River drainage (25.6%); and the internally drained Escalante Desert (20.8%). The Sevier River originates outside of the Central Basin ecoregion on the Markagunt and Paunsaugunt Plateaus, flows north and enters our study area near the town of Joseph in Sevier County, changes direction to head southwest east of the town of Leamington, and then eventually enters Sevier Lake, a typically dry terminal basin lake. The largest tributaries to the Sevier River are the San Pitch River, which enters our study area at the south end of Sanpete Valley and joins the Sevier River near Gunnison in Sanpete County, and the Salina River, which enters our study area and joins the Sevier River near the town of Salina in Sevier County. Three major reservoirs, all within our study area, dam the Sevier River, including Yuba Reservoir in Juab County and DMAD and Gunnison Bend Reservoirs in Millard County. In most years, all of the river water is stored in reservoirs or diverted from the Sevier River before reaching Sevier Lake, and new appropriations of surface water for the area were closed in 1946 (Utah Division of Water Rights, 2011).

Four segments of the Sevier River are impaired or have had TMDLs developed to address impairments, including the segment in Sevier Valley and segments extending from Yuba Reservoir to Gunnison Bend Reservoir (Utah Division of Water Quality, 2021). Impairments include total phosphorus, sediment, total dissolved solids, and macroinvertebrates. Several tributaries to the Sevier River in the study area, including Salina Creek, Lost Creek, Peterson Creek, Chicken Creek, and the San Pitch River, are also all impaired or have TMDLs for total dissolved solids and some are also impaired for copper, boron, or temperature. The only impaired reservoir in this part of the Sevier Basin is Ninemile Reservoir near the San Pitch River, impaired for temperature, dissolved oxygen, pH, and total phosphorus.

The Beaver River originates in the Tushar Mountains, enters the study area near the town of Beaver, is held in the Minersville Reservoir, and is shortly thereafter diverted completely for irrigation and other uses. The river may have historically reached the Sevier River on an annual basis but was already labeled as “dry bed” in an 1871 survey map of the area, only 16 years after the town of Beaver was settled (Kelsey and Kelsey, 2020). The Beaver River above Minersville Reservoir is impaired for *E. coli*, macroinvertebrates, and aluminum, and an approved TMDL has been prepared for dissolved oxygen and temperature impairments. Minersville Reservoir has an approved TMDL for dissolved oxygen, total phosphorus, and pH impairments and is also impaired for temperature.

The Escalante Desert region of the Sevier Basin is an internally drained basin with perennial surface water limited to a few streams that flow off the ranges to the east and south before becoming intermittent or ephemeral. UDWQ assesses water quality for these streams, though the assessment units are primarily in the headwater regions of each stream outside of the Central Basin study area. Pinto Creek, in the southern section of the Escalante Desert region, is impaired for *E. coli*, aluminum, dissolved oxygen, and temperature, and Coal Creek, which just barely enters the study area at Cedar City, is impaired for temperature. Two small reservoirs, Upper Enterprise and Newcastle, on the southern edge of the region are also impaired for a variety of contaminants, and the latter has a TMDL developed for dissolved oxygen and total phosphorus.

The USGS identifies seven areas of significant groundwater development in the Sevier Basin, including Central Sevier Valley and Sevier Desert along the Sevier River, Pahvant Valley south of Delta, Parowan Valley and Cedar Valley (Iron County) in the southeastern part of the stratum, and both the Beryl-Enterprise and Milford area of Escalante Valley (Smith and others, 2019). Well water levels in each of these areas have generally declined since the 1950s due to the long-term effects of groundwater withdrawals, with some recovery during periods of high precipitation such as the early 1980s. The Sevier Basin is predominantly closed to new groundwater development, except for the west-central region west of Delta around Sevier Lake, which is restricted or open.

## Wildlife

The large wetland complexes located in the Central Basin represent a very small percentage of the land and thus have a disproportionate importance for providing water and habitat for wildlife. The National Audubon Society has designated Bear River Bay, Farmington Bay, Ogden Bay, Gunnison Bay, and Gilbert Bay of Great Salt Lake as globally important bird areas, and Fish Springs NWR and Clear Lake Waterfowl Management Area (WMA) as state level priority bird areas (Audubon, undated). Great Salt Lake supports large populations of breeding birds and provides habitat for millions of birds each year as they migrate between northern breeding grounds and winter locations. Although much of the marsh, wet meadow, and aquatic bed habitat is on the eastern shore of Great Salt Lake just outside the study area, the study area itself contains extensive areas of open water, mudflat, and playa, as well as some areas of marsh and wet meadow. Great Salt Lake’s aquatic habitat supports the world’s largest staging concentration of Snowy Plover and Wilson’s Phalarope, the world’s largest breeding population of White-Faced Ibis, one of the largest staging populations of California Gull and Eared Grebe in North America, and one of the three largest breeding colonies of American White Pelican in the world (Paul and Manning, 2002). Both Clear Lake WMA, the largest WMA in Utah not in close proximity to Great Salt Lake, and Fish Springs NWR, the only significant wetland habitat within a 50-mile radius of its location, provide important habitat for migrating and breeding birds as well, albeit in lower quantities than Great Salt Lake (Audubon, undated).

Springs in the Central Basin provide habitat for rare mollusk species, including many that are known from only one or a few wetland complexes. Fourteen mollusk species known from the study area are listed as SGCN, including five known from the Sevier Basin, seven from the West Desert, and two known from both strata (Utah Wildlife Action Plan Joint Team, 2015). All but one of these species are snails, including eight in the genus *Pyrgulopsis* and one each in the genera of *Physa, Physella, Planorbella, Tryonia,* and *Stagnicola*. The California Floater (*Anodonta califorlniensis*) is the only mussel SGCN known from the study area.

Central Basin wetlands provide crucial habitat for at least two other SGCN species: least chub and Columbia spotted frog. Least chub is a small minnow endemic to Utah that historically was found in numerous locations along the Wasatch Front, Beaver River, Sevier River, and in spring-fed pools of Utah and Snake Valleys (Utah Division of Wildlife Resources, 2005). Habitat loss as well as competition with and predation by non-native species have caused population declines and severe range contraction with current distribution limited to six wild populations (Utah Division of Wildlife Resources, 2005) and numerous refuge populations across the state (Least Chub Conservation Team, 2014). Five of the six populations are in the study area, including three in Snake Valley in the West Desert and one each in Mills Valley and Clear Lake in the Sevier Basin (Utah Division of Wildlife Resources, 2005). Columbia spotted frogs are highly aquatic and are broadly distributed across western North America but known in Utah from a few occurrences in streams and springs along the Wasatch Front and in isolated spring complexes in the study area, including in Snake, Tule, and Ibapah Valleys in the West Desert (Utah Division of Wildlife Resources, 2006).

## Land Ownership and Land Use

Land ownership and land cover in the Great Salt Lake stratum differ substantially from the other two strata. The Utah Division of Forestry, Fire and State Lands manages the lakebed of Great Salt Lake, which accounts for 96.6% of the area, and Utah State Parks manages another 2.2% of the land in the stratum (table 1). Small parts of several state-managed WMAs also overlap the Great Salt Lake stratum. About 93% of the land in the Great Salt Lake stratum is mapped as open water or barren by the National Land Cover Dataset; barren land is mainly exposed shoreline along the lake (Multi-Resolution Land Characteristics Consortium, 2019). Less than 8% of the stratum is vegetated, and development and agriculture are absent, though impounded evaporation ponds used to extract minerals such as salt and magnesium compose about 1.3% of the area and impounded wetland associated with WMAs compose 0.2%. Mineral extraction around Great Salt Lake was estimated to contribute $1,130.8 billion in economic benefit to the State of Utah as of 2012 (Bioeconomics, 2012). Other important economic uses of Great Salt Lake include brine shrimp fishing and recreation including hunting, bird watching, boating, and general recreation. Although land within the Great Salt Lake stratum is not itself threatened by development or agriculture, it is very sensitive to changes in land use in the surrounding area, including changes that alter water inputs to the lake as well as encroaching development adjacent to the lake that may disturb wildlife and open up more of the lake to anthropogenic disturbances.

Across the other two strata, about 70% of the land is federally managed, 21% private, and 8% state (table 1). Major public land managers in the Sevier Basin and West Desert include the Bureau of Land Management (BLM, 55.7%), Department of Defense (10.6%), State of Utah School and Institutional Trust Lands Administration (7.3%), and the U.S. Forest Service (3.4%). Two large Department of Defense installations, Dugway Proving Grounds and Utah Test and Training Range, are located in the West Desert. Several WMAs that protect important wetland areas are also in the project area. In the Sevier Basin, the Utah Division of Wildlife Resources operates the Clear Lake, Topaz Slough, and Mills Meadow WMAs and in the West Desert, the Utah Division of Wildlife Resources operates Timpie Springs, Blue Lake, and Locomotive Springs WMAs and the U.S. Fish and Wildlife Service operates Fish Springs NWR. A small part of Bear River Migratory Bird Refuge, also operated by the U.S. Fish and Wildlife Service, overlaps the West Desert stratum as well.

The majority of land cover in the Sevier Basin and West Desert is shrubland (table 1). Aquatic features make up a very small portion of the Sevier Basin and West Desert—about 0.2% is mapped as open water and 0.6% as wetlands. An additional 17% is mapped as barren land; some of this area may be high salinity playas that currently or historically had high groundwater. Development accounts for 1% and agriculture just under 2% of the land cover; both land uses are more common in the Sevier Basin than in the West Desert.

The West Desert is sparsely populated. The only large concentration of people in the region is in Tooele Valley, which is home to its two largest municipalities, Tooele and Grantsville. Tooele County is projected to increase its population from an estimated 74,000 in 2020 to 93,258 by 2030 and to almost 130,000 by 2060 (Kem C. Gardner Policy Institute, undated); most of that population growth will be in Tooele Valley. Agricultural jobs are projected to decline while construction, manufacturing, utilities, and government jobs increase (Utah Division of Water Resources, 2001). Major employment in the area also includes salt, mineral, and brine industries located near Great Salt Lake. Agriculture is a primary economic activity in much of the rest of the West Desert, where much of the irrigated land is used as pasture or to grow alfalfa for cattle feed (Utah Division of Water Resources, 2001).

In the Sevier Basin, the largest municipality is Cedar City; all other towns have populations below 10,000. Other population centers include the Sevier Valley, Delta and vicinity, and towns including Beaver, Fillmore, and Parowan on the eastern edge of the study area along the base of the Wasatch Range. Population in Iron County, home to Cedar City, Enoch, and Parowan, is expected to increase by 16% within 10 years and 55% in 30 years (Kem C. Gardner Policy Institute, undated). Growth in the other three counties that hold the majority of the remaining population in the Sevier Basin—Beaver, Millard, and Sevier—are projected to see between 30% and 38% growth through 2060. Agriculture is the primary industry in the majority of the Sevier Basin and beef production is a major agricultural output, with irrigated agriculture mostly used to support beef production (Utah Division of Water Resources, 1999).

# FIELD STUDY DESIGN AND SURVEY METHODS

## Site Selection

### Target Population and Sample Frame

The target population for the field study was wetlands that were at least 0.1 ha in size and with surface water less than 1 m deep. The target population included all vegetated wetlands and unvegetated wetlands less than 8 ha in area. Wetlands are areas that receive periodic substrate saturation or inundation, which often results in distinct plant communities and soils due to the physiological constraints imposed by anoxic soil conditions (Federal Geographic Data Committee, 2013). Three characteristics are required to identify wetlands in a regulatory setting: wetland hydrology indicators, hydric soil indicators, and a predominance of hydrophytic plant species (Cowardin and others, 1979; U.S. Army Corps of Engineers, 2008). We surveyed sites when two of the three indicators were present. We used these broader criteria for several reasons. First, we were interested in surveying wetlands that may be flooded less frequently than required under the Army Corps definition and yet may still provide important functions and services. Second, Army Corps indicators were developed for delineating wetland edges whereas we frequently sampled in the middle of wetlands where indicators may not always be present. Third, most of the study area was in moderate to severe drought during the survey season, which made it less likely that we would observe hydrology indicators.

The U.S. Fish and Wildlife Service's NWI program maps wetlands and deepwater habitat throughout the United States using the Cowardin classification system. We downloaded NWI data for the state of Utah from the online NWI mapper (U.S. Fish and Wildlife Service, 2019). Most of the wetland mapping for the study area was out-of-date, particularly in the West Desert and Sevier Basin strata, where at least 72% of the area in each stratum was mapped using imagery from 1983 and less than 11% of the area was mapped using imagery from 2000 or later. About equal portions of the Great Salt Lake stratum were mapped using imagery from 1981, 2005, and 2014. The eastern shore of Great Salt Lake, where the majority of wetlands are concentrated, was mapped using 2014 imagery.

We removed deepwater areas from the NWI data by removing all polygons mapped as lacustrine limnetic (L1) and kept polygons mapped as lacustrine littoral (L2) only if they were mapped as the aquatic bed class. In the Cowardin classification system, riverine systems include wetlands and deepwater habitat in channels, unless the wetlands are dominated by persistent vegetation or mosses and lichens (Federal Geographic Data Committee, 2013). We wanted to include oxbows and backwaters in our sample frame, but not perennially flowing streams or washes that only occasionally contained water. We eliminated all riverine polygons from the sample frame that were in the unconsolidated bottom or streambed classes. We kept riverine unconsolidated shore features in the sample frame because these were often on the edges of streams in areas that receive frequent overbank flooding. Our final sample frame included all features mapped as lacustrine littoral aquatic bed, riverine unconsolidated shore, and palustrine. NWI data were clipped to the edge of the study area and intersected with watershed boundaries to assign them to strata.

### Strata and Selection of Study Sites

We stratified site selection by the two HUC6 watersheds in the study area, the Escalante Desert-Sevier Lake and Great Salt Lake. We used the spsurvey package (Kincaid and Olsen, 2019) in R 4.0.3 (R Core Development Team, 2020) to select survey sites using a Generalized Random Tessellation Stratified (GRTS) survey design. GRTS is a statistical method to select random sample locations that are spatially balanced and ordered so that all consecutive sets of sample points are themselves spatially balanced (Stevens and Olsen, 2004). We selected sample points instead of wetland polygons because URAP evaluates fixed area plots rather than whole wetlands. We used a stratified equal weight selection design, meaning that all wetland area within each stratum had equal probability of selection. We selected 40 sample points and 100 oversample points in each stratum. Oversample points were used to replace the primary sample points that could not be surveyed due to lack of permission from landowners or absence of target wetland.

Manually selected sites supplemented our randomly selected sites to serve as examples of high-quality sites. We asked for recommendations of minimally impacted wetlands from native aquatic biologists and other resource specialists working in the region, including individuals working for the Utah Division of Wildlife Resources, BLM, Natural Resources Conservation Service, and UDWQ. We also reviewed sites identified as being in good or excellent condition by Hoven (2010). In some cases, resource specialists recommended general regions or large wetland complexes rather than specific sites. We narrowed down our list of subjectively selected sites to those that represented a diversity of types, were easy to access, and were not adjacent to randomly selected sites. We also eliminated some sites in the field if they appeared disturbed when we went to survey them. We ended up surveying six subjectively selected sites, five based on recommendations from resource specialists or identified in Hoven (2010) and one selected in the field after surveying a nearby randomly selected site.

## Site Office Evaluation and Landowner Permission

Sample points were evaluated in the office to determine whether they were located near target wetlands based on true color and infrared aerial imagery, digital elevation data, land use and irrigation data (Utah Division of Water Resources, 2019), and hydric soils data. We conducted URAP surveys at 18 sites in 2019, including the reference sites described above, to better understand the range of wetlands and conditions in the study area and better prepare for the larger survey effort in 2020. We also conducted brief early season field visits in May 2020 to evaluate questionable sites that were mapped as wetland but did not appear to be wetlands in aerial imagery. Survey points were moved up to 100 m from the original location to account for spatial inaccuracies in the NWI data. We contacted landowners through phone calls and a mailer to request permission to survey sites. We rejected all sample points where access was denied or where we were unable to obtain permission.

We conducted an office evaluation for each site before field surveys to gather useful landscape data to support field efforts. We examined elevation, land use, and hydrography data, including watershed boundaries and flowlines, to assess likely sources of site hydrology and visible hydrologic stressors, such as dams, water control structures, and irrigation return flows. We determined whether there were stressors with potential to degrade water quality in the contributing basin, including development, agriculture, point source dischargers, oil and gas wells, and mines. We also determined whether contributing streams or lakes were listed as impaired or have a TMDL (Utah Division of Water Quality, 2016b). We filled out the hydrology component of the stressor checklist (described in Field Methods) during the office evaluation and then updated the checklist values as needed during the field survey. We also obtained information to inform field evaluation of the functional metrics, including information about water quality impairments, toxic algal blooms, and history of flooding near the site.

## Field Methods

### Establishment of Assessment Area

We used a combination of best professional judgement and easily observable hydrologic, soil, and vegetation indicators to determine whether sites were within the target population, loosely following standards from the U.S. Army Corps of Engineers wetland delineation guide for the Arid West Region (U.S. Army Corps of Engineers, 2008). Wetland determination was conducted rapidly using traits such as redoximorphic features or gleying in augured soil samples rather than full soil profiles, as well as readily apparent hydrology indicators. We assessed sites for the presence of hydrophytic vegetation if plant species were known and otherwise only keyed out dominant plant species when site status was uncertain. Wetland determinations done for this project should not be considered U.S. Army Corps delineations due to the limited time spent on each determination and the broader definition of wetland used in this study.

If a site contained a target wetland, we next set up an assessment area (AA). AAs were 40-m-radius circular survey plots centered on the sample point where possible or rectangular or free form plots between 0.1 and 0.5 ha and at least 10 m wide when necessary to avoid upland inclusions or areas with water greater than 1 m deep; no more than 10% of the AA was permitted to be non-target. AAs were also shifted to avoid features that would divide the hydrology of the wetland, such as dikes and bermed ditches. AAs were generally placed in a single wetland type.

### Wetland Soils and Water Quality Samples

Surveyors used a handheld auger to dig at least one soil pit to a depth no less than 60 cm at a representative location within the dominant plant community at each site. An additional pit was sometimes dug if no hydric soil indicators were found in the first pit or if multiple plant communities were co-dominant. For each soil layer, surveyors recorded the layer depth, color of the matrix, presence and color of any dominant and secondary redox features (based on a Munsell Soil Color Chart), soil texture, and percent coarse (>2 mm) material. Hydric soil indicators were recorded based on the U.S. Army Corps Arid West Region wetland delineation guide (U.S. Army Corps of Engineers, 2008). Settling time for soil pits varied depending on total AA survey time but was generally between 50 and 120 minutes. If water was evident after the settling period, we recorded the depth to free water. We collected soil electroconductivity (EC) data from an approximately 15-cm-deep soil sample adjacent to the soil pit (appendix C). We homogenized the sample by hand, removing rocks and roots as needed. We then combined 50 mL of the soil sample with 250 mL distilled water and mixed the sample together. We measured EC using a handheld Hach Pocket Pro meter after allowing the sediment to settle out of the sample.

Water chemistry data were also collected with a handheld meter when surface water was present at sites. We measured pH, EC, and temperature of water samples from groundwater in soil pits, channels and pools, at points of groundwater discharge, and at the surface of flooded wetlands. We collected water samples for laboratory analysis at sites with surface water; samples were generally not taken when water depth was very low (<10 cm) due to the high probability of contamination from soil sediments. Water sample containers for general chemistry, total metals, and total non-filtered nutrients contained necessary preservatives added by the Utah Public Health Laboratory Chemical and Environmental Services Laboratory (Utah Public Health Laboratory). After containers were filled, they were stored on ice until transferred to a refrigerator and then transferred to the Utah Public Health Laboratory within five days of collection. Samples were analyzed at the Utah Public Health Laboratory following the procedures outlined in the Client Services Manual (Utah Public Health Laboratory, 2013).

## Rapid Assessment Metrics and Stressor Data

We collected wetland condition data using a series of predominantly qualitative metrics (appendices A and B). Each metric is composed of a series of potential states, ranked from A through D, to denote wetland condition ranging from pristine or reference condition to severely altered wetlands that may have little conservation value and be extremely difficult to restore. Metrics are divided into five categories: landscape context, hydrologic condition, physical structure, vegetation structure, and plant species composition (table 2). Plant species composition metrics were calculated in the office using plant community data collected in the field. Observers used office evaluation data, maps, and information obtained from walking around AAs and the surrounding area to score the remaining metrics. Photos and notes were frequently taken to better capture conditions, especially when sites were difficult to evaluate.

***Table 2.*** *Condition metrics evaluated by the Utah Rapid Assessment Procedure, listed under metric categories.*

| Metric | Description |
|---|---|
| **Landscape Context** | |
| Percent Intact Landscape | Percentage of 500 m buffer surrounding AA that is directly connected to AA and composed of natural or semi-natural (buffer) land cover |
| Percent Buffer[1] | Percentage of AA edge composed of buffer land cover |
| Buffer Width[1] | Mean width of buffer land cover (evaluated up to 100 m in width) |
| Buffer Condition: Soil and Substrate[1] | Soil and substrate condition within buffer (e.g., presence of unnatural bare patches, ruts, etc.) |
| Buffer Condition: Vegetation[1] | Vegetation condition within buffer (i.e., nativity of species in buffer) |
| **Hydrologic Condition** | |
| Hydroperiod[2] | Naturalness of wetland inundation frequency and duration |
| Turbidity and Pollutants[3] | Visual evidence of degraded water quality, based on evidence of turbidity or pollutants |
| Algae Growth[3] | Evidence of potentially problematic algal blooms within AA (evaluated both in water and in areas with large patches of dried algae) |
| Water Quality | Evidence of water quality stressors reaching AA or within AA |
| Connectivity | Hydrologic connection between AA edge and surrounding landscape |
| **Physical Structure** | |
| Substrate and Soil Disturbance | Soil disturbance within AA |
| **Vegetation Structure** | |
| Horizontal Interspersion[4] | Number and degree of interspersion of distinctive vegetation patches within AA |
| Litter Accumulation[5] | Naturalness of herbaceous litter accumulation within AA |
| Woody Debris[5, 6] | Naturalness of woody debris within AA |
| Woody Species Regeneration[5, 6] | Naturalness of woody species regeneration within AA |
| **Plant Species Composition** | |
| Relative Native Cover | Relative cover of native species (native species cover / total cover) |
| Absolute Noxious Cover | Absolute cover of noxious weeds |

[1]Buffer metrics are combined into an overall buffer metric.
[2]Evaluated with respect to similar wetlands within hydrogeomorphic class.
[3]Only evaluated when water or large patches of dry algae were present at sites.
[4]Excluded from scoring for shallow water, aquatic bed, and playa wetland types.
[5]Evaluted with respect to similar wetlands within wetland type.
[6]Only evaluated when woody debris and woody species are expected at sites.

Surveyors recorded data on stressors observed in the field. Stressors were grouped into four categories of impact: landscape stressors within 100 m surrounding the AA, stressors to vegetation within the plot, stressors to soil and substrate within the plot, and stressors to hydrology (appendix B). Stressors to hydrology were initially evaluated during the office evaluation since many stressors to site hydrology originated at the landscape scale, but then ratings were updated in the field as needed based on conditions found at the site. For each stressor, we recorded the extent of the evaluated area where the stressor was present as one of four quantitative cover classes, and the degree of severity as one of four qualitative severity classes to define the degree of degradation. Severity classes for many stressors were pre-assigned based on typical severity levels though surveyors were not limited to these values. The four extent categories (labeled as "scope" in field forms) were: 1 = small – affects small portion (1–10% of AA or landscape); 2 = restricted – affects some (11–30%) of AA or landscape; 3 = large – affects much (31–70%) of AA or landscape; 4 = pervasive – affects all or most (71–100%) of AA or landscape. The four severity categories were 1 = slight – likely to slightly degrade/reduce; 2 = moderate – likely to moderately degrade/reduce; 3 = serious – likely to seriously degrade/reduce; 4 = extreme – likely to extremely degrade/destroy or eliminate. The stressor data collection method is adapted from Colorado Natural Heritage Program's Ecological Integrity Assessment (Lemly and others, 2016, 2017).

## Plant Community and Ground Cover Data

We recorded all plant species within the AA after searching the area using a progressive timed meander method adapted from the Minnesota Pollution Control Agency's Rapid Floristic Quality Assessment (Minnesota Pollution Control Agency, 2014). In this method, a base time of 30 minutes is set for each site, with 20 minutes added for each additional community. Communities were identified as distinct groupings of species having similar physiognomy (e.g., wet meadow or shrub complex). If three or more species were found in the last 10 minutes of the survey, an additional 10 minutes were added. Additional 10-minute increments were added as needed until less than three new species were encountered in the final 10 minutes. For each species found, we recorded predominant height class, percent cover within the AA, and phenology. We also collected data on the percent cover of ground cover features within the AA including bare ground, litter, water, bryophytes, lichens, algae, and various classes of woody debris. Plant species not identified in the field were pressed in newspaper, brought to the office, and dried in a drying oven at approximately 38°C for at least 24 hours. We used a dissecting microscope, standard set of plant dissection tools, and several plant treatments to aid with identification, including *A Utah Flora* (Welsh and others, 2003), all volumes of the *Intermountain Flora* series (see introductory volume, Cronquist and others, 1972), *Grasses of the Intermountain West* (Anderton and Barkworth, 2000), *Field Guide to Intermountain Sedges* (Hurd and others, 1998), and *Flora of North America* (http://floranorthamerica.org). We used species' scientific names as listed in the U.S. Department of Agriculture (USDA) Plants Database (http://plants.usda.gov) to reference plants throughout this report.

## Wetland Function

We collected data on wetland potential for water quality improvement and hydrologic functions (flood and erosion reduction) using Washington State's wetland rating system (Hruby, 2014). We used the Washington State protocol to collect information on potential for water quality improvement in the Bear River watershed (Menuz and McCoy-Sulentic, 2019) and evaluated several methods for evaluating hydrologic functions during the first season of field work for this project (appendix D). Based on those results, we decided to use the Washington State wetland rating system to evaluate both water quality and hydrologic functions with a few minor modifications. The wetland rating system has separate metrics for four different HGM classes of wetland—depressional, riverine, lacustrine fringe, and slope. Depressional, depressional impoundment, depressional impoundment fringe, and impoundment release wetlands were all usually considered depressional for the sake of the functional assessment, except in a few cases when they were considered slope. Indicators are grouped into three categories for each function: site potential to provide the function, landscape potential to support the function, and societal value. We made several modifications to the protocol and field form to adapt the protocol for use in Utah based on results of the protocol evaluation (appendix D). First, in the original protocol, the societal value is typically assessed based on regional flood plans or other documents which generally do not exist for much of the study area. In lieu of a flood plan, we conducted an internet search for flood issues in towns and regions adjacent to or downstream from survey sites. Second, we added clarifying text to some of the metrics to make it easier for observers to rate sites consistently. In general, this clarifying text was taken from the field manual for the Washington State protocol. Last, we asked surveyors to subjectively rate sites with an overall score of "low," "medium," or "high" for each function and record their reasoning for either agreeing or disagreeing with the rating provided by the method. These subjective ratings were used to calibrate a final scoring method for assigning scores to the water quality and hydrologic functional ratings.

We collected amphibian habitat data for Columbia spotted frog using several metrics developed by the UGS in 2015 (Menuz and Sempler, 2018). These metrics have a similar structure to the condition metrics and include types of breeding waterbodies present, waterbody substrate, vegetation growing in waterbody, presence of north shore, overwintering waterbodies, waterbody slope and depth, livestock impact, distance to impervious surface, and evidence of mining.

# DATA SUMMARIZATION AND ANALYSIS

## Weight Adjustment, Population Estimation, and Data Summaries

Sites were assigned a weight when they were originally selected by the R package spsurvey proportional to the amount of area represented by the site relative to the total wetland area in the study area. For this project, sites in the Great Salt Lake HUC6 were assigned a higher weight than sites in the Escalante Desert-Sevier River HUC6 because the Great Salt Lake stratum has more total mapped target wetland area. Weights allow for accurate estimation within a stratum, where all weights are the same, and across the whole study area, where weights differ. We adjusted the assigned weights based on the total number of sites evaluated in each stratum by dividing the total stratum area by the number of sites evaluated in the stratum, including surveyed sites, non-target sites, and sites where access was denied. Site evaluation did not deviate from the original sample order so additional adjustments to weights were not necessary. Though we analyzed data from the Great Salt Lake HUC8 separately from data from the rest of the Great Salt Lake HUC6, we did not need to additionally adjust weights because all sites within each unit had equal chance of selection. We used cat.analysis and cont.analysis in the spsurvey package in R to estimate parameters for categorical and continuous variables. We used boxplots to compare overall URAP condition, URAP condition categories, and selected vegetation metrics among the three strata and used analysis of variance (ANOVA) and Tukeys' HSD, or Kruskal-Wallis rank sum tests and Wilcoxon pairwise tests when data did not meet assumptions of equal variance or normal distribution, to test for significant differences among strata.

We estimated parameters using spsurvey for most wetland assessment data, including wetland stressors, URAP condition metrics, and function. However, in some cases we present raw, unweighted data. Data used for descriptions of wetland types are presented as raw data, which limits our ability to make inference to the whole study area from these results. For example, if we report that the mean cover of native plants in wet meadows in our study area is 70%, we cannot expect that the mean cover of all wet meadows in the study area is also 70% because more heavily weighted wet meadows in the Great Salt Lake stratum may have higher or lower native plant cover than those in the Sevier Basin stratum. Usually, results obtained from weighted data are referred to as estimates of the percent of wetland area or total wetland area and include a measure of uncertainty. Results obtained from raw data are typically presented as a number or percent of sites. All statistical analysis was conducted in R 4.0.3 statistical software (R Core Development Team, 2020).

## Stressors

Stressor values were translated to impact ratings based on scope and severity values, following methods from Lemly and others (2017). Impact scores range from 1 (low) for stressors that have extent or severity ratings of 1 or both extent and severity ratings of 2 to 10 (very high) for stressors that have extent and severity ratings of 4 (table 3). Impact scores were then summed within each stressor category (landscape, hydrology, site soil, and site vegetation) to obtain categorical impact scores. To obtain an overall impact score for each site, we took a weighted sum of the four categorical scores, multiplying each categorical score by 0.3, except for soils which is multiplied by 0.1, then summing the scores together. We then categorized the overall site stressor scores into ratings ranging from absent to very high using thresholds (table 4). We estimated the percent of wetland area in each stratum impacted by each stressor for stressors found in over 10% of sites within the stratum, and also estimated the categorical and overall stressor impacts for each stratum.

***Table 3.*** *Calculator for translating scope and severity ratings to an impact score.*

| **Threat Impact Calculator** | | **Scope** | | | |
|---|---|---|---|---|---|
| | | Pervasive = 4 | Large = 3 | Restricted = 2 | Small = 1 |
| **Severity** | Extreme = 4 | Very High = 10 | High = 7 | Medium = 4 | Low = 1 |
| | Serious = 3 | High = 7 | High = 7 | Medium = 4 | Low = 1 |
| | Moderate = 2 | Medium = 4 | Medium = 4 | Low = 1 | Low = 1 |
| | Slight = 1 | Low = 1 | Low = 1 | Low = 1 | Low = 1 |

***Table 4.*** *Formula for converting categorical impact scores and overall weighted score to an overall impact rating.*

| Score | Rating |
|---|---|
| 10+ | Very High |
| 7 – 9.9 | High |
| 4 – 6.9 | Medium |
| 1 – 3.9 | Low |
| 0 – 0.9 | Absent |

## Rapid Assessment Condition Results

Rankings for the relative native cover and absolute noxious cover metrics were obtained by calculating cover estimates using plant composition data and then converting estimates to ranks using the URAP thresholds (appendix A). Records of *Phragmites australis* were considered to be the noxious subspecies *australis* if they were encountered around the margins of Great Salt Lake and the native subspecies *americanus* if they were encountered elsewhere, unless a positive identification to subspecies was recorded (Kulmatiski and others, 2010). We refer to the noxious subspecies *P. australis* ssp. *australis* as Phragmites throughout this report.

We calculated categorical and overall condition scores using the following procedure. We converted metric ranks to point values based on the following: A or AB=5, A-=4.5, B=4, C=3, C-=2, D=1. We combined metric scores for the percent buffer, buffer width, buffer soil condition, and buffer vegetation condition into an overall buffer score using the following equation:

$$\text{Overall Buffer}=(\text{Percent Buffer}*\text{Buffer Width})^{0.5}*([\text{Buffer Condition: Soil}+\text{Buffer Condition: Vegetation}]/2)^{0.5}$$

We then calculated the mean metric score within each category (only using the overall buffer score and not the derivative components for the landscape context category) based on the categories shown in table 2. Means were taken across a variable number of metrics per site since not all metrics were evaluated at every site. Overall condition scores were obtained by taking the mean value across all categorical scores.

## Plant Coefficient of Conservatism Values

We report on two vegetation metrics that rely on coefficient of conservatism values (C-values): mean C and cover-weighted mean C. C-values between 1 and 10 are assigned to species based on their association with disturbance through a combination of best professional judgment, literature review, and field observations. Low values indicate that species are usually found at disturbed sites, high values indicate that species are associated with pristine sites, and values in the middle indicate that species may be found equally at either type of site (Rocchio and Crawford, 2013). All non-native species are assigned a C-value of 0. We calculated mean C by taking the mean C-value for all species at a site and cover-weighted mean C by multiplying the C-value for each species by its cover at the site, summing up the result for all species, and dividing by the cover of all species at the site. Both mean C and cover-weighted mean C range from 0 to 10.

C-values are often developed for individual states or regions to capture regional variability in how species respond to disturbance. The EPA contracted to convene a working group in fall 2018 to assign C-values to plant species in states where C-values had not been previously assigned (Arizona, California, Idaho, New Mexico, Nevada, Oregon, Texas, Utah), but only for those species recorded in one of the EPA's National Wetland Condition Assessment surveys. We used C-value assignments from that workshop and from previous work in nearby states, including Colorado (Rocchio, 2007), Montana (Jones, 2005), Washington (Rocchio and Crawford, 2013), and Wyoming (Washkoviak and others, 2015) to assign C-values to species in Utah. First, all introduced species were assigned a value of 0. Second, species with Utah-specific assignments retained that assignment. Next, unassigned species with assignments in one or more of the states immediately surrounding Utah, including Colorado, Wyoming, Arizona, Idaho, and Nevada, were assigned the mean value from those states. Last, unassigned species with assignments in Montana or Washington or in one or more of the other states that were part of the EPA workshop were assigned the mean value from the states where assigned. If C-values for Utah plus the surrounding states or C-values for species that only had values in more distant states varied by more than three across states, we manually inspected the values to determine whether the values should be kept, modified, or removed, based on best professional judgment.

Despite these efforts to assign C-values, a small number of species recorded in the Central Basin surveys did not have assigned C-values, including several species that were common or frequently dominant in playa wetlands. To address these data gaps, we convened a panel of five Utah botanists representing both state and federal agencies, all with working familiarity of Utah flora, to fill gaps in species' C-values. Botanists on the panel were given instructions on how to assign C-values and a list of 24 target species. After each botanist independently assigned ratings, a virtual workshop was held to discuss differences in species' ratings that were greater than or equal to 3 to come up with consensus values where possible. A lack of familiarity with many of the uncommon species prevented the group from assigning values to many of the species but we arrived at an agreement on the following nine species: *Atriplex tridentata*: 6; *Azolla microphylla*: 4; *Bidens tripartita*: 3; *Chenopodium salinum*: 3; *Cordylanthus maritimus*: 7; *Polypogon interruptus*: 3; *Rorippa tenerrima*: 4; *Sarcocornia utahensis*: 6; and *Solidago spectabilis*: 8.

## Wetland Function

### Water Quality and Hydrologic Function

We totaled the scores in each component (site potential, landscape potential, and societal value) to assign sites to "low," "medium," and "high" categories for each component based on thresholds in Hruby (2014). We then calculated an overall score for each of the two functions—water improvement and hydrology—by converting low to 1, medium to 2, and high to 3, so that, for example, a site that scored low in site potential, medium in landscape potential, and low in societal value would have an overall score of 4. The total number of points for each function was arranged in a confusion matrix with the subjective scores to aid in defining the cutoff values for the overall function categories of low, medium, and high. This approach was taken because the overall scoring system used in the Washington functional assessment incorporates scores from other assessment metrics that we did not evaluate. After initial evaluation, we defined low function as scoring 3–5 overall points, medium function as scoring 6–7 points, and high function as scoring 8 points. No site in the study area received more than 8 points.

### Columbia Spotted Frog

We converted ranks (i.e., A, B, C, D) for the six Columbia spotted frog metrics to numeric values (i.e., 5, 4, 3, 1) and then calculated the mean score for each site. To obtain a threshold to distinguish sites with suitable habitat from other sites, we looked at data from sites surveyed at locations with known populations. This group of sites includes four surveyed along the Provo River in 2016 by the UGS as part of the Jordan River watershed wetland assessment (Menuz and Sempler, 2018) and eight surveyed in 2017 by wildlife biologists from the BLM, UDWR, and the Bureau of Reclamation. The sites surveyed by wildlife biologists included three along the Provo River, one along Diamond Fork River, and four in Central Basin spring complexes. All but one of these sites had a mean habitat score between 4.5 and 5 with no apparent difference in scores between spring and river sites. We therefore considered scores ≥4.5 to indicate potentially suitable habitat. We did not have any information to help us identify marginal habitat that may be suitable following restoration or under optimal conditions. We assigned sites with scores ≥3.5 and <4.5 as marginal habitat and sites with lower scores as poor habitat.

## Reference Condition

We used data from all sites surveyed by the UGS in the Central Basin to identify and describe least disturbed sites for each wetland type. This included sites surveyed in 2013 in Snake Valley and around Great Salt Lake (Jones and others, 2014; Menuz and others, 2014), in 2014 in the Weber River watershed (Menuz and others, 2016), in 2015 and 2016 in the Jordan River watershed (Menuz and Sempler, 2018), and in 2018 in the Bear River watershed (Menuz and McCoy-Sulentic, 2019), as well as sites from the present study. We excluded sites that had two or more dominant wetland types to allow us to focus on typical conditions for each type, which left us with 251 sites across the ecoregion. We used the overall stressor impact value to assign sites to least and most disturbed categories. The current method for collecting stressor information was not implemented until 2019, though similar stressor data was collected in previous years. We used the older stressor data, other relevant site data, and GIS evaluation to convert the older stressor data to the new format and calculate comparable overall impact scores for all sites in the Central Basin.

Sites with no disturbance were very uncommon, so we instead sought to identify sites that were the least disturbed for each wetland class. We set a goal of selecting approximately 15%–20% of sites per wetland type as least disturbed, following methods used by the EPA in the National Wetland Condition Assessment (U.S. Environmental Protection Agency, 2016). We identified the lowest overall impact value that could be used as a threshold to select an appropriate number of sites for each wetland type. We used a similar approach to identify sites that were most disturbed, looking for the maximum overall impact score threshold that allowed us to select approximately 20%–30% of sites, again following EPA methods.

After classifying sites, we examined whether least and most disturbed sites differed by URAP overall and categorical scores, vegetation community metrics, water quality parameters, and soil salinity. We calculated 41 vegetation metrics based on species characteristics and attributes, including metrics based on absolute cover, relative cover, and richness (appendix E). We included the field measures of surface water pH, EC, and temperature and soil salinity and also analyzed the more than 30 water quality parameters that were obtained through laboratory analysis (appendix E). We evaluated how well each metric separated least and most disturbed sites using t-tests ($\alpha = 0.01$) for the wetland types and metrics where we had adequate sample sizes and pooled all least and most disturbed sites where sample sizes for comparison within wetland types were insufficient. Laboratory water samples were only collected starting in 2014 and soil salinity measurements starting in 2016, so we frequently had low sample sizes for these parameters.

## Hydrologic Resources Analysis

We compiled data on stream flow, lake elevation, groundwater levels, and surface water extent to assess trends in hydrologic conditions across the study area and to better understand conditions during the study in context with historical hydrologic conditions. Stream flow and lake elevation data were obtained from Saltair Harbor on Great Salt Lake and two USGS gages on the Sevier River, on the Lower Sevier at Lynndyl and along the Middle Sevier below the confluence with the San Pitch River. Groundwater data were obtained from USGS well monitoring data. Surface water extent data were obtained from data modeled from satellite imagery. For the gage data, we qualitatively explored trends by plotting 30-year mean flow or water elevation data alongside flow or elevation data during the field surveys and from 1983, the year when the majority of the study area's wetlands were mapped. For the groundwater and surface water extent analyses, we conducted a more formal trend analysis using Mann Kendall trend tests.

### Groundwater Well Data

Groundwater well data for wells that overlapped the Great Salt Lake and Escalante Desert-Sevier Lake HUC6 watersheds were downloaded from the USGS using the dataRetrieval package in R (DeCicco and others, 2018). We processed the data to obtain one water level value per year per well, preferentially using values recorded in the spring months whenever possible (typically March). If no level was recorded during the spring, we used a water level from later in the year if available. To better examine long-term trends in groundwater levels, we pared down the available data to wells with records that started no later than 1965 with at least 50 years of data through 2020 and no more than three consecutive years of missing data (figure 2). Well level records from before 1960 were excluded to better standardize the period of analysis. This resulted in data from 150 wells, including 123 wells in the Sevier Basin and 27 wells in the West Desert. No wells within the Great Salt Lake stratum met our filtering criteria. Well hole depth was not considered in the selection process, and water levels in wells ranged from -66.5 to 305.37 feet below the surface.

We conducted Mann-Kendall tests for significant monotonic trend and calculated Sen's slope for individual wells. We checked for autocorrelation for each well, and we applied a Mann-Kendall Trend test without modifications when we found no autocorrelation, a modified Mann-Kendall Test using the Yue and Wang (2004) variance correction approach with the lag-1 correlation coefficient when there was correlation at lag 1, or a modified Mann-Kendall test using the Yue and Wang (2004) variance correction approach when we found correlation at multiple lags, using the mkttest, mmky1lag, and mmky functions in the modifiedmk R package, respectively (Patakamuri and O'Brien, 2020). These functions also calculate a Sen's slope value, a nonparametric estimate of the slope of a trend (Sen, 1968). We used an alpha level of 0.01 for all statistical tests due to the large number of comparisons.

### Surface Water Extent

We used the JRC Monthly Water History data available on Google Earth Engine to examine trends in surface water extent from 1990 to 2019 for watersheds in the study area (Pekel and others, 2016). The JRC Monthly Water History data map the location of open surface water (i.e., water not obscured by vegetation) between the years 1984 and 2020 across the entire Earth. The data are derived by classifying pixels from images from Landsat 5, 7, and 8 satellites. Validation of the global dataset showed less than 1% of water detections were false and less than 5% of water surfaces were missed, though errors of omission for seasonal water are much higher than errors of omission for permanent water. We used HUC12 and HUC8 watershed boundaries, clipped to only include portions within the study area, to explore surface water extent trends.

For each area of interest, we calculated the mean area of surface water extent from May to September for each year. We used May to September because those months had the most data available and coincided with the growing season. If a month had

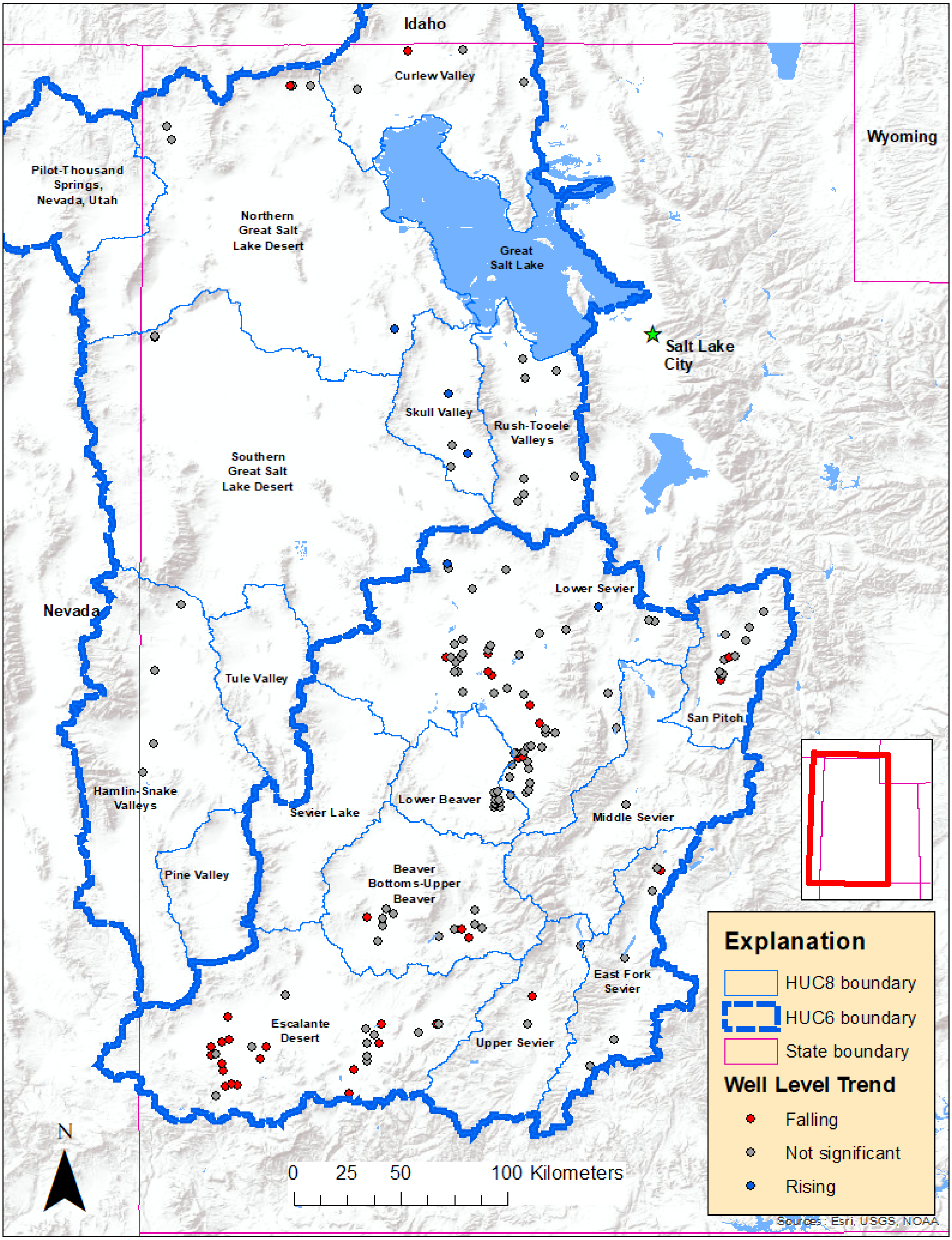


***Figure 2.*** *Map of well locations used in long-term groundwater well water level analysis and associated trends from Mann-Kendall trend analysis.*

more than 20% no data (because of clouds, etc.) we excluded it from the average. We used a NAD83 Conus Albers projection to conserve area in our calculations. All analysis was done in Google Earth Engine and R (Gorelick and others, 2017; R Core Development Team, 2020). To see whether the surface water trends over time were significant, we ran a Mann Kendall analysis with the modifiedmk package in R on each area, accounting for temporal autocorrelation when appropriate with the mmky1lag or mmky test (Patakamuri and O'Brien, 2020). We did not run a Mann Kendall test when sites did not have at least 10 years with water present within the area of interest. We used an alpha level of 0.05 for tests in the HUC8s and an alpha level of 0.01 for tests in the HUC12s, due to the large number of units at the latter watershed scale.

## Landscape Profile

We used the most recent published data from NWI for the landscape profile analysis (U.S. Fish and Wildlife Service, 2021). We first classified features in the NWI as one of six classes and then attributed the data with land ownership, stress model values, land use, and irrigation class. This attribution allowed us to summarize information on the types, protection status, and potential vulnerability of aquatic features within the study area.

We classified aquatic features into six classes based on Cowardin attributes, including aquatic bed, marsh/mudflat, meadow (both saline and fresh), playa, scrub-shrub, and forested (table 5). We developed a method for translating Cowardin attributes to those classes by comparing wetland type designations from current and past UGS survey sites in the study area with mapped NWI data overlapping those survey sites. We did not have data for any sites that overlapped NWI polygons mapped as forested, scrub-shrub, or emergent with water regimes D or K; these wetland polygons were classified as forested, scrub-shrub, and meadow, respectively. Agreement between these landscape wetland classes and wetland types were between about 77% and 83% for playas, meadows, and marsh/mudflat and only 57% for aquatic bed, where we also had the lowest sample size with only seven sites. We used only the first class when we classified split class features, except that features mapped as split between emergent and unconsolidated shore were also classified as playa. We excluded all features mapped as palustrine unconsolidated bottom (pond), riverine, and lacustrine if not within the aquatic bed or unconsolidated shore classes; these feature types were largely excluded from our sample frame and almost completely unrepresented in our final data. It should be noted that the accuracy assessment and classification do not take into account the fact that many wetland features are no longer present on the landscape; we only compared NWI data with wetland types for those sites that were determined to be wetland in the field.

We used land ownership data from SITLA, BLM, and partners (undated) to classify mapped wetlands as private, state, federal, and tribal. Land use and irrigation data were extracted from Water Related Land Use (WRLU) data (Utah Division of Water Resources, 2019), an effort to map all agricultural areas in the state as well as other lands that consume or evaporate water other than natural precipitation (which generally excludes deserts, rangeland, and forested areas). Urban areas, open water, and riparian features are only mapped if they are near irrigated lands, so these land use classes are likely underrepresented in the data. We combined the land use categories in the WRLU data into six categories based on their similarity to one another and prevalence in the study area: aquatic and riparian (riparian, open water, and wetlands), agriculture and idle/fallow land, hay/turf and pasture, urban, non-agricultural dryland, and unmapped. We calculated the percentage of aquatic feature area in each land use class as well as the percentage in one of two irrigation classes—irrigated and subirrigated. Subirrigated lands are naturally irrigated agricultural lands that usually have a high water table, though they sometimes also receive direct or indirect irrigation water, and irrigated lands are lands that are directly irrigated through flood, sprinkler, or drip irrigation.

***Table 5.*** *Classes included in landscape analysis and number of UGS survey sites classified as each class. Selection criteria show the Cowardin attributes assigned to each class, with wildcards indicated by %. Wetlands with split Cowardin classes were assigned to the first assigned class, except those attributed as PEM1/US%, which were classified as playa. The percent accuracy indicates the percent of sites that were assigned to the wetland class based on Cowardin attributes and were of the corresponding wetland type in the field (or, in a few cases, secondary wetland type). Wetland types that sites were frequently misclassified as are shown in the final column.*

| Class | # Sites | Selection Criteria | % Accuracy | Other Common Wetland Types |
|---|---|---|---|---|
| Aquatic bed | 7 | %AB% | 57.1 | shallow water, marsh, mudflat (one each) |
| Marsh/ mudflat | 18 | PEM%F, PEM%C%[1] | 83.3 | saline meadow, fresh meadow, forested-shrubland (one each) |
| Meadow | 38 | PEM%A%, PEM%B%, PEM%E%, PEM%D%. PEM%C%[1] | 78.9 | marsh (5), playa (2) |
| Playa | 39 | %US%, PEM%J%, PEM%C%[1] | 76.9 | saline meadow (5), marsh (2), mudflat (2) |
| Scrub-shrub | 0 | %SS% | N/A | |
| Forested | 0 | %FO% | N/A | |

[1]PEM%C% sites were classified as marsh or mudflat in the Great Salt Lake stratum, meadow in the West Desert, and playa in the Sevier Basin.

We classified wetland polygons as having low, moderate, or high levels of local stress based on values from a GIS-based aquatic resource stress model (Menuz, 2015). The local stress model is a 30-m-resolution data layer that combines multiple predictors together to obtain an overall estimate of potential wetland stress. The model only accounts for local stress within set distances from each wetland (based on the estimated area of influence of each predictor), not stressors that originate higher in a watershed. Furthermore, the model does not include many important stressors, such as livestock grazing intensity, non-native species cover, and water diversion impacts, due to lack of available geospatial data. For the landscape analysis, we assigned a mean stress value to each polygon and then summarized the percent of wetland area in each stress class by stratum and wetland type.

# RESULTS

## Survey Site Characteristics

### Site Evaluation and Surveyed Sites

We evaluated 210 randomly selected sites to obtain 81 target sites to survey and surveyed two additional sites that were later determined to be non-target based on a review of the field data. In the Sevier Basin stratum, 100 of 140 evaluated sites were non-target and an additional 6 sites had uncertain status because aerial imagery evaluation was inconclusive, and we could not obtain landowner permission to evaluate the sites in the field (table 6, figures 3 and 4). Of the 100 non-target sites, six were ditches, two were wastewater ponds, three were too small or narrow to meet survey dimension requirements, and the remainder did not appear to be wetland or aquatic features. We conducted field visits at 15 of the non-target wetlands to determine their status. In contrast, 90% of the evaluated West Desert and 100% of Great Salt Lake sites were target wetland. Of the five non-target features in the West Desert, three were too small or narrow to survey. Two target wetland sites in the Great Salt Lake stratum were inaccessible due to dense stands of Phragmites and were not surveyed.

After accounting for sites that were non-target, inaccessible or with no landowner access, we surveyed 17 sites in the Great Salt Lake, 38 sites in the West Desert, and 26 sites in the Sevier strata. We also surveyed six subjectively selected sites, including one in the Sevier Basin, four in the West Desert, and one outside the study area but within the Central Basin south of Utah Lake. Surveys were conducted from June 17 to August 21, 2019, and from June 23 to September 9, 2020. Sites were frequently moved away from the originally selected center point, though all but 12 assessment areas included the original randomly selected point within the assessment area boundary.

We evaluated our data to look for the presence of U.S. Army Corps wetland indicators to verify that our survey sites were in the target population. Of the 87 surveyed sites, 49 either had all three indicators present or had hydrophytic vegetation and hydrology indicators with no soil pit data and 33 sites had two indicators present. Five sites had only one indicator present but were determined to be in the target population due to factors such as location within an obvious spring area or dominance by facultative wetland and obligate wetland species. Hydric soil indicators were absent in just over one-third of sampled sites; however, hydric soil indicators were developed to help delineate the boundary of wetlands and thus may not always be present in the interior of wetlands where we typically sampled (U.S. Army Corps of Engineers, 2008).

### Hydrogeomorphic and Wetland Type Classification

Sites were assigned HGM classes based on their dominant class, though some contained more than one class. Depressional wetlands were the most common HGM class in the Sevier Basin and West Desert, comprising half of the wetlands in each stratum. Other common HGM classes in these strata include slope wetlands and, in the Sevier Basin, riverine wetlands. In the

***Table 6.*** *Sample frame evaluation results, including number of sites evaluated in each stratum and percent that were target, non-target, or uncertain and standard error in parentheses.*

| Site Evaluation | Great Salt Lake | West Desert | Sevier Basin | Study Area |
|---|---|---|---|---|
| # Sites Evaluated | 19 | 51 | 140 | **210** |
| Sample Frame Area (ha) | 9209 | 25,794 | 19,136 | **54,139** |
| Percent Target (SE) | 100 (0) | 90.2 (3.5) | 24.3 (2.5) | **57.0 (1.8)** |
| Percent Non-Target | 0 | 9.8 (3.5) | 71.4 (2.6) | **40.7 (1.8)** |
| Percent Uncertain | 0 | 0 | 4.3 (1.4) | **2.2 (0.7)** |

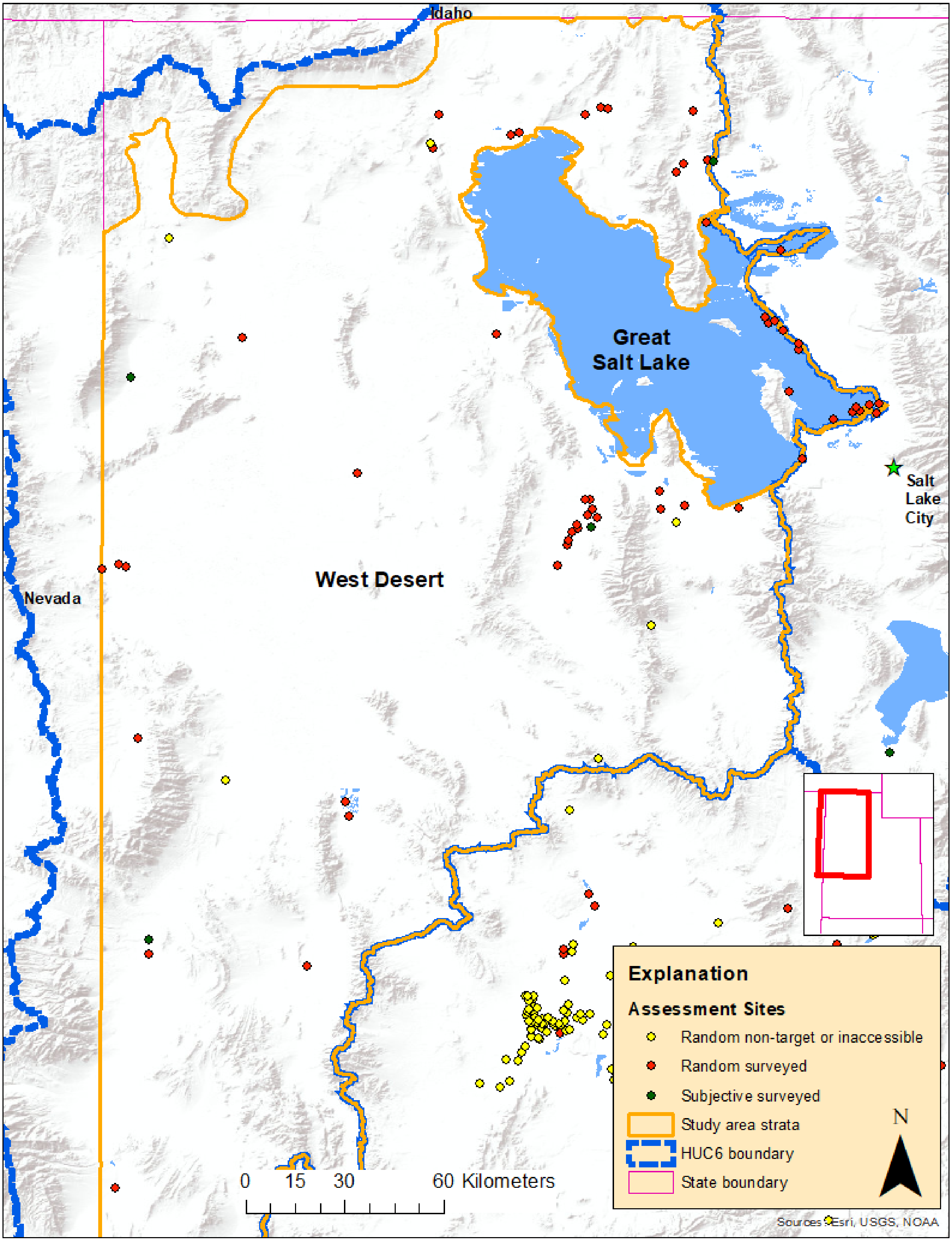


*Figure 3. Surveyed wetland sites in the West Desert and Great Salt Lake strata. Sites displayed include all randomly and subjectively selected surveyed sites and randomly selected sites that were not surveyed due to lack of access or because they were non-target.*

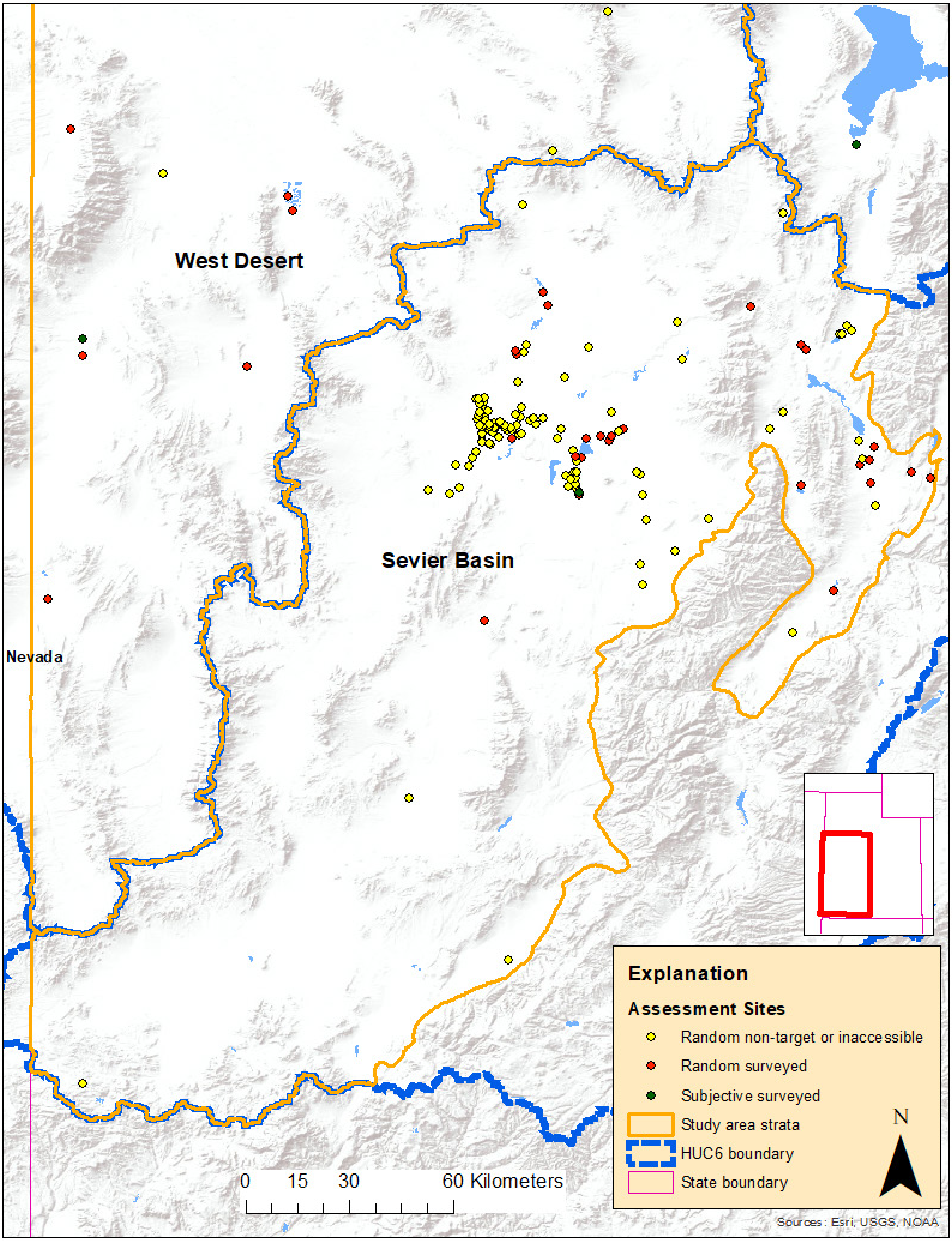


***Figure 4.*** *Surveyed wetland sites in the Sevier Basin stratum. Sites displayed include all randomly and subjectively selected surveyed sites and randomly selected sites that were not surveyed due to lack of access or because they were non-target.*

Great Salt Lake stratum, 70% of wetlands are estimated to be impoundment release, with the remaining depressional, depressional impoundment, or depressional impoundment fringe (table 7).

Playas are the most common wetland type in the study area, followed by saline meadow and marsh (table 7). The least common wetland types in the study area are shallow water and forested-shrublands, which were estimated to occupy 0.4% and 1.3% of wetland area, respectively. Marshes, mudflats, aquatic bed, and saline meadow each occupy between 17% and 29% of the area in the Great Salt Lake stratum. Playas were the most common wetland type in the Sevier Basin and West Desert, occupying 42% and 53% of wetland area, respectively. Saline meadows were also common in both strata, occupying about 23% of area in each. Forested-shrubland wetlands, though uncommon overall, were found at 11.5% of sites in the Sevier Basin.

## Stressors

Non-native or invasive plants at both the landscape and plot scale, agricultural runoff or manure, and landscape soil disturbance by animals were the four most commonly noted stressors across the study area and were noted in more than one-half of all sites. Sixty-eight percent of sites had non-native species at the landscape scale, 57% had non-native species in the plot, 57% had agricultural runoff or direct livestock inputs impacting the hydrology, and 54% had landscape soil disturbance by animals. Landscape soil disturbance was typically from cows, but occasionally from wildlife or wild horses. Other common stressors included three hydrology stressors—diking or impoundments, canals or ditches, control of flow and energy—as well as plot soil disturbance from animals, landscape disturbance from vehicle ruts, and excessive grazing at the landscape and plot scales, all recorded at 25% or more of sites. The three hydrology stressors had mean impact values in the medium range (4–6.9), whereas plot soil disturbance by animals and humans and landscape excessive grazing had low mean impact values (1–3.9). Infrequently encountered stressors with high impact scores include excess salinity, which occurred at three sites having high or very high mean impact values at the site and landscape scale and herbicide or fertilizer application which occurred in the plot and landscape scale at one site with a high impact value.

Across the whole study area, overall stressor impact levels were estimated to be high or very high at about 40% of wetlands and absent in about 20% of wetlands (table 8). Almost 50% and about 40% of wetland area is estimated to have high or very high impact values for hydrology and landscape stressors, respectively. Plot vegetation and plot soil stress categories typically had lower impact ratings. About 24% and 9% of wetland area, respectively, was estimated to have high or very high impact for these stressors, and more than 37% of wetland area is estimated to have low or no stress in each category.

***Table 7.*** *Hydrogeomorphic classes and wetland types in the study area, including estimated percent of wetland area in each class and standard error in parentheses.*

| Wetland Class | Study Area | GSL | Sevier Basin | West Desert |
|---|---|---|---|---|
| **HGM Class** | | | | |
| Depressional | 39.5 (4.4) | 11.8 (7.1) | 50.0 (7.8) | 50.0 (6.2) |
| Depressional impoundment | 5.3 (2.1) | 11.8 (5.5) | 3.9 (3.4) | 2.6 (2.4) |
| Depressional impoundment fringe | 1.6 (1.4) | 5.9 (4.8) | 0 | 0 |
| Impoundment release | 22.5 (3.3) | 70.6 (10.0) | 0 | 5.3 (3.1) |
| Lacustrine fringe | 0.4 (0.4) | 0 | 3.9 (3.3) | 0 |
| Riverine | 5.4 (2.1) | 0 | 19.2 (6.3) | 5.3 (3.3) |
| Slope | 25.2 (3.9) | 0 | 23.1 (6.7) | 36.8 (6.1) |
| **Wetland Type** | | | | |
| Aquatic bed | 8.9 (2.8) | 17.7 (7.3) | 7.7 (4.7) | 5.3 (3.2) |
| Fresh meadow | 7.3 (2.6) | 0 | 7.7 (4.4) | 10.5 (4.2) |
| Forested-shrubland | 1.3 (0.6) | 0 | 11.5 (4.9) | 0 |
| Marsh | 13.3 (3.7) | 29.4 (9.8) | 3.9 (3.2) | 7.9 (4.0) |
| Mudflat | 8.1 (2.5) | 29.4 (9.7) | 0 | 0 |
| Playa | 38.7 (3.9) | 5.9 (5.3) | 42.3 (5.9) | 52.6 (5.8) |
| Saline meadow | 22.0 (4.5) | 17.7 (8.2) | 23.1 (6.5) | 23.7 (6.4) |
| Shallow water | 0.4 (0.4) | 0 | 3.9 (3.3) | 0 |

The Great Salt Lake stratum had the highest percent of wetlands with high or very high overall impact values (about 94%), driven by frequent high and very high values in the hydrology, buffer, and plot vegetation categories. Hydrology stressors were the most prevalent and high impact of the stressors in the Great Salt Lake stratum; all but one Great Salt Lake site was rated as very high for hydrology impact (table 8). Diking or impoundments and control of flow and energy were both the most widespread and most frequently high impact stressors (table 9). Point source dischargers and impaired source water were also very common, though frequently found with lower impact scores because the source of stress was further upgradient from sites. None of the Great Salt Lake wetlands received landscape scores of absent or low, largely due to the widespread presence of non-native and invasive plants in the landscape. Livestock grazing and soil disturbance were present at the landscape scale at about 41% of sites, though typically with low impact. Plot vegetation and plot soil stressors were not very widespread and rarely high impact, with the exception of non-native and invasive plants within the site. About 65% of wetlands in the Great Salt Lake stratum were rated as high impact for non-native plants in the plot, compared to 12% in the Sevier and 0% in the West Desert.

In the Sevier Basin, about one-third of sites had absent or low overall impact scores and 15% of sites had very high scores. Sites in the Sevier Basin had the highest percent of sites with "very high" buffer impact scores, compared to the other two strata, but also had 42% of wetland area with absent or low buffer impact (table 8). Non-native and invasive plants and livestock soil disturbance were both found in over 50% of sites at the landscape scale in the Sevier Basin (table 10). One-half of the sites in the Sevier Basin were rated as very high for impact in the hydrology stressors. Agricultural runoff or manure from livestock was the most common hydrology stressor, found at over 80% of sites. Impacts from canals or ditches and from groundwater extraction were each found at about 46% of sites. The Sevier Basin is the only stratum where more than 10% of sites had evidence of groundwater extraction impacts. The Sevier Basin had the highest percent of sites with plot soil impacts of high or very high and the lowest percent of sites with plot soil impact ratings of absent, largely due to soil disturbance from livestock.

***Table 8.*** *Categorical and overall stressor impact ratings for each stratum. Values are percent of wetland sites in each impact category, followed by the standard error in parentheses.*

| Strata | Absent | Low | Medium | High | Very High |
|---|---|---|---|---|---|
| **Landscape** | | | | | |
| Great Salt Lake | 0 | 0 | 29.4 (9.7) | 41.2 (11.6) | 29.4 (9.8) |
| Sevier Basin | 7.7 (4.7) | 34.6 (6.7) | 3.9 (3.2) | 15.4 (6.2) | 38.5 (5.7) |
| West Desert | 7.9 (3.3) | 44.7 (6.9) | 23.7 (6.0) | 5.3 (3.2) | 18.4 (5.0) |
| Study Area | 5.7 (2.1) | 31.3 (4.3 | 23.0 (4.6) | 16.3 (3.9) | 23.7 (4.1) |
| **Hydrology** | | | | | |
| Great Salt Lake | 0 | 5.9 (4.8) | 0 | 0 | 94.1 (4.8) |
| Sevier Basin | 7.7 (4.5) | 15.4 (5.8) | 11.5 (5.5) | 15.4 (6.6) | 50.0 (8.4) |
| West Desert | 36.8 (6.4) | 21.1 (5.9) | 15.8 (5.1) | 10.5 (4.4) | 15.8 (5.3) |
| Study Area | 23.4 (3.9) | 16.3 (3.9) | 11.0 (3.3) | 8.2 (2.8) | 41.1 (3.8) |
| **Plot Soil** | | | | | |
| Great Salt Lake | 52.9 (10.4) | 35.3 (10.2) | 0 | 11.8 (7.4) | 0 |
| Sevier Basin | 19.2 (6.9) | 50.0 (8.8) | 11.5 (4.8) | 11.5 (4.9) | 7.7 (4.8) |
| West Desert | 39.5 (6.3) | 39.5 (6.4) | 15.8 (5.0) | 0 | 5.3 (3.2) |
| Study Area | 40.8 (5.0) | 39.5 (5.0) | 11.0 (3.1) | 4.5 (2.1) | 4.1 (2.1) |
| **Plot Vegetation** | | | | | |
| Great Salt Lake | 11.8 (7.2) | 0 | 23.5 (8.8) | 41.2 (11.3) | 23.5 (9.5) |
| Sevier Basin | 30.8 (7.4) | 34.6 (8.1) | 7.7 (4.4) | 23.1 (6.9) | 3.9 (3.1) |
| West Desert | 36.8 (7.1) | 44.7 (7.4) | 13.2 (4.7) | 5.3 (3.1) | 0 |
| Study Area | 29.3 (4.9) | 31.3 (4.6) | 15.4 (3.8) | 17.2 (3.8) | 6.9 (2.6) |
| **Overall Impact** | | | | | |
| Great Salt Lake | 0 | 0 | 5.9 (4.8) | 29.4 (10.6) | 64.7 (10.4) |
| Sevier Basin | 3.9 (3.4) | 30.8 (7.6) | 23.1 (7.2) | 26.9 (7.6) | 15.4 (6.0) |
| West Desert | 31.6 (6.1) | 39.5 (6.7) | 13.2 (4.9) | 10.5 (4.3) | 5.3 (3.1) |
| Study Area | 19.8 (3.8) | 27.7 (4.3) | 12.3 (3.4) | 17.6 (4.0) | 22.7 (3.7) |

***Table 9.*** *Great Salt Lake impact score estimates for stressors present in >10% of sites within the stratum. Estimates include percent of wetland area with impact score for each stressor and standard error in parentheses.*

| Stressor | Percent of Wetland Area with Impact Score | | | | |
|---|---|---|---|---|---|
| | Absent | Low | Medium | High | Very High |
| **Landscape** | | | | | |
| Livestock or excessive native grazing | 58.8 (10.5) | 23.5 (9.7) | 11.8 (7.6) | 5.9 (5.2) | 0 |
| Non-native or invasive plants | 11.7 (5.5) | 5.9 (5.3) | 17.7 (8.5) | 64.7 (10.6) | 0 |
| Soil disturbance by animals | 58.8 (10.8) | 29.4 (10.6) | 0 | 11.8 (7.4) | 0 |
| Hiking trails or vehicle ruts | 88.2 (7.0) | 11.8 (7.0) | 0 | 0 | 0 |
| Non-motorized recreation | 88.2 (5.5) | 5.9 (4.9) | 5.9 (4.9) | 0 | 0 |
| Motorized recreation | 76.5 (8.5) | 5.9 (4.9) | 17.7 (8.4) | 0 | 0 |
| **Hydrology** | | | | | |
| Point source discharge | 17.7 (6.1) | 29.4 (7.0) | 47.1 (7.7) | 5.9 (4.9) | 0 |
| Stormwater runoff | 11.8 (6.8) | 29.4 (7.0) | 52.9 (8.2) | 5.9 (4.9) | 0 |
| Agriculture runoff or manure | 35.3 (7.4) | 17.7 (8.2) | 41.2 (5.6) | 5.9 (5.1) | 0 |
| Diking or impoundments | 11.8 (6.6) | 11.8 (7.3) | 23.5 (8.3) | 52.9 (10.7) | 0 |
| Canals, ditches | 64.7 (10.7) | 0 | 17.7 (7.5) | 17.7 (8.5) | 0 |
| Control of flow and energy | 11.8 (6.0) | 0 | 41.2 (6.3) | 47.1 (7.4) | 0 |
| Direct water source is impaired | 17.7 (7.6) | 41.2 (9.6) | 29.4 (8.9) | 11.8 (5.5) | 0 |
| **Plot Soil** | | | | | |
| Soil disturbance by animals | 58.8 (10.6) | 29.4 (10.3) | 0 | 11.8 (7.4) | 0 |
| Hiking trails or vehicle ruts | 88.2 (7.0) | 11.8 (7.0) | 0 | 0 | 0 |
| **Plot Vegetation** | | | | | |
| Livestock or excessive native grazing | 70.6 (10.4) | 17.7 (8.6) | 5.9 (5.4) | 5.9 (5.2) | 0 |
| Non-native or invasive plants | 17.7 (7.6) | 0 | 17.7 (7.3) | 64.7 (9.6) | 0 |
| Motorized recreation | 88.2 (6.9) | 5.9 (4.9) | 5.9 (4.8) | 0 | 0 |

West Desert wetlands, with over 70% of sites in the absent or low overall impact categories, had the lowest levels of disturbance and a lower percent of wetlands rated as high or very high in each of the individual impact categories, compared to wetlands in the other two strata (table 8). About 26% of West Desert wetlands had high or very high impact ratings for hydrology, 24% for landscape, and 5% for plot soil and vegetation. The most widespread stressors found in the West Desert included non-native plants and soil disturbance by animals at both the landscape and plot scales (table 11). The stressors that were most commonly rated as high or very high include agriculture runoff or manure, diking or impoundments, and excessive livestock grazing within the site, each found at between 5% and 11% of wetlands in the stratum.

## Wetland Condition

Sixteen sites had overall wetland condition scores greater than 4.5, including two subjectively selected reference sites. Twelve of the high-scoring sites were in the West Desert stratum and the remaining in the Sevier Basin. High scoring sites were almost always playa or aquatic bed (sometimes mixed with other site types), and all but two had fewer than 10 species; the exceptions included an isolated marsh in Tule Valley and a mixed playa-saline meadow site in northern Snake Valley, both in the West Desert. The three lowest scoring sites (all <2.5) included a marsh in Farmington Bay of Great Salt Lake with high cover of invasive Phragmites, altered hydrology, and extensive pugging, a saline meadow in the Sevier Basin on private land used for grazing, and a forested-shrubland wetland on private land in the Sevier Basin dominated by *Phalaris arundinacea* (reed canarygrass) with high soil disturbance.

Wetland conditions in randomly selected sites differed among strata, with West Desert wetlands generally in the best condition and Great Salt Lake wetlands in the worst condition. West Desert wetlands scored significantly higher than both the Great Salt Lake and Sevier Basin in hydrologic and overall condition (figure 5). West Desert and Sevier Basin wetlands both scored significantly higher in the vegetation composition category than Great Salt Lake wetlands. The three strata did not significantly differ in landscape, physical structure, or vegetation structure components.

***Table 10.*** *Sevier Basin impact score estimates for stressors present in >10% of sites within the stratum. Estimates include percent of wetland area with impact score for each stressor and standard error in parentheses.*

| Stressor | Percent of Wetland Area with Impact Score | | | | |
|---|---|---|---|---|---|
| | Absent | Low | Medium | High | Very High |
| **Landscape** | | | | | |
| Livestock or excessive native grazing | 65.4 (7.2) | 23.1 (7.2) | 3.9 (3.5) | 7.7 (4.5) | 0 |
| Non-native or invasive plants | 38.5 (7.3) | 30.8 (8.8) | 23.1 (7.3) | 7.7 (4.3) | 0 |
| Trash or dumping | 84.6 (6.4) | 15.4 (6.4) | 0 | 0 | 0 |
| Soil disturbance by animals | 42.3 (6.4) | 23.1 (6.5) | 15.4 (5.0) | 11.5 (5.4) | 7.7 (4.5) |
| Hiking trails or vehicle ruts | 53.9 (7.2) | 42.3 (7.5) | 3.9 (3.5) | 0 | 0 |
| Roads or railroads | 76.9 (7.1) | 23.1 (7.1) | 0 | 0 | 0 |
| Non-motorized recreation | 88.5 (5.1) | 7.7 (4.7) | 3.9 (3.1) | 0 | 0 |
| Motorized recreation | 73.1 (6.8) | 19.2 (6.2) | 3.9 (3.5) | 3.9 (3.1) | 0 |
| **Hydrology** | | | | | |
| Agriculture runoff or manure | 19.2 (4.5) | 19.2 (6.6) | 34.6 (8.3) | 26.9 (7.8) | 0 |
| Dams or reservoirs | 88.5 (5.4) | 0 | 3.9 (3.2) | 7.7 (4.4) | 0 |
| Diking or impoundments | 84.6 (6.0) | 3.9 (3.6) | 11.5 (5.1) | 0 | 0 |
| Canals, ditches | 53.9 (8.3) | 15.4 (6.4) | 7.7 (4.8) | 23.1 (7.4) | 0 |
| Groundwater extraction | 53.9 (6.5) | 23.1 (6.4) | 11.5 (5.7) | 11.5 (5.6) | 0 |
| Direct water source is impaired | 88.5 (5.3) | 3.9 (3.1) | 7.7 (4.8) | 0 | 0 |
| **Plot soil** | | | | | |
| Trash or dumping | 80.8 (7.2) | 19.2 (7.2) | 0 | 0 | 0 |
| Soil disturbance by animals | 50.0 (6.3) | 26.9 (7.0) | 7.7 (3.5) | 11.5 (4.9) | 3.9 (3.4) |
| Hiking trails or vehicle ruts | 69.2 (7.1) | 26.9 (6.3) | 3.9 (3.2) | 0 | 0 |
| **Plot vegetation** | | | | | |
| Livestock or excessive native grazing | 69.2 (7.7) | 15.4 (6.3) | 7.7 (4.7) | 7.7 (4.5) | 0 |
| Non-native or invasive plants | 50.0 (6.5) | 23.1 (7.3) | 15.4 (5.9) | 11.5 (4.9) | 0 |
| Motorized recreation | 84.6 (5.5) | 15.4 (5.5) | 0 | 0 | 0 |

Among the individual URAP metrics, connectivity, percent buffer, and buffer width were scored as A at 84% or more sites in each of the three strata, including at 100% of sites in the Great Salt Lake stratum (tables 12–14). Percent intact landscape was also scored as A in almost all Great Salt Lake sites, nearly 75% of West Desert sites, and in more than one-half the sites in the Sevier Basin. In the Great Salt Lake stratum, 47% or more of the sites were rated as D for the three metrics related to vegetation (buffer vegetation, relative native cover, and absolute noxious cover) and for hydroperiod. Horizontal interspersion, water quality, and algae were rated as C or D at over one-half the sites in the stratum. In the Sevier Basin, horizontal interspersion, water quality, woody debris, and woody species regeneration were rated as C or D at 50% of sites, though the latter two metrics were only rated at 4 and 12 sites, respectively. In the West Desert stratum, all metrics other than horizontal interspersion were rated as A at one-half or more sites and no sites were scored as C or D at one-half or more sites. The lowest scoring metrics in the West Desert include horizontal interspersion, relative native cover, and litter accumulation. Woody debris was not present at any West Desert site. C and D ratings for three of the vegetation structure metrics—litter accumulation, woody debris, and woody regeneration—are divided into categories to provide more detail about the specific characteristics of low-scoring sites. For example, the litter accumulation metric can be scored as C1 to indicate a site somewhat lacking in litter or C2 for sites with somewhat excessive litter. The majority of sites that scored below AB for the litter accumulation metric were scored as having excessive litter rather than lacking litter.

Among wetland types, playas and aquatic bed sites had the highest overall URAP scores and marshes and mudflats the lowest, though not all differences were significant (figure 6). Marshes and mudflats had the lowest median hydrologic and plant species composition scores. Fresh meadows had the lowest median landscape scores, driven largely by lower buffer soil disturbance scores, whereas saline meadows had the lowest median vegetation structure scores, driven by lower litter accumulation scores. All of the forested-shrubland wetlands were scored as D for the woody regeneration metric due to excessive cover of invasive woody species and more than two-thirds of playas scored as C or D for the metric due to excessive branch die-off and stress in woody shrub species.

*Table 11. West Desert impact score estimates for stressors present in >10% of sites within the stratum. Estimates include percent of wetland area with impact score for each stressor and standard error in parentheses.*

| Stressor | Percent of Wetland Area with Impact Score | | | | |
|---|---|---|---|---|---|
| | Absent | Low | Medium | High | Very High |
| **Landscape** | | | | | |
| Livestock or excessive native grazing | 76.3 (6.0) | 13.2 (4.5) | 7.9 (4.0) | 2.6 (2.2) | 0 |
| Non-native or invasive plants | 36.8 (6.4) | 47.4 (6.4) | 15.8 (4.2) | 0 | 0 |
| Trash or dumping | 79.0 (4.7) | 15.8 (4.6) | 5.3 (3.2) | 0 | 0 |
| Soil disturbance by animals | 42.1 (6.3) | 44.7 (7.0) | 13.2 (4.9) | 0 | 0 |
| Hiking trails or vehicle ruts | 63.2 (6.8) | 34.2 (6.7) | 0 | 2.6 (2.3) | 0 |
| Roads or railroads | 71.1 (5.8) | 21.1 (5.3) | 7.9 (3.6) | 0 | 0 |
| Non-motorized recreation | 81.6 (5.5) | 18.4 (5.5) | 0 | 0 | 0 |
| **Hydrology** | | | | | |
| Agriculture runoff or manure | 63.2 (6.9) | 23.7 (5.8) | 7.9 (4.0) | 2.6 (2.3) | 2.6 (2.2) |
| Diking or impoundments | 68.4 (6.5) | 5.3 (2.8) | 15.8 (5.1) | 10.5 (4.5) | 0 |
| Canals, ditches | 76.3 (5.9) | 10.5 (4.3) | 10.5 (4.6) | 2.6 (2.2) | 0 |
| Control of flow and energy | 89.5 (4.2) | 2.6 (2.4) | 5.3 (3.3) | 2.6 (2.2) | 0 |
| **Plot soil** | | | | | |
| Trash or dumping | 84.2 (4.6) | 13.2 (4.7) | 2.6 (2.2) | 0 | 0 |
| Soil disturbance by animals | 50.0 (6.4) | 36.8 (5.5) | 13.2 (4.5) | 0 | 0 |
| Hiking trails or vehicle ruts | 79.0 (5.2) | 18.4 (5.3) | 0 | 2.6 (2.3) | 0 |
| **Plot vegetation** | | | | | |
| Livestock or excessive native grazing | 81.6 (5.6) | 10.5 (4.4) | 2.6 (2.3) | 5.3 (3.1) | 0 |
| Non-native or invasive plants | 50.0 (6.7) | 39.5 (6.8) | 10.5 (4.1) | 0 | 0 |
| Non-motorized recreation | 86.8 (4.5) | 13.2 (4.5) | 0 | 0 | 0 |

# Wetland Function

## Water Quality and Hydrologic Function

The Great Salt Lake stratum had the highest potential to improve water quality with 71% of the wetland area rated as medium for overall water quality function, whereas the Sevier Basin and West Desert were estimated to have mostly low potential, with 62% and 89% of area rated as low, respectively (table 15). Much of the study area was rated as medium for the site potential component of the water quality function. Of the metrics in this component, ponding was estimated to be greater in Great Salt Lake wetlands than the other strata, and cover of persistent vegetation was estimated to be very low at most Sevier Basin wetlands. In the Great Salt Lake and Sevier Basin, the landscape potential component was estimated as medium for most sites, whereas the majority of sites in the West Desert were estimated as low for this component. Among the landscape component metrics, more area in the Great Salt Lake stratum was estimated to be in land uses generating pollutants and to be surrounded by land uses generating pollutants. More than half of wetlands in the Great Salt Lake stratum were rated as high for the societal value component, whereas wetlands in the Sevier Basin and West Desert were typically rated as low. More Great Salt Lake wetlands were located in basins with TMDLs or water bodies listed as impaired.

Low hydrologic function was more prevalent than low water quality function throughout the study area, with all strata having the majority of wetland area estimated to provide low overall hydrologic function. All of the wetlands in the Great Salt Lake stratum were estimated as low for this function, whereas the Sevier Basin and West Desert were estimated to have 69% and 97%, respectively, of wetland area with low hydrologic function. Most sites lacked dense and rigid vegetation and had low storage capacity. For the site potential component of hydrologic function, the majority of wetlands in all strata were estimated as low and no area estimated as having high potential. The landscape potential component of the hydrologic function was mostly rated as medium in the Great Salt Lake and Sevier Basin (100% and 73% of the area, respectively), whereas 66% of the West Desert area received a low landscape potential rating. None of the West Desert sites were in areas where >25% of the contributing basin was covered with intensive human land uses whereas the majority of the Great Salt Lake and Sevier Basin strata

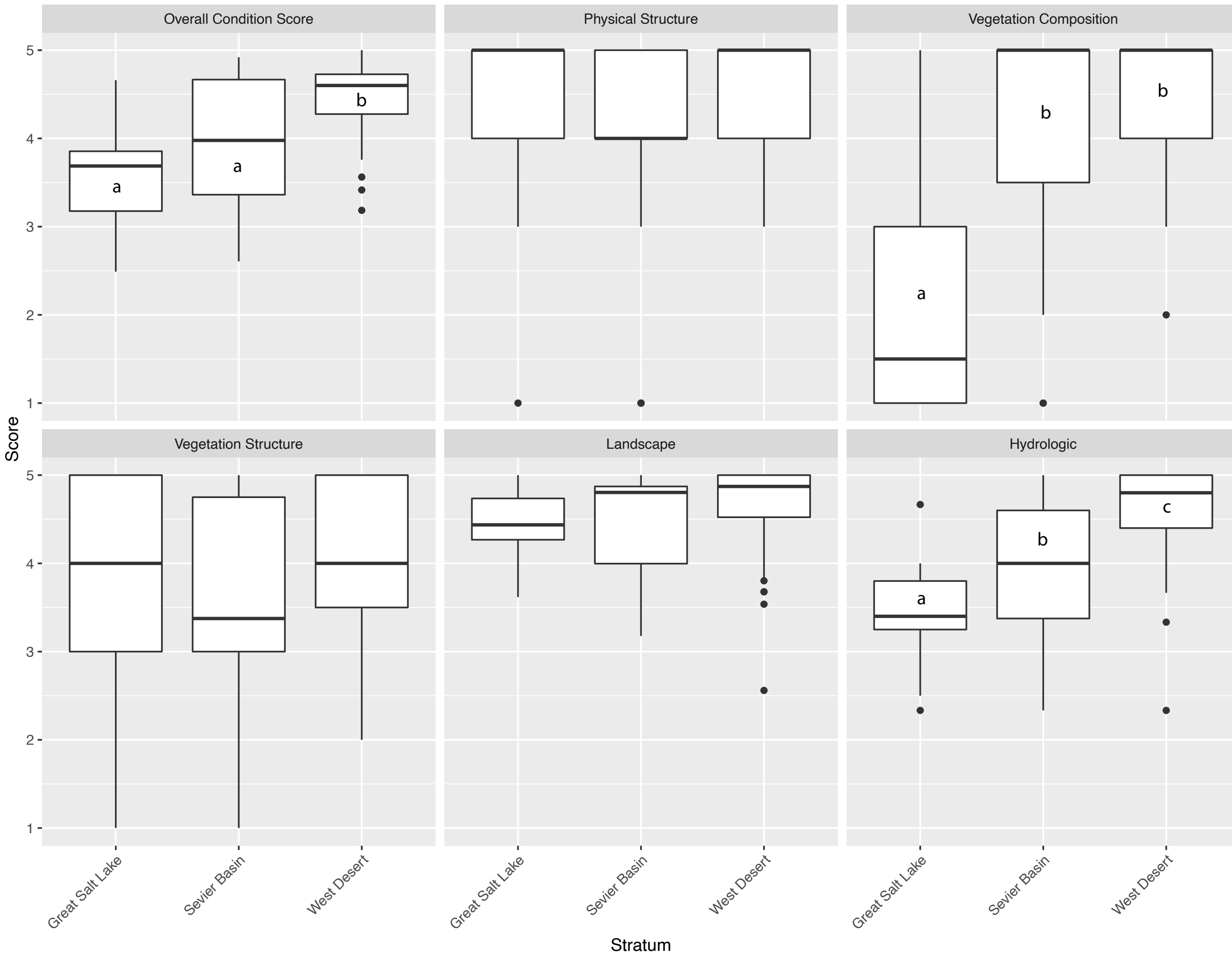


*Figure 5.* *Boxplots showing differences in overall and categorical URAP scores across strata. ANOVA and Tukey's HSD were used to test for significant differences between strata. Significantly different strata indicated by letter codes.*

were. All of the wetland area in the Great Salt Lake and West Desert strata, and 69% of area in the Sevier Basin, was estimated to provide low hydrologic functional societal value. Only the Sevier Basin riverine wetlands had evidence of flooding issues in the immediate or downstream area.

Wetland function ratings varied by HGM class. Riverine wetlands were typically scored as medium for water quality improvement and medium or high for hydrologic function. Most depressional wetlands were scored as low for both functions, except that depressional wetlands in the Great Salt Lake stratum were typically scored as medium for water quality improvement. Slope wetlands were scored as low for hydrologic function and low or medium for water quality improvement. Only one lake fringe site was surveyed; this site was rated as low for both functions.

## Columbia Spotted Frog

Suitable habitat for Columbia spotted frog was absent from the Great Salt Lake stratum and uncommon in the West Desert and Sevier Basin, based on habitat scores (table 16). Only 3.7% of wetland area in the study area is estimated to be suitable and 16.5% marginal for Columbia spotted frog breeding; the remaining area is poor. Only four sites were considered suitable for breeding, including one subjectively selected and two randomly selected sites in the West Desert and one site in the Sevier Basin. Sites in the West Desert included a site in Skull Valley with a flowing spring channel, a spring near Hansel Valley, and a spring on the eastern side of the Pilot Mountains. In the Sevier Basin, the suitable site was located along the shallow edge of Scipio Lake. None of these areas are within watersheds with known historical or current populations (Bailey and others, 2006). Sites with marginal habitat scores include eight sites in the West Desert (including one subjective), three in the Great Salt Lake,

***Table 12.*** *Condition metric results for the Great Salt Lake stratum showing the estimated percent of wetland area in each rank and standard error in parentheses. Metrics are sorted by the lowest to highest mean score, calculated by converting ranks to values as detailed in the text. Empty cells indicate ranks not scored for particular metrics.*

| Metric | Mean Score | A | A- | B | C | C- | D |
|---|---|---|---|---|---|---|---|
| Woody Debris[1] | NA | 0[2] | | | 0 | | 0 |
| Woody Species Regeneration[1] | NA | 0 | | 0 | 0 | | 0 |
| Hydroperiod | 2.18 | 5.9 (4.8) | | 0 | 47.1 (10.9) | | 47.1 (10.8) |
| Relative Native Cover | 2.18 | 17.7 (7.6)[2] | | | 11.8 (6.6) | 23.5 (8.6) | 47.1 (11.2) |
| Absolute Noxious Cover | 2.24 | 17.7 (7.3) | | 5.9 (5.3) | 17.7 (8.0) | | 58.8 (10.4) |
| Buffer Condition: Vegetation | 2.47 | 17.7 (7.6) | | 5.9 (5.1) | 29.4 (10.2) | | 47.1 (10.9) |
| Water Quality | 2.71 | 0 | | 5.9 (4.9) | 76.5 (8.7) | | 17.7 (7.4) |
| Horizontal Interspersion[3] | 3 | 14.3 (7.9) | | 14.3 (8.6) | 50.0 (12.4) | | 21.4 (10.5) |
| Algae Growth | 3.27 | 6.7 (5.6) | | 26.7 (9.2) | 60.0 (10.9) | | 6.7 (6.0) |
| Litter Accumulation | 3.82 | 52.9 (11.4)[2] | | | 35.3 (9.9) | | 11.8 (7.0) |
| Overall Buffer | 4.03 | 23.5 (8.8) | | 64.7 (10.3) | 5.9 (5.1) | 5.9 (5.3) | 0 |
| Buffer Condition: Soil | 4.24 | 52.9 (10.9) | | 29.4 (10.6) | 11.8 (7.1) | | 5.9 (5.3) |
| Soil Disturbance | 4.35 | 58.8 (10.7) | | 29.4 (10.0) | 5.9 (5.2) | | 5.9 (5.3) |
| Turbidity and Pollutants | 4.62 | 75.0 (14.7) | | 12.5 (10.2) | 12.5 (11.0) | | 0 |
| Percent Intact Landscape | 4.94 | 94.1 (4.9) | | 5.9 (4.9) | 0 | | 0 |
| Buffer Width | 5.0 | 100 (0) | 0 | 0 | 0 | | 0 |
| Percent Buffer | 5.0 | 100 (0) | 0 | 0 | 0 | | 0 |
| Connectivity | 5.0 | 100 (0) | | 0 | 0 | | 0 |

[1]Not recorded at any sites in stratum.
[2]Recorded as AB rank.
[3]Interspersion not included in calculation of mean interspersion for shallow water, aquatic bed, and playa sites unless site mixed with another wetland type.

***Table 13.*** *Condition metric results for the Sevier Basin stratum showing the estimated percent of wetland area in each rank and standard error in parentheses. Metrics are sorted by the lowest to highest mean score, calculated by converting ranks to values as detailed in the text. Empty cells indicate ranks not scored for particular metrics.*

| Metric | Mean Score | A | A- | B | C | C- | D |
|---|---|---|---|---|---|---|---|
| Horizontal Interspersion[1] | 2.54 | 7.7 (6.3) | | 15.4 (9.3) | 38.5 (13.2) | | 38.5 (12.3) |
| Woody Species Regeneration | 3 | 33.3 (13.0) | | 0 | 33.3 (11.5) | | 33.3 (9.7) |
| Woody Debris[2] | 3 | 0[2] | | | 100 (0) | | 0 |
| Hydroperiod | 3.46 | 19.2 (6.8) | | 30.8 (8.1) | 38.5 (8.5) | | 11.5 (3.2) |
| Water Quality | 3.46 | 34.6 (5.9) | | 7.7 (5.4) | 42.3 (8.0) | | 15.4 (6.1) |
| Litter Accumulation[3] | 3.85 | 50.0 (7.0)[2] | | | 42.3 (6.8) | | 7.7 (4.9) |
| Buffer Condition: Soil | 3.88 | 30.8 (7.6) | | 42.3 (8.1) | 19.2 (5.8) | | 7.7 (4.4) |
| Soil Disturbance | 3.92 | 38.5 (7.6) | | 38.5 (7.7) | 11.5 (5.3) | | 11.5 (5.1) |
| Relative Native Cover[3] | 3.96 | 64.0 (7.4)[2] | | | 16.0 (6.9) | 8.0 (4.7) | 12.0 (5.12) |
| Turbidity and Pollutants[2] | 4 | 75.0 (20.7) | | 0 | 0 | | 25.0 (20.7) |
| Buffer Condition: Vegetation | 4.15 | 50.0 (8.2) | | 30.8 (8.4) | 11.5 (5.1) | | 7.7 (4.3) |
| Algae Growth[2] | 4.25 | 50.0 (16.3) | | 25.0 (14.9) | 25.0 (13.9) | | 0 |
| Absolute Noxious Cover | 4.27 | 69.2 (6.4) | | 11.5 (5.3) | 7.7 (4.4) | | 11.5 (5.4) |
| Percent Intact Landscape | 4.38 | 57.7 (6.2) | | 23.1 (6.8) | 19.2 (5.5) | | 0 |
| Overall Buffer | 4.42 | 53.9 (5.6) | | 42.3 (6.4) | 3.9 (3.2) | 3.9 (3.2) | 0 |
| Buffer Width | 4.88 | 84.6 (5.8) | 7.7 (4.5) | 7.7 (4.4) | 0 | | 0 |
| Percent Buffer | 4.94 | 88.5 (4.9) | 11.5 (4.9) | 0 | 0 | | 0 |
| Connectivity | 4.96 | 96.2 (3.6) | | 3.9 (3.6) | 0 | | 0 |

[1]Interspersion not included in calculation of mean interspersion for shallow water, aquatic bed, and playa sites unless site mixed with another wetland type.
[2]Not scored when attribute not present in wetland.
[3]Recorded as AB rank.

***Table 14.*** *Condition metric results for the West Desert stratum showing the estimated percent of wetland area in each rank and standard error in parentheses. Metrics are sorted by the lowest to highest mean score, calculated by converting ranks to values as detailed in the text. Empty cells indicate ranks not scored for particular metrics.*

| Metric | Mean Score | A | A- | B | C | C- | D |
|---|---|---|---|---|---|---|---|
| Woody Debris | NA | 0[2] | | | 0 | | 0 |
| Horizontal Interspersion[1] | 3.3 | 15.0 (7.3) | | 40.0 (8.7) | 25.0 (7.3) | | 20.0 (8.2) |
| Relative Native Cover | 4.24 | 68.4 (6.3)[2] | | | 18.4 (5.2) | 13.2 (5.2) | 0 |
| Litter Accumulation | 4.26 | 63.2 (6.7)[2] | | | 36.8 (6.7) | | 0 |
| Woody Species Regeneration | 4.33 | 73.3 (10.6) | | 0 | 20.0 (9.3) | | 6.7 (5.8) |
| Hydroperiod | 4.37 | 65.8 (6.2) | | 15.8 (4.7) | 13.2 (4.4) | | 5.3 (3.2) |
| Buffer Condition: Soil | 4.39 | 52.6 (6.3) | | 34.2 (5.7) | 13.2 (5.0) | | 0 |
| Soil Disturbance | 4.47 | 52.6 (5.8) | | 42.1 (4.8) | 5.3 (3.1) | | 0 |
| Percent Intact Landscape | 4.53 | 73.7 (5.8) | | 10.5 (4.0) | 13.2 (4.5) | | 2.6 (2.3) |
| Water Quality | 4.55 | 71.1 (6.8) | | 18.4 (5.8) | 7.9 (3.9) | | 2.6 (2.2) |
| Buffer Condition: Vegetation | 4.55 | 60.5 (6.4) | | 34.2 (6.5) | 5.3 (3.2) | | 0 |
| Turbidity and Pollutants | 4.62 | 69.2 (11.1) | | 23.1 (10.5) | 7.7 (6.6) | | 0 |
| Overall Buffer | 4.69 | 68.4 (6.3) | | 31.6 (6.3) | 0 | 0 | 0 |
| Algae Growth | 4.79 | 78.6 (9.2) | | 21.4 (9.2) | 0 | | 0 |
| Absolute Noxious Cover | 4.79 | 89.5 (4.2) | | 5.3 (3.4) | 2.6 (2.2) | | 2.6 (2.2) |
| Connectivity | 4.84 | 86.8 (4.3) | | 10.5 (4.2) | 2.6 (2.4) | | 0 |
| Buffer Width | 4.89 | 84.2 (4.5) | 10.5 (4.1) | 5.3 (3.3) | 0 | | 0 |
| Percent Buffer | 4.97 | 94.7 (3.3) | 5.3 (3.3) | 0 | 0 | | 0 |

[1]Interspersion not included in calculation of mean interspersion for shallow water, aquatic bed, and playa sites unless site mixed with another wetland type.
[2]Recorded as AB rank.

and two in the Sevier Basin (including one subjective), and at one subjective site in the Bear River watershed. Additional information would need to be evaluated to determine if any of the sites were suitable for introduction efforts. All four of the suitable sites were impacted by livestock grazing, and the site at Scipio Lake may be unsuitable due to proximity to a major road, very turbid water, and higher water temperatures.

We surveyed one site within a wetland complex that is a known Columbia spotted frog breeding location, Coyote Springs in Tule Valley. This site received a Columbia spotted frog habitat score of 3.33, receiving ratings of D for the north shore and vegetation cover metrics and A or B ratings for the remaining metrics. The site was densely vegetated with bulrush and rushes with a dense litter layer and no openings in the water. The site did not overlap any locations with Columbia spotted frog egg masses documented between 2015 and 2019 by Utah Division of Wildlife Resources' biologists, though egg masses were found within a few meters of the edge of the AA and in many other areas of the wetland complex (K. Wheeler, unpublished information, December 10, 2019). The site we surveyed is likely not suitable for Columbia spotted frog breeding but could potentially be suitable if the vegetation were opened up.

## Sensitive Ecological Features

### Wildlife Species

Surveyors noted wildlife species observed during surveys, including signs such as tracks and droppings, and took photographs to document any amphibians observed. Identification of other wildlife was at the discretion and ability of surveyors; observations were sometimes recorded very generally, such as "fish" or "bird." Wildlife observation data are presented as a minimum list of wildlife use in the study area and should not be considered a complete list because wildlife observations were not a focus of the survey method. Birds, mammals, amphibians, reptiles, and invertebrates were documented in all strata, and fish in all but the Sevier Basin (table 17). No state or federally sensitive wildlife species were documented. Evidence of wildlife from at least four taxonomic groups (e.g., bird, amphibian, etc.) were documented in each wetland type and at least 75% of sites of each wetland type had wildlife observations (table 18). Aquatic beds had the highest mean number of distinct species and playas had the fewest.

Surveyors also conducted a brief focused survey for aquatic mollusks at each site, encountering evidence of aquatic mollusks at 36 sites. Live mollusks were most frequently encountered in the Great Salt Lake stratum and least common in the Sevier Basin, following the frequency with which sites had surface water in each stratum. Collections of mollusks were made at 82% of sites in the Great Salt Lake stratum, with live mollusks found at 8 of 17 sites. In the West Desert stratum, mollusks were documented at 32% of sites, with live mollusks found at 5 of 38 sites. Mollusks were documented at 35% of sites in the Sevier Basin, with live mollusks found at only 2 of 26 sites. The live mollusks were found in two adjacent impoundments in the Clear Lake WMA. Four additional sites that were deemed not to be target wetland in the Sevier Basin had evidence of empty mollusk shells. Live snails were found in a variety of wetland types, including aquatic bed, marsh, mudflat, and fresh and saline meadows.

Three invasive species of aquatic mollusks were encountered: Big-Eared Radix (*Radix auricularia*), New Zealand Mudsnail (*Potamopyrgus antipodarum*), and red rimmed melania (*Melanoides tuberculata*). We documented empty shells of Big-Eared Radix on the shore of Scipio Lake, live New Zealand Mudsnail in the Salt Wells area, empty shells of New Zealand Mudsnail in Snake Valley, and empty shells of red rimmed melania at Blue Lake WMA.

## Sensitive Plant Species

We recorded six plant species considered sensitive within the state of Utah: *Cleomella plocasperma* (twisted cleomella), *Epilobium leptophyllum* (bog willowherb), *Puccinellia simplex* (California alkaligrass), *Solidago spectabilis* (Nevada goldenrod), *Stuckenia filiformis* (fineleaf pondweed), and *Thelypodium sagittatum* (arrow thelypody) (M. Wheeler, Rare Plant Conserva-

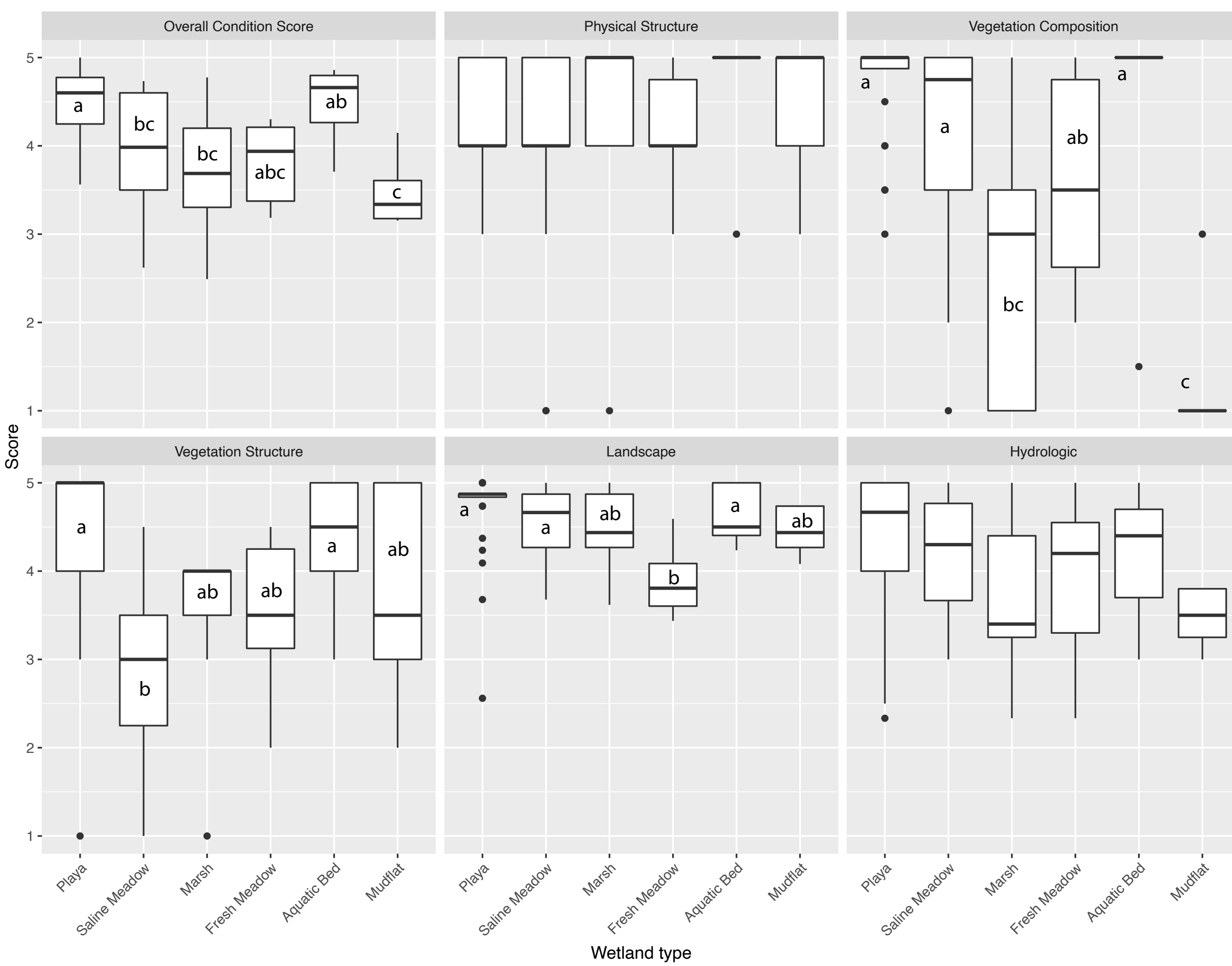


***Figure 6.*** *Boxplot comparisons of overall and categorical URAP scores by wetland type using random sites from this study only. Forested-shrubland and shallow water wetlands are excluded due to low sample size. Letters indicate significant differences from Tukey's HSD test. Sample sizes are: playa = 32, saline meadow = 18, marsh = 9, fresh meadow = 6, aquatic bed = 7, mudflat = 5.*

***Table 15.*** *Overall and categorical scores for water quality improvement and hydrologic functions, including estimated percent of wetland area performing each component at low, medium, and high levels, with standard error in parentheses.*

| Metric | Low | Medium | High |
|---|---|---|---|
| **Great Salt Lake** | | | |
| *Water Quality Improvement* | | | |
| *Overall score* | *5.9 (4.8)* | *70.6 (8.6)* | *23.5 (8.5)* |
| Site potential to improve water quality | 5.9 (4.8) | 52.9 (10.6) | 41.2 (10.6) |
| Landscape potential to support water quality function | 0 | 100 (0) | 0 |
| Societal value | 17.7 (7.6) | 29.4 (8.5) | 52.9 (7.9) |
| *Hydrologic Function* | | | |
| *Overall score* | *100 (0)* | *0* | *0* |
| Site potential to reduce flooding and erosion | 58.8 (10.1) | 41.2 (10.1) | 0 |
| Landscape potential to support hydrologic function | 0 | 100 (0) | 0 |
| Societal value | 100.0 (0) | 0 | 0 |
| **Sevier Basin** | | | |
| *Water Quality Improvement* | | | |
| *Overall score* | *61.5 (5.7)* | *34.6 (6.3)* | *3.9 (3.2)* |
| Site potential to improve water quality | 26.9 (7.9) | 69.2 (8.2) | 3.9 (3.5) |
| Landscape potential to support water quality function | 23.1 (6.7) | 57.7 (8.9) | 19.2 (6.0) |
| Societal value | 65.4 (6.5) | 3.9 (3.4) | 30.8 (5.6) |
| *Hydrologic Function* | | | |
| *Overall score* | *69.2 (4.9)* | *15.4 (6.0)* | *15.4 (5.6)* |
| Site potential to reduce flooding and erosion | 61.5 (7.9) | 15.4 (6.2) | 23.1 (7.1) |
| Landscape potential to support hydrologic function | 23.1 (5.6) | 73.1 (6.4) | 3.9 (3.1) |
| Societal value | 69.2 (4.9) | 7.7 (4.5) | 23.1 (5.0) |
| **West Desert** | | | |
| *Water Quality improvement* | | | |
| *Overall score* | *89.5 (4.2)* | *10.5 (4.2)* | *0* |
| Site potential to improve water quality | 15.8 (4.4) | 65.8 (6.9) | 18.4 (5.7) |
| Landscape potential to support water quality function | 65.8 (6.8) | 31.6 (6.9) | 2.6 (2.2) |
| Societal value | 92.1 (2.5) | 5.3 (2.7) | 2.6 (2.2) |
| *Hydrologic Function* | | | |
| *Overall score* | *97.4 (2.4)* | *2.6 (2.4)* | *0* |
| Site potential to reduce flooding and erosion | 79.0 (6.2) | 18.4 (5.7) | 2.6 (2.4) |
| Landscape potential to support hydrologic function | 65.8 (6.7) | 34.2 (6.7) | 0 |
| Societal value | 100.0 (0) | 0 | 0 |

***Table 16.*** *Estimates of Columbia spotted frog breeding habitat in each stratum. Estimates of percent of wetlands in each category are reported followed by the standard error in parentheses.*

| Subpopulation | Habitat Condition | | |
|---|---|---|---|
| | Suitable | Marginal | Poor |
| Study Area | 3.7 (2.1) | 16.5 (4.1) | 79.8 (4.2) |
| Great Salt Lake | 0 | 17.7 (8.4) | 82.4 (8.4) |
| Sevier Basin | 3.9 (3.3) | 3.9 (3.4) | 92.3 (4.7) |
| West Desert | 5.3 (3.3) | 18.4 (5.5) | 76.3 (5.6) |

*Table 17. Wildlife observations during wetland surveys by stratum.*

| Taxonomic Group | Great Salt Lake | West Desert | Sevier Basin |
|---|---|---|---|
| **Birds** | swallow, ibis, duck, wading bird, goose, shorebird, grebe, tern, American avocet, black-necked stilt, coot, yellowlegs, pelican | shorebird, duck, red-winged blackbird, American avocet, sandhill crane, owl, ibis, songbird | duck, American goldfinch, mourning dove, owl, hummingbird, songbird, raptor, swallow, ibis, stilt |
| **Mammals** | mammal, raccoon, rodent | coyote, pronghorn, raccoon, mammal, rabbit | coyote, beaver, deer, rodent, rabbit, pronghorn |
| **Amphibians and Reptiles** | frog | horned lizard, snake, lizard, toad | lizard |
| **Fish** | carp | fish, carp | |
| **Invertebrate** | aquatic mollusks, dragonfly/ damselfly, ladybug, mosquito, spider | aquatic mollusks, dragonfly/damselfly, spider, grasshopper, pinacate beetle, ladybug, praying mantis, pillbug, ant, wasp | aquatic mollusks, dragonfly/ damselfly, butterfly, mosquito, cabbage white butterfly, aphid, locust, mollusk, grasshopper, aquatic insect, praying mantis |

*Table 18. Percent of surveyed sites with observations of wildlife in each taxonomic group or no wildlife observed and mean number of distinct species recorded per site, by wetland type. Values above 50% are in bold.*

| Wetland Type | # Sites | Mean Distinct Species | None (%) | Amphibian (%) | Reptile (%) | Bird (%) | Fish (%) | Mammal (%) | Mollusk (%) | Insect (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| Aquatic Bed | 7 | 6.4 | 0.0 | 14.3 | 0.0 | **85.7** | **57.1** | 14.3 | **85.7** | **85.7** |
| Fresh Meadow | 8 | 3.4 | 12.5 | 0.0 | 12.5 | **62.5** | 0.0 | 12.5 | 37.5 | **87.5** |
| Marsh | 9 | 5.0 | 0.0 | 0.0 | 0.0 | **77.8** | 22.2 | 11.1 | **88.9** | **88.9** |
| Mudflat | 6 | 3.7 | 0.0 | 0.0 | 0.0 | **66.7** | 16.7 | 16.7 | **83.3** | **66.7** |
| Playa | 34 | 1.8 | 26.5 | 0.0 | 11.8 | 11.8 | 0.0 | **52.9** | 23.5 | 23.5 |
| Saline Meadow | 19 | 3.2 | 5.3 | 5.3 | 5.3 | 36.8 | 5.3 | 10.5 | 36.8 | **94.7** |
| Shallow Water | 1 | 5.0 | 0.0 | 0.0 | 0.0 | **100.0** | 0.0 | 0.0 | **100.0** | **100.0** |
| Woodland-Shrubland | 3 | 5.0 | 0.0 | 0.0 | 0.0 | **100.0** | 0.0 | 33.3 | 0.0 | **100.0** |

tion Coordinator for the State of Utah, written communication, February 9, 2018). Species were encountered at one site each with an estimated canopy cover of ≤2% except *S. filiformis*, which was estimated to have 15% cover at the one site where it was encountered. Sites with sensitive plant species included two sites on BLM land (one with two sensitive species) and three privately owned sites. One BLM site in Millard County had two potential species of greatest conservation need (PSGCN). All but *P. simplex* are listed as PSGCN (table 19). *P. simplex* is listed as status uncertain. The species is only known from Utah and California and is considered a rare or endangered species in California, though some sources believe that populations in Utah are introduced (Anderton and Barkworth, 2000). Collections were made for each species, and vouchers will be submitted to the Intermountain Herbarium at Utah State University in Logan, Utah.

## Wetland Vegetation

We recorded 732 encounters with 148 unique plant species across all survey sites, including 63 species found at only one site. Non-native species composed 25% of these records. The Great Salt Lake stratum had lower species diversity than both the Sevier Basin and West Desert strata, with only 36 different species recorded, and the highest proportion of non-native species. The Sevier Basin and West Desert strata had greater and more similar species diversity with 99 and 117 species, respectively. We were unable to identify 55 of the plants we encountered to species, of which 38 were identified as the genera *Atriplex* (saltbush), *Bassia* (smotherweed), or *Chenopodium* (goosefoot), all members of the Chenopodiaceae family. Mature fruit is often required for positive identification of this family, which typically fruit late in the growing season. Other genera occasionally not identified to species include *Tamarix* (tamarisk), *Typha* (cattail), *Polygonum* (knotweed), and *Lemna* (duckweed). All *Typha* in the study area are native and have a C-value of 3 and all *Tamarix* were considered introduced, noxious, and to have a facultative (FAC) wetland indicator, so we included unidentified members of each genus in the vegetation community analysis. All *Bassia* identified only to genus were assumed to be either *Bassia hyssopifolia* (fivehorn smothered) or *Bassia scoparia* (burning bush), which are both introduced annuals and vegetatively similar to one another. They are also distinct from the perennial *Bassia americana* (green molly), the only native *Bassia* known in Utah. We assumed all unidentified *Bassia* to be introduced but did not assign a wetland indicator. All but eight unidentified plant records had less than 2% cover.

## Plant Community Composition Metrics

Great Salt Lake wetlands had significantly higher cover of noxious weeds and significantly lower relative native cover and mean C-value than the other two strata (figure 7). Mean C-values across the study area ranged from 0.3 to 7. The lowest mean C-value was found at a saline meadow on the eastern shore of Antelope Island in the Great Salt Lake stratum and the highest mean C-value was found at an aquatic bed in Clear Lake WMA in the Sevier Basin. Half of the sites in the Great Salt Lake stratum had mean C-values of 1.5 versus less than 25% of sites in both the Sevier Basin and West Desert strata. Mean relative native cover was about 55%, 84%, and 93%, for the Great Salt Lake, Sevier Basin, and West Desert strata, respectively. Mean absolute noxious cover was about 28%, 5%, and <1% for the Great Salt Lake, Sevier Basin, and West Desert strata, respectively. All strata had at least one site with 100% relative native cover, no noxious weeds, and no non-native species.

## Noxious Weed Plant Species

Eight noxious weed species were documented in the study area, including six Class 3, one Class 2, and one Class 4 noxious weed (table 20). Class 3 species are widely spread species where management should focus on containing new populations; Class 2 species are considered a high priority for control and are at concentrations where control or eradication may be possible; and Class 4 are noxious weeds that pose a threat through the retail sale or propagation in nurseries. Phragmites was the most widespread and abundant noxious weed species, found at 14 sites overall and estimated to occupy almost 28% of wetland

***Table 19.*** *Sensitive plant species encountered during wetland surveys. PSGCN stands for Potential Species of Greatest Conservation Need.*

| Species | Common Name | Wetland Type | County Locations | State Sensitive Status | NatureServe Status |
|---|---|---|---|---|---|
| *Cleomella plocasperma* | twisted cleomella | Fresh Meadow | Millard | PSGCN | critically imperiled |
| *Epilobium leptophyllum* | bog willowherb | Fresh Meadow | Tooele | PSGCN | - |
| *Puccinellia simplex* | California alkalaigrass | Playa | Box Elder | Uncertain | critically imperiled |
| *Solidago spectabilis* | Nevada goldenrod | Fresh Meadow | Millard | PSGCN | critically imperiled |
| *Stuckenia filiformis* | fineleaf pondweed | Aquatic Bed | Box Elder | PSGCN | - |
| *Thelypodium sagittatum* | arrow thelypody | Saline Meadow | Tooele | PSGCN | - |

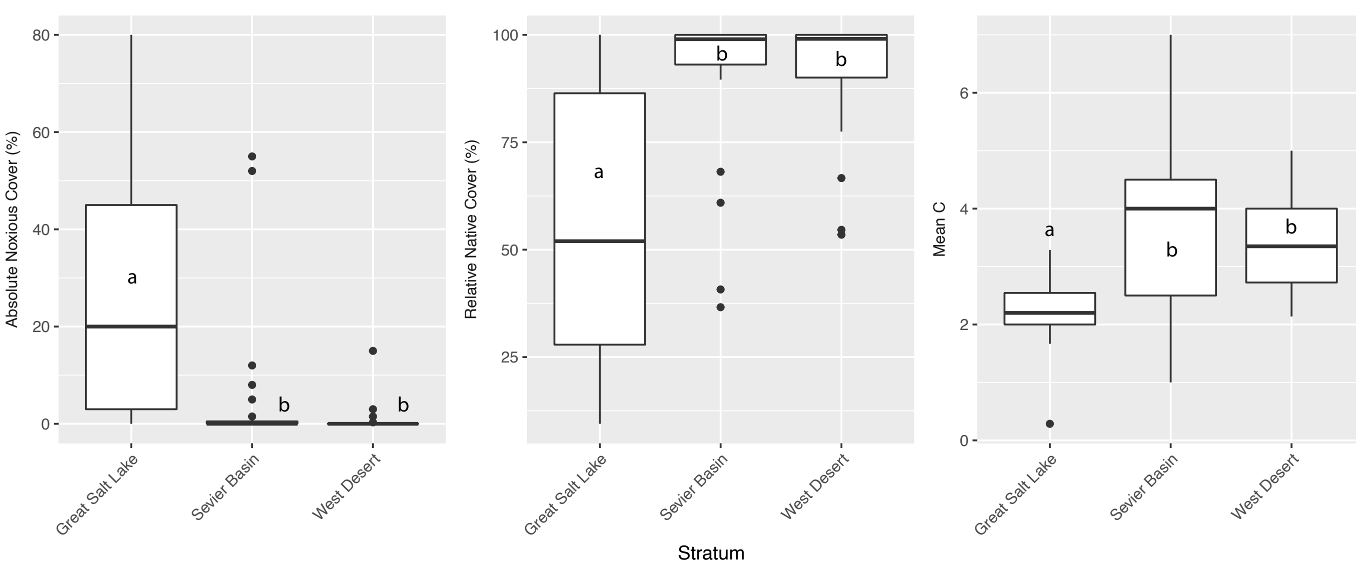


***Figure 7.*** *Boxplots showing differences in selected vegetation metrics across strata. Tukey's HSD or Wilcoxon pairwise tests were used to test for significant differences between strata, with significantly different strata indicated by letter.*

***Table 20.*** *Noxious weed species detected in the study area, including estimates of percent cover in each stratum and standard error in parentheses. The number of sites where each species was detected follows the cover estimates. Estimates for* Lythrum salicaria *were not made because it was only found at one manually selected site.*

| Scientific Name (Common Name) | Noxious Weed Listing | Wetland Indicator | Study Area | Great Salt Lake | Sevier Basin | West Desert |
|---|---|---|---|---|---|---|
| *Cardaria draba* (white top) | Class 3 | None listed | 0.4 (3.5) | 0 (0) | 1.8 (8.7) n=2 | 0.4 (2.4) n=1 |
| *Cirsium arvense* (Canada thistle) | Class 3 | FACU | 0.02 (0.1) | 0 (0) | 0.02 (0.1) n=1 | 0.03 (0.2) n=1 |
| *Elaeagnus angustifolia* (Russian olive) | Class 4 | FAC | 0.05 (0.50) | 0 (0) | 0.4 (1.4) n=3 | 0 (0) n=0 |
| *Elymus repens* (quackgrass) | Class 3 | FAC | 0.03 (0.3) | 0 (0) | 0.2 (1.0) n=1 | 0.01 (0.08) n=1 |
| *Lepidium latifolium* (broadleaf pepperweed) | Class 3 | FAC | 0.04 (0.4) | 0.06 (0.2) n=1 | 0.2 (1..0) n=3 | 0 (0.02) n=1 |
| *Lythrum salicaria* (purple loosestrife) | Class 2 | OBL | NA | NA | NA | NA |
| *Phragmites australis* ssp. *australis* (European common reed) | Class 3 | FACW | 7.6 (19.0) | 27.8 (27.5) n=13 | 0 (0) | 0 (0.02) n=1 |
| *Tamarix* spp.[1] (tamarisk) | Class 3 | FAC | 0.4 (3.4) | 0.06 (0.2) n=2 | 2.5 (9.6) n=6 | 0.08 (0.5) n=2 |

[1]Utah lists only *Tamarix ramosissimum* (saltcedar) as noxious, but all species of Tamarisk were considered noxious for this study.

area within the Great Salt Lake stratum, though only found at one site outside that stratum. *Tamarix* spp. was the second most abundant species, found at 10 random sites and one manually selected site, and was most abundant in the Sevier Basin, where it is estimated to occupy 2.5% of wetland area. *Cardaria draba* (white top) was the only other noxious weed estimated to cover more than 1% of wetland area in a stratum, with an estimated 1.8% of area in the Sevier Basin. *Lythrum salicaria* (purple loosestrife), the only recorded Class 2 species, was encountered at one manually selected site in the West Desert.

## Reference Condition

### Least Disturbed Sites

We had data from 37 or more marsh, saline meadow, fresh meadow, and playa sites, between 12 and 20 mudflat, aquatic bed, and forested-shrubland sites, and 4 shallow water sites to use in the analysis of least and most disturbed conditions. Ecological attributes for each wetland type based on these sites are summarized in table 21. We omitted shallow water sites from the analysis due to low sample size. Impact thresholds to select least disturbed sites ranged from <1 for playa wetlands to <9 and <10 for forested-shrublands and mudflats (table 22). Impact thresholds to select most disturbed sites were set at 11 or higher, except for playa wetlands, which had a threshold of ≥8. We did not conduct any additional analyses for shallow water, mudflat, and forested-shrubland wetlands due to small sample sizes and because, for the latter two wetland types, the least disturbed wetlands had high impact levels that did not differ much from the most disturbed sites.

We identified 40 sites as least disturbed for the remaining wetland types, including 7 saline meadow, 9 fresh meadow, 9 marsh, and 15 playa sites. Comparison of attributes between least and most disturbed sites is in appendix F. In selecting least disturbed sites, we did not directly filter out sites that had high cover of non-native species, unlike previous studies by the UGS (Menuz and Sempler, 2018; Menuz and McCoy-Sulentic, 2019). However, at least 90% of the vegetation cover at all of the least disturbed sites was composed of native vegetation.

Least disturbed fresh meadow sites were mostly found in the West Desert in Snake Valley or Fish Springs NWR. These sites had an average cover weighted mean C of 3.9 and very high relative native cover and often had some surface water input from nearby springs. Interestingly, a couple of most disturbed fresh meadows that were highly impacted by grazing activities in the Snake Valley area had cover-weighted mean C-values in the range of least disturbed sites, suggesting that high soil disturbance may not be a limiting factor in floristic quality in this wetland type.

***Table 21.** Summary of ecological attributes by wetland types found in the Central Basin and Range ecoregion, based on surveys by the UGS from 2013 to 2020. Summary values for all non-mixed sites include the mean with the range in parentheses. Values are derived from unweighted data from both random and subjective sites.*

| Metric | Aquatic Bed | Fresh Meadow | Mudflat | Marsh | Playa | Saline Meadow | Forested- Shrub Wetland |
|---|---|---|---|---|---|---|---|
| # Sites | 12 | 44 | 20 | 64 | 57 | 37 | 13 |
| Elevation (m) | 1294 (1282-1400) | 1437 (1285-1697) | 1296 (1280-1400) | 1309 (1280-1644) | 1320 (1281-1497) | 1321 (1280-1533) | 1394 (1290-1592) |
| Soil Salinity (5:1 h20:soil by volume) ($\mu$S) | 902.0 (902.0-902.0) | 541.3 (125-1850) | 4021.4 (150-7850) | 1205.8 (160-2670) | 9452.3 (503-18560) | 4404.4 (265-19800) | 367.2 (98-1016) |
| % Shallow Water (<20 cm) | 21.1 (0-100) | 8.9 (0-95) | 11 (0-100) | 36.6 (0-100) | 0 (0-0.5) | 8.5 (0-100) | 14.2 (0-90) |
| % Deep Water (>20 cm) | 78.5 (0-100) | 0.2 (0-2) | 4 (0-80) | 9.2 (0-98)) | 0 (0-0) | 0.2 (0-5) | 1.8 (0-16) |
| Total Water Cover (%) | 99.6 (95-100) | 9.2 (0-95) | 14.9 (0-100) | 46 (0-100) | 0 (0-0.5) | 8.6 (0-97.5) | 16.1 (0-90) |
| Surface Water pH | 8.9 (6.5-9.9) | 7.6 (7.2-8) | 8.8 (8-10.8) | 7.8 (6.4-9.2) | 9 (7.7-9.8) | 8.3 (7.4-9.3) | 7.8 (7.2-8.6) |
| Surface Water EC ($\mu$S) | 2300.2 (1069-4530) | 1778.3 (560-5350) | 3235 (2490-4090) | 3019.6 (783-9800) | 3914 (3498-4330) | 7810.6 (2630-13320) | 1230.5 (393-3132) |
| Species Richness (# of Species) | 3.5 (1-17) | 23 (8-38) | 7.8 (1-27) | 12.3 (1-26) | 5.7 (1-17) | 11.8 (2-27); | 32.2 (9-53) |
| Herbaceous Species Richness (# of Species) | 1.5 (0-13) | 22.2 (8-35)) | 7.2 (1-26) | 11.3 (1-26) | 4.4 (0-16) | 11.2 (1-27) | 26.8 (7-44) |
| Aquatic Herbaceous Richness (# of Species) | 1.8 (1-3) | 0.2 (0-2) | 0.3 (0-2) | 0.8 (0-3) | 0 (0-0) | 0.1 (0-1) | 0.6 (0-2) |
| Shrub Richness (# of Species) | 0.1 (0-1) | 0.1 (0-2) | 0 (0-0) | 0.1 (0-1) | 1.3 (0-4) | 0.3 (0-2) | 1.9 (0-5) |
| Tree Richness (# of Species) | 0.1 (0-1) | 0.2 (0-2) | 0.2 (0-1) | 0.1 (0-2) | 0.1 (0-1) | 0.1 (0-1) | 2.5 (0-5) |
| Absolute cover of Emergents[1] (%) | 1.7 (0-16) | 83.1 (18.9-144.6) | 55.6 (4.2-104) | 63.7 (12.8-113.6) | 14.1 (0-77) | 64.4 (17.1-111.8) | 66.1 (31.4-92.5) |
| Absolute cover of Aquatic Species[2] (%) | 71.9 (0.5-107) | 0.1 (0-1) | 2.6 (0-22) | 9.6 (0-92.5) | 0 (0-0) | 0.1 (0-1) | 1.8 (0-20) |
| Absolute Shrub Cover (%) | 0 (0-0.5) | 0 (0-1) | 0 (0-0) | 0 (0-0.5) | 9.3 (0-40.1) | 0.5 (0-5) | 10.4 (0-32) |
| Absolute Tree Cover (%) | 0 (0-0.5) | 0.1 (0-2) | 3 (0-55) | 0.1 (0-1) | 0.3 (0-15) | 0.2 (0-6) | 23.3 (0-78) |
| Relative Native Cover (%) | 99.7 (96.6-100) | 74.1 (3-100) | 36.1 (0-100) | 72.2 (0-100) | 85.5 (11.4-100) | 78 (4.7-100) | 39.8 (4.4-90.7) |
| Mean C[3] | 3.2 (2.3-7) | 2.5 (0.5-4.2) | 2.4 (0-4.4) | 2.4 (0-4) | 3.4 (1.3-5.5) | 2.5 (0.3-4.3) | 1.7 (0.5-2.3) |
| Cover Weighted Mean C[4] | 3.6 (2.1-7) | 2.7 (0.1-4.8) | 1.2 (0-4.2) | 2.3 (0-4.3) | 3.9 (0.6-7.8) | 2.3 (0.1-3.3) | 1.4 (0.1-3.6) |
| Absolute Cover of Noxious Species (%) | 0.1 (0-1) | 4.4 (0-45.6) | 41.1 (0-99) | 18.4 (0-100) | 0.6 (0-15.1) | 9.3 (0-73) | 33.2 (0.8-92.2) |

[1] Emergent species include grass, graminoid, sedge, rush, vine, forb, and aquatic emergent.
[2] Aquatic species include aquatic floating, and aquatic submergent.
[3] Calculated using only species with known C-value.
[4] At sites where ≥80% of plant species by cover had known nativity, C values, or wetland indicator status.

*Table 22. Impact scores used to determine least and most disturbed sites by wetland type.*

| Wetland Type | # Sites | Least Disturbed | | | Most Disturbed | | |
|---|---|---|---|---|---|---|---|
| | | Impact Threshold | # Sites | % Sites | Impact Threshold | # Sites | % Sites |
| Marsh | 64 | <4 | 9 | 14.1 | >=13 | 17 | 26.6 |
| Saline Meadow | 37 | <2 | 7 | 18.9 | >=12 | 9 | 24.3 |
| Fresh Meadow | 44 | <5 | 9 | 20.5 | >=11 | 12 | 27.3 |
| Mudflat | 20 | <10 | 3 | 15.0 | >=14 | 5 | 25 |
| Playa | 57 | <2 | 15[1] | 17.5 | >=8 | 14 | 24.6 |
| Aquatic Bed | 12 | <5 | 2 | 16.7 | >=11 | 4 | 33.3 |
| Forested-Shrubland | 13 | <8.3 | 3 | 23.1 | >=12 | 3 | 23.1 |

[1]Two least disturbed playa sites were omitted from some subsequent analysis due to lack of vegetation at site or lack of known C-values.

The least disturbed marsh sites were mostly supported by springs in remote areas such as Snake Valley, Tule Valley, and Salt Wells, though two sites were supported by a combination of groundwater and irrigation returns along the Weber and Bear Rivers. Most least-disturbed marsh sites had some standing water at the time of survey and had low species diversity (~13 species), high relative native cover, and an average cover-weighted mean C of 3.5.

Least disturbed playa sites were concentrated in Skull Valley where a number of springs contribute to relatively high groundwater levels and support a variety of wetland types. Other least disturbed playas were located near Grantsville, Utah, and in the northern end of the historical lakebed of Great Salt Lake in Bear River Bay. One least disturbed playa had no vegetation, and one did not have enough species with known C-values to calculate a cover-weighted mean C-value. These sites were excluded when summarizing some vegetation metrics but were otherwise included in analysis. Least-disturbed playas had high soil salinity, lacked surface water, had very low species diversity (~4 species), and had a mean cover-weighted mean C of 4.7.

Least-disturbed saline meadow sites were associated with natural springs in remote locations including Skull Valley, Blue Lake, Baker Hot Springs, Railroad Springs, and an unnamed spring near Corrine, Utah. These sites had high soil salinity, high surface water conductivity when present, low species diversity (~7.6 species), and a mean cover-weighted mean C of 3.1.

### Least and Most Disturbed Comparison

In all four wetland types (playa, saline meadow, fresh meadow, marsh), least disturbed sites showed significantly higher overall URAP scores than most disturbed sites ($p<0.01$, figure 8). Least disturbed sites also had higher mean C, cover-weighted mean C, relative native cover, and relative native perennial cover values and lower percent highly tolerant species and relative highly tolerant species cover than most disturbed sites for all four wetland types (figure 8, appendix E). Some metrics only performed well in one or a few wetland types. For example, relative cover of native graminoids performed well in graminoid-dominated wetlands such as meadows and marshes, but not in playas.

Water quality parameters and soil EC values did not differ between least and most disturbed sites, though sample sizes for these analyses were small due to lack of data in some years and the high number of sites without surface water (appendix E). We were only able to compare field measurements of surface water EC, pH, and temperature for marsh sites and soil EC for playa sites. We also compared water quality parameter values for least and most disturbed sites after grouping all wetland types together for parameters with at least five least and five most disturbed sites. None of these parameters showed a significant difference between least and most disturbed sites.

## Trends in Hydrologic Resources

### Stream and Lake Gages

Annual water year flow data at the two Sevier River gages were between 66% and 126% of the 30-year historical mean during the two years of field surveys (table 23). Peak flows at the gage location along the Sevier River below the San Pitch River were much higher than average in 2019 and much lower than average in 2020, whereas flows at the gage along the Sevier River near Lynndyl were more similar to, though lower than, the historical mean (figure 9). The Lynndyl gage likely sees less variability in flows because it is downstream of and controlled by Yuba Reservoir. Stream gage levels in 1983, when the majority of wetland mapping occurred, were more than 450% higher than the 30-year mean values. Great Salt Lake levels at Saltair Harbor were lower than the 30-year average during the study period and have steadily declined in the last 30 years (figure 9). Lake levels were more than 5 feet higher in 1983 than the 30-year mean.

## Groundwater Wells

Though more than 85% of groundwater wells used in analysis had slopes indicating declining trends, trends only showed significant declines in 23% of wells, and 3% of wells showed increasing trends. Two wells in the Sevier Basin (figure 10) and three wells in the West Desert (figure 11) showed a significant rising trend (mean rate of 0.12 and 0.11, respectively). Three wells in the West Desert showed a significant falling trend; falling trends were more common in the Sevier Basin, where 32 wells showed a significant falling trend. The mean Sens's slope of significantly falling wells was 0.45 in both the Sevier Basin and West Desert. No significant trend was observed in 90 wells in the Sevier Basin and 21 wells in the West Desert. Six of ten HUC8 watersheds in the West Desert have wells used in the groundwater trend analysis; these watersheds had between two and seven wells each (table 24). Two watersheds have rising trends in some wells, including one of six wells in the Northern Great Salt Lake Desert and two of four wells in Skull Valley, whereas the other four watersheds have only wells with falling trends or no significant trend. All but one of the nine watersheds in the Sevier Basin had wells used in the analysis. The Middle Sevier

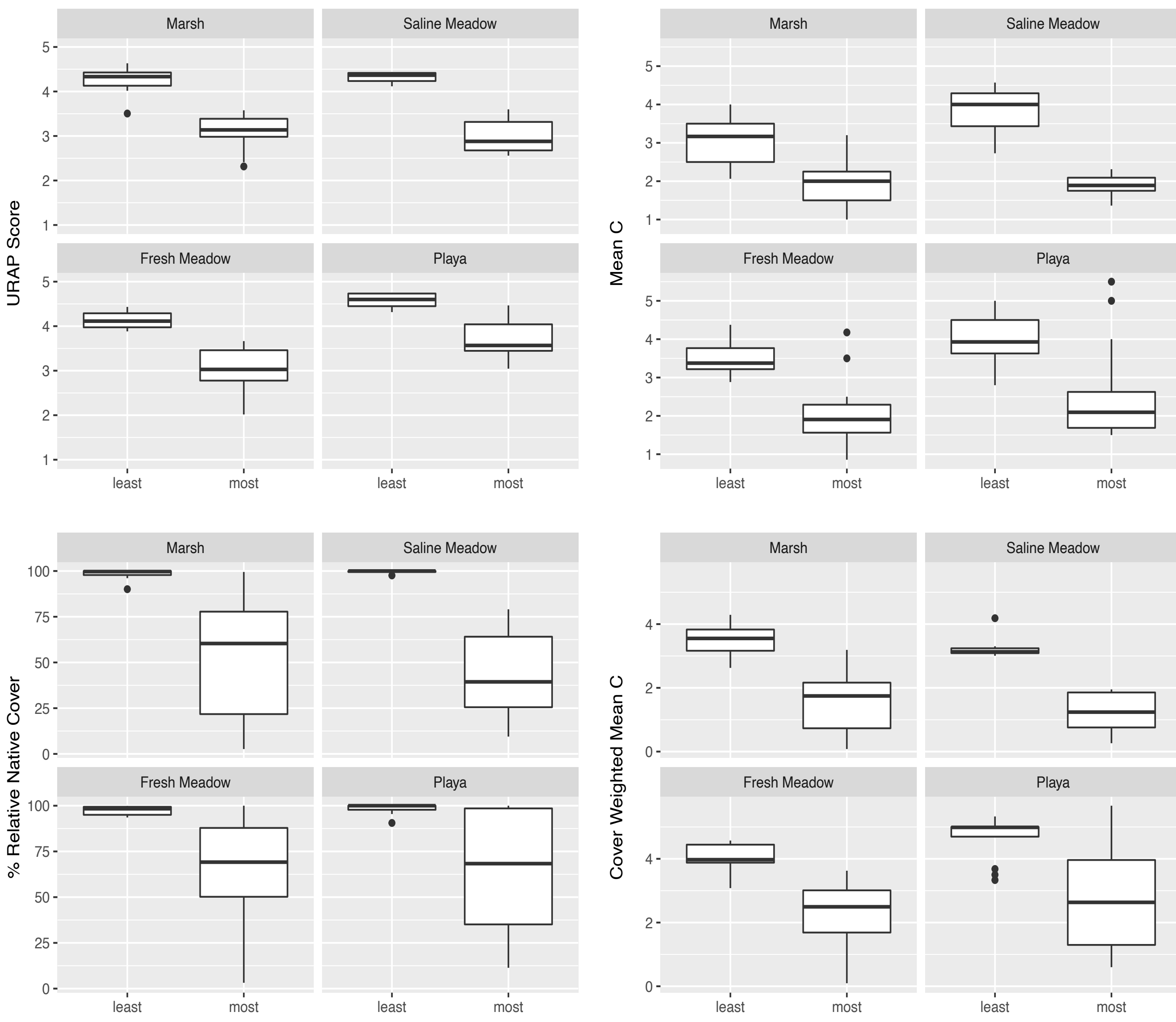


***Figure 8.*** *Boxplot comparison of URAP scores and three vegetation metrics between least and most disturbed sites for four wetland types. All differences between least and most disturbed sites were significant (p<0.01).*

***Table 23.*** *Mean yearly gage values for the water year (October 1 to September 3) at gaging stations along the Sevier River and at Saltair Harbor on Great Salt Lake. Historical means calculated for 1991–2020. Most NWI wetland mapping occurred in 1983. Values in feet above NGVD 1929 for Great Salt Lake and cubic feet per second for the Sevier River.*

| Location | Site Number | 30 Year Mean (1991-2020) | 1983 Mean (% of Historical Mean) | 2019 Mean (% of Historical Mean) | 2020 Mean (% of Historical Mean) |
|---|---|---|---|---|---|
| Great Salt Lake at Saltair Harbor, Utah | 10010000 | 4197.3 | 4202.7 (100.1) | 4193.4 (99.9) | 4193.9 (99.9) |
| Sevier River near Lynndyl, Utah | 10224000 | 215.4 | 1226.2 (569.4) | 142.5 (66.2) | 184.9 (85.9) |
| Sevier River below San Pitch River near Gunnison, Utah | 10217000 | 236.8 | 1132.2 (478.2) | 298.7 (126.2) | 163.2 (68.9) |

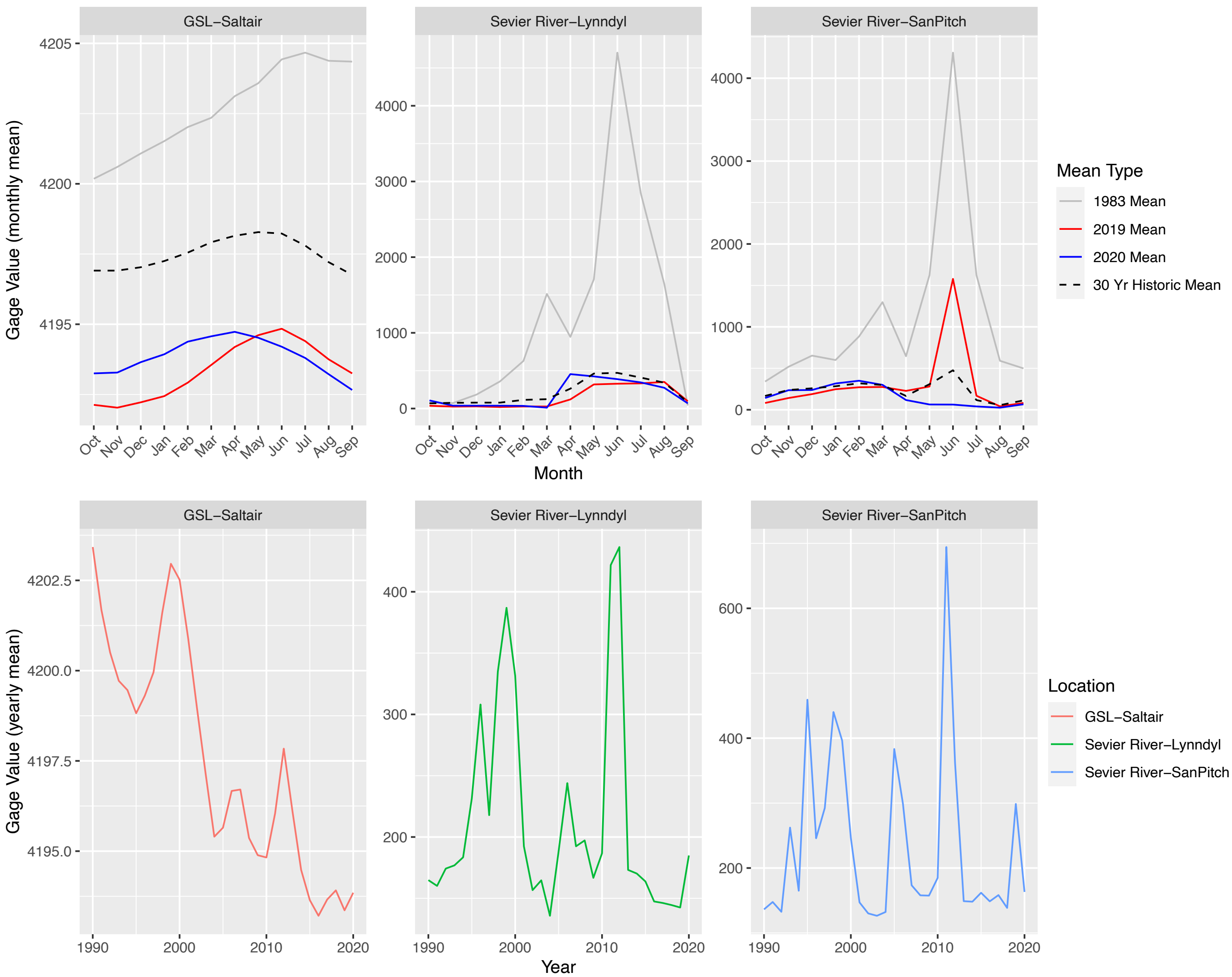


***Figure 9.*** *Trends in surface water discharge along the Sevier River and Great Salt Lake surface elevation levels. Yearly means calculated by water year. Units for Great Salt Lake are in feet above NGVD 1929 and for the Sevier River in cubic feet per second.*

and Upper Sevier only had one or two wells each, but all other watersheds had between 7 and 52 wells. Only one watershed, the Lower Sevier, had some wells with rising trends, and each watershed had a higher percent of wells with falling trends than rising trends (or had no significant trends in all wells).

## Surface Water Extent

We found significant declining trends in surface water extent in three of ten HUC8s in the Great Salt Lake HUC6 and two of seven HUC8s in the Escalante Desert-Sevier Lake HUC6; the remaining HUC8s did not have significant trends (table 25; figure 12). Of the 788 HUC12s in the study area, 47.2% did not have enough data to analyze, 42.9% had no significant trend, 5.8% had an increasing trend, and 4.1% had a declining trend (table 25). All of the HUC8s in the Sevier Basin had at least one HUC12 with increasing trends, though these HUC12s generally had very little overall surface water (<0.1% of HUC12 area). Examination of HUC12s with increasing and decreasing trends versus aerial imagery generally corroborated trends, though in some cases drivers of change were unclear. Increasing trends were often due to expansion of wastewater or salt evaporation ponds or development of other small new ponds. Decreasing trends were often due to declining water levels in larger lakes and reservoirs.

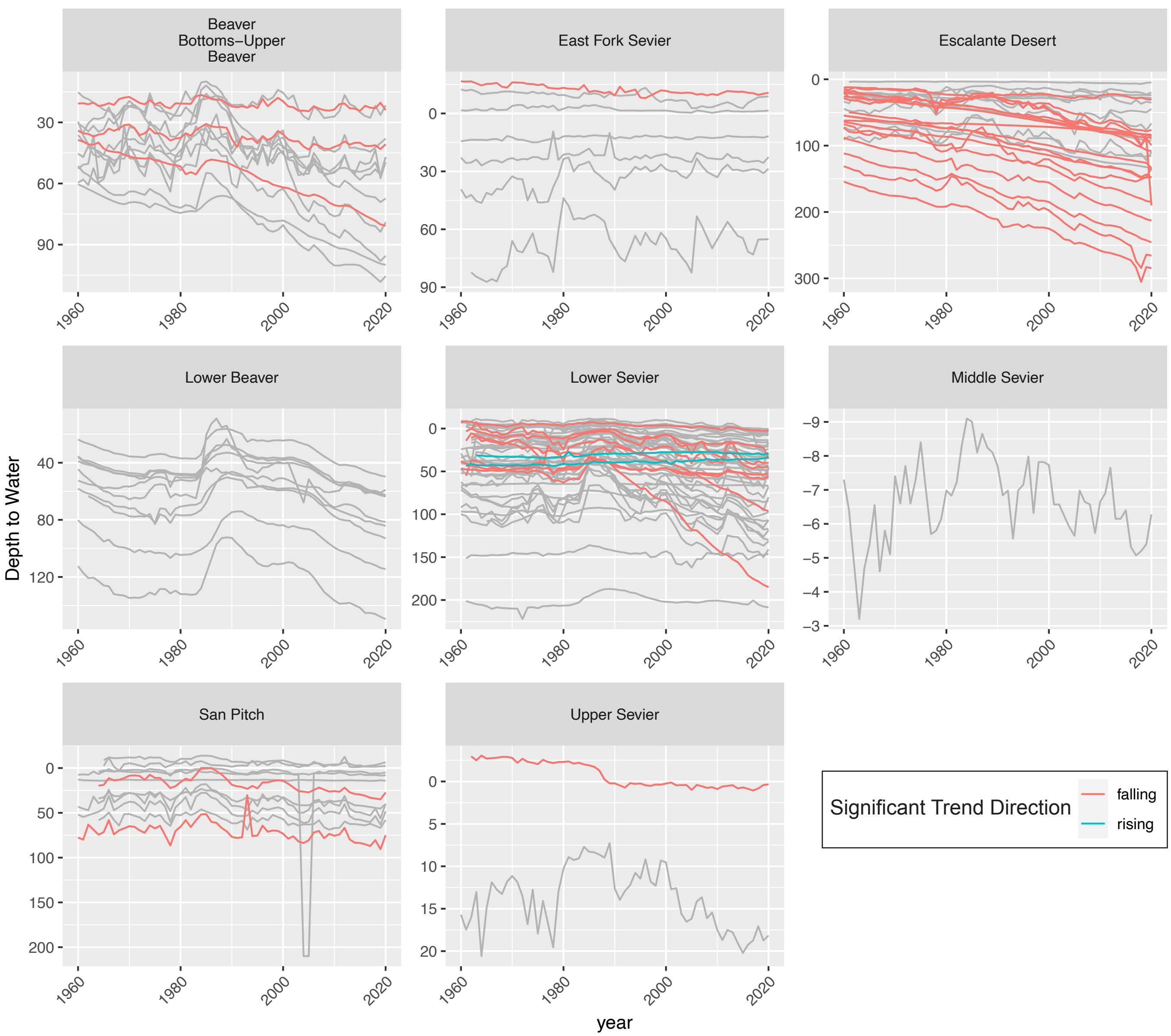


***Figure 10.*** *Depth to groundwater over time for individual wells in HUC8s in the Sevier Basin stratum. Gray lines indicate wells with no significant trend.*

## Landscape Profile

The West Desert had the most wetland area in the NWI data and the Sevier Basin the least (table 26). For all three strata, playa was the most common wetland type, accounting for 88% or more of wetland area, and forested and scrub-shrub wetlands were amongst the least common. After playas, meadows were the most common wetland class in the Sevier Basin and West Desert and marsh in the Great Salt Lake stratum. The majority of wetland area was classified as having low local stress and very little was classified as having high stress with large differences among wetland classes (table 26). Aquatic bed in all three classes, forested and meadow wetlands in the Sevier Basin, and marsh in the West Desert all had at least 50% of wetland area in the medium or high stress categories.

About 99% of wetlands in the Great Salt Lake stratum are under state ownership, and 65% and 74% of wetlands are federally owned in the Sevier Basin and West Desert strata, respectively (table 27). However, if playa wetlands are excluded from consideration, then over 50% of wetland area is privately owned in both the West Desert and Sevier Basin, despite the fact that

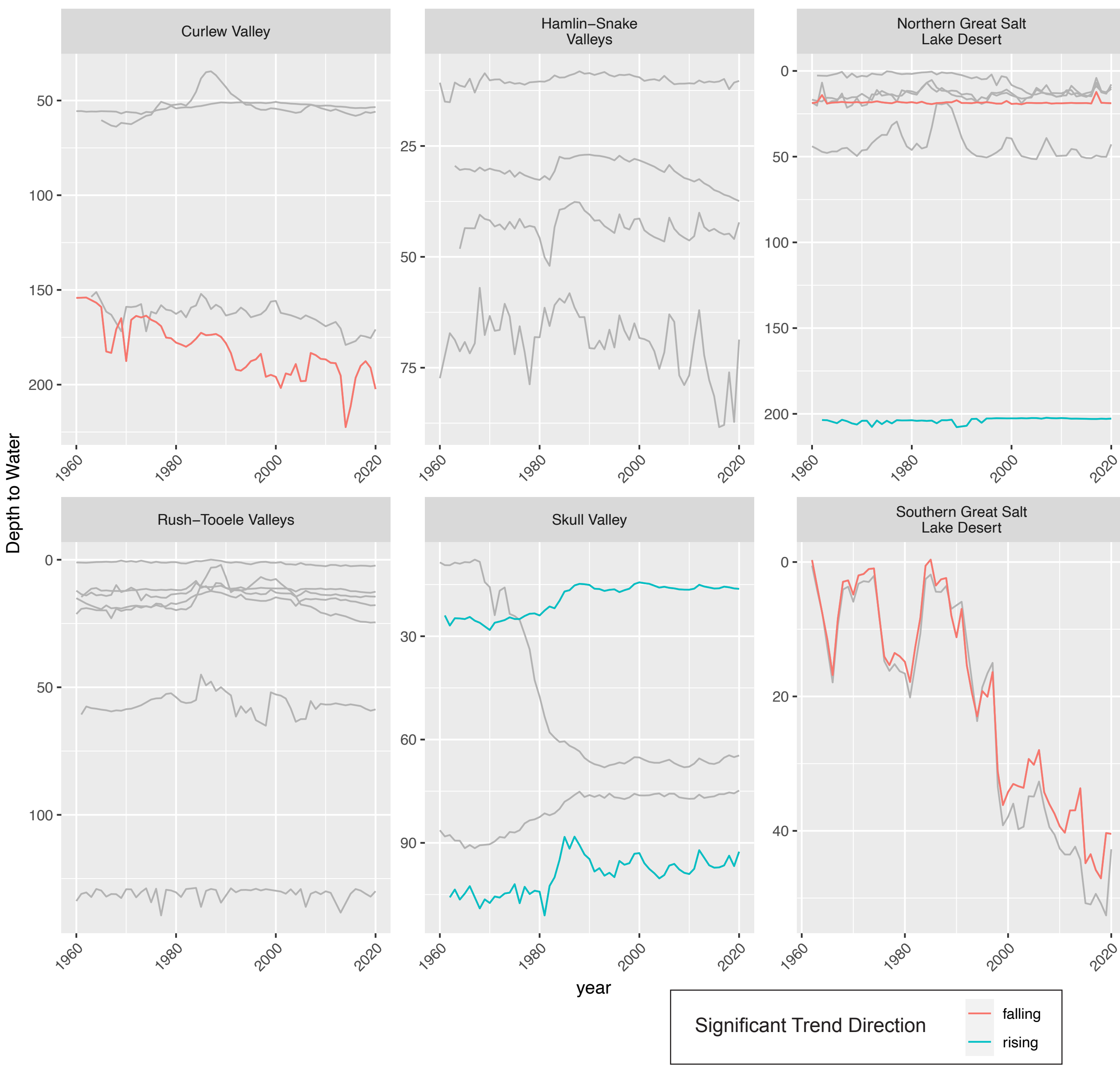


***Figure 11.*** *Depth to groundwater over time for individual wells in HUC8s in the West Desert stratum. Gray lines indicate wells with no significant trend.*

***Table 24.*** *Summary of groundwater well trends. HUC8s with at least one well used in the analysis are listed under each stratum; the Great Salt Lake stratum did not contain any wells and was excluded from the table. A positive Sen's slope indicates an increase in the depth to water. Trends for all wells are highlighted in gray, trends among wells with significant Mann-Kendall results are in white.*

| Name | # Wells | All Wells Falling Trend (%) | All Wells Rising Trend (%) | Significant Wells Falling Trend (%) | Significant Wells Rising Trend (%) | Mean Sen's Slope for Wells with Significant Trend (ft/yr) |
|---|---|---|---|---|---|---|
| **West Desert stratum** | | | | | | |
| Curlew Valley | 4 | 75.0 | 25.0 | 25.0 | 0 | 0.6 |
| Hamlin-Snake Valleys | 4 | 75.0 | 25.0 | 0 | 0 | NA |
| Northern Great Salt Lake Desert | 6 | 50.0 | 50.0 | 16.7 | 16.7 | -0.01 |
| Rush-Tooele Valleys | 7 | 85.7 | 14.3 | 0 | 0 | NA |
| Skull Valley | 4 | 25.0 | 75.0 | 0 | 50.0 | -0.2 |
| Southern Great Salt Lake Desert | 2 | 100.0 | 0 | 50.0 | 0 | 0.73 |
| **Sevier Basin stratum** | | | | | | |
| Beaver Bottoms-Upper Beaver | 13 | 84.6 | 15.4 | 23.2 | 0 | 0.3 |
| East Fork Sevier | 7 | 57.1 | 42.9 | 14.3 | 0 | 0.1 |
| Escalante Desert | 28 | 92.9 | 7.1 | 60.7 | 0 | 1.4 |
| Lower Beaver | 10 | 100.0 | 0 | 0 | 0 | NA |
| Lower Sevier | 52 | 88.5 | 11.5 | 15.4 | 3.9 | 0.5 |
| Middle Sevier | 1 | 100.0 | 0 | 0 | 0 | NA |
| San Pitch | 11 | 100.0 | 0 | 18.2 | 0 | 0.2 |
| Upper Sevier | 2 | 100.0 | 0 | 50.0 | 0 | 0.07 |

less than 30% of land area in each stratum is privately owned. Federal lands have lower concentrations of all types of wetlands except playa; playa sites are highly concentrated on Department of Defense land, which makes up about 10% of the study area but contains 41% of playa lands. State lands have a disproportionately high percent of aquatic bed and marsh wetlands for the amount of area they occupy; those wetland classes are heavily concentrated on state WMAs in all three strata. In the West Desert, tribal ownership accounts for only 0.7% of land ownership but almost 27% and 11% of forested and scrub-shrub wetland ownership, respectively.

More than 94% of the wetland area evaluated for the landscape analysis was mapped as riparian, wetland, or water by the WRLU data and only 3.7% of the area was not mapped at all, though the amount of mapped area differed substantially by stratum and wetland type (table 28). In the Sevier Basin, 61% of wetland area was either not mapped or mapped as dryland and about 5% was mapped as idle or active agriculture or as urban. Scrub-shrub and forested wetlands were typically not mapped or mapped as dryland, except for forested wetlands in the Sevier Basin, which were mapped as aquatic or riparian features 85% of the time. Marsh and meadow wetlands frequently overlapped areas mapped as hay/turf or pasture in the West Desert and Sevier Basin strata. Only 0.31% and 0.25% of mapped features overlapped areas mapped as irrigated or subirrigated, respectively. However, between 15% and 19% of meadow in the Sevier Basin and marsh, meadow, and scrub-shrub in the West Desert overlapped flood or sprinkler irrigated areas; overlap was less than 5% for all other classes. Those classes also had the highest rate of overlap with subirrigated features.

# DISCUSSION

## Target Population and Limitations on Inference

Generalizations about wetland condition and other study findings only pertain to the target population. We used a broad definition of wetland for our target population, including both vegetated wetlands and unvegetated and sparsely vegetated playas and areas with aquatic bed and shallow water. We also excluded lacustrine littoral features that were not mapped as aquatic bed, which likely mostly excluded larger (>8 ha) complexes of playas, mudflats, and areas of shallow water, leading to underrepresentation of these wetland types. Not all sites had evidence of all three wetland indicators, meaning that they might not

*Table 25. Surface water extent trend analysis results for HUC8 watersheds, including maximum percent of watershed with surface water, lag type used in Mann-Kendall analysis and associated p-value, Sen's slope, and Tau, and the number of HUC12s within each HUC8 and the percent of HUC12s with significant positive or negative trends at the alpha = 0.01 value. Results in bold have p-value <0.05 for the HUC8-wide surface water extent analysis.*

| HUC8 Watershed Name | Maximum Water Extent (%) | Lag Type | P-Value | Sen's Slope (ha/year) | Tau | # HUC12s | % Increasing HUC12 | % Decreasing HUC12 |
|---|---|---|---|---|---|---|---|---|
| ***Great Salt Lake HUC6*** | | | | | | | | |
| Hamlin-Snake Valleys | 0.2 | no lag | 0.89 | -1.0 | -0.02 | 68 | 1.5 | 5.9 |
| Pine Valley | <0.01 | no lag | 0.67 | 0.0 | 0.06 | 20 | 0.0 | 0.0 |
| **Tule Valley** | **0.1** | **no lag** | **0.03** | **-2.3** | **-0.28** | **28** | **0.0** | **21.4** |
| **Rush-Tooele Valleys** | **3.9** | **lag1** | **0.02** | **-138.3** | **-0.42** | **35** | **0.0** | **17.1** |
| Skull Valley | 1.5 | no lag | 0.08 | 18.6 | 0.23 | 20 | 20.0 | 5.0 |
| Southern Great Salt Lake Desert | 1.8 | no lag | 0.21 | 103.7 | 0.16 | 130 | 3.8 | 1.5 |
| **Pilot-Thousand Springs, Nevada, Utah** | **<0.01** | **lag1** | **<0.01** | **<-0.1** | **-0.69** | **5** | **0.0** | **20.0** |
| Northern Great Salt Lake Desert | 7.6 | no lag | 0.27 | 322.1 | 0.14 | 95 | 6.3 | 0.0 |
| Curlew Valley | 4.2 | lag1 | 0.52 | -24.9 | -0.13 | 47 | 2.1 | 2.1 |
| **Great Salt Lake** | **96.3** | **lag1** | **<0.01** | **-4400.4** | **-0.65** | **2** | **0.0** | **50.0** |
| ***Escalante Desert-Sevier Lake HUC6*** | | | | | | | | |
| Middle Sevier | 2.7 | lag1 | 0.29 | -34.6 | -0.22 | 31 | 12.9 | 12.9 |
| San Pitch | 4.3 | lag1 | 0.39 | -2.9 | -0.15 | 5 | 20.0 | 0.0 |
| **Lower Sevier** | **0.4** | **no lag** | **0.01** | **-25.3** | **-0.32** | **111** | **4.5** | **4.5** |
| Escalante Desert | 0.3 | no lag | 0.06 | 7.4 | 0.24 | 86 | 15.1 | 0.0 |
| Beaver Bottoms-Upper Beaver | 0.2 | no lag | 0.43 | 2.0 | 0.10 | 53 | 7.5 | 0.0 |
| **Lower Beaver** | **0.2** | **lag1** | **<0.01** | **-6.7** | **-0.61** | **22** | **4.5** | **4.5** |
| Sevier Lake | 5.04 | lag1 | 0.78 | 33.3 | 0.07 | 30 | 3.3 | 0.0 |

all meet the regulatory definition of wetland (though further field effort would be needed to determine this). Furthermore, our study design only allows us to make inference to mapped wetlands. NWI data are outdated for much of the study area and were created during an abnormally wet period. A large number of oversample sites had to be used in the Sevier Basin stratum because many of the original sample points were no longer wetland.

Although we can estimate the amount of mapped wetland area that is not target wetland, we cannot estimate the amount of unmapped wetland that was left out of the sample frame (i.e., there may be more wetland area than estimated in this report). Excluded wetlands may include small or otherwise difficult to detect wetlands or newly created wetlands. If unmapped wetlands are similar in characteristics to mapped wetlands or small in proportion to the size of the mapped target population, then target population estimates will still be robust. Survey results could also be skewed by our inability to access a large percent of sites if, for example, owners of poorly managed sites were less likely to grant permission for surveys than owners of better managed sites. We were not able to obtain access to 14 sites in the Sevier Basin and 8 sites in the West Desert strata. We also were not able to survey two sites in the Great Salt Lake stratum because they were inaccessible due to extremely high cover of Phragmites.

## Wetland Condition

Wetland condition varied by strata and was generally best in the West Desert stratum and worst in the Great Salt Lake stratum. Variation across the strata was mostly driven by differences in vegetation composition and hydrologic stress. The most prevalent stressors at the buffer and plot levels were largely the same across all three strata, including non-native plants and livestock impacts to soils at both the plot and buffer scale, though the severity of the stressors varied by strata. These same stressors have been noted as widespread stressors in previous studies of wetlands in the Central Basin ecoregion (Menuz and others, 2016; Menuz and Sempler, 2018; Menuz and McCoy-Sulentic, 2019). In contrast, stressors related to hydrology varied markedly by strata, most notably with higher prevalence and impact of water management and water quality stressors in Great Salt Lake and high prevalence of groundwater withdrawal impacts in the Sevier Basin.

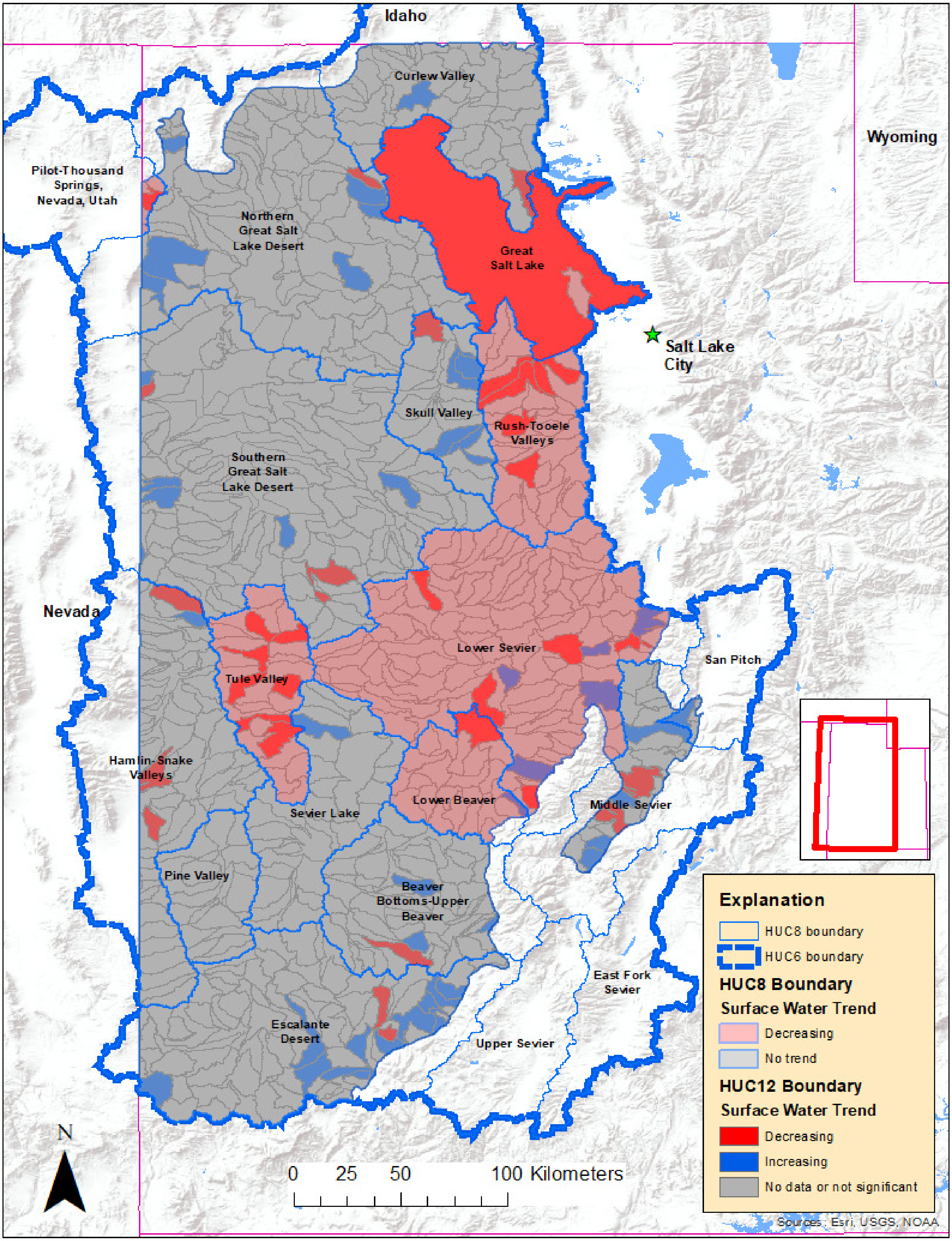


***Figure 12.*** *Map of surface water trend analysis at the HUC12 and HUC8 scale within the study area.*

***Table 26.*** *Wetland area by stratum, percent of wetland area in each class, and percent of wetland area in low, medium, or high local landscape stress classes for each wetland class and stratum. Forested class not present in Great Salt Lake stratum and omitted from results.*

| Strata and Wetland Class | Wetland Area and % By Class | Low | Medium | High |
|---|---|---|---|---|
| **Great Salt Lake** | **1176.1 km$^2$** | **97.0%** | **3.0%** | **0.0%** |
| Aquatic Bed | 0.8% | 2.6% | 97.3% | 0.1% |
| Marsh | 4.8% | 98.9% | 1.1% | 0.0% |
| Meadow | 1.5% | 97.5% | 2.5% | 0.0% |
| Playa | 93.0% | 97.7% | 2.3% | 0.0% |
| Scrub-Shrub | <0.1% | 100.0% | 0.0% | 0.0% |
| **Sevier Basin** | **500.7 km$^2$** | **86.6%** | **11.0%** | **2.3%** |
| Aquatic Bed | 2.2% | 35.6% | 56.8% | 7.6% |
| Forested | <0.1% | 14.9% | 73.6% | 11.5% |
| Marsh | 1.8% | 83.9% | 15.2% | 0.9% |
| Meadow | 5.1% | 28.0% | 64.8% | 7.2% |
| Playa | 88.7% | 91.8% | 6.3% | 1.9% |
| Scrub-Shrub | 2.1% | 69.1% | 25.9% | 5.0% |
| **West Desert** | **9772.3 km$^2$** | **95.5%** | **3.8%** | **0.7%** |
| Aquatic Bed | 0.1% | 22.3% | 65.3% | 12.3% |
| Forested | <0.1% | 51.4% | 45.2% | 3.5% |
| Marsh | <0.1% | 46.7% | 47.9% | 5.4% |
| Meadow | 1.1% | 56.0% | 40.7% | 3.2% |
| Playa | 98.7% | 96.1% | 3.3% | 0.7% |
| Scrub-Shrub | <0.1% | 53.7% | 41.0% | 5.4% |

***Table 27.*** *Land and wetland ownership by wetland class and stratum. Forested class not present in Great Salt Lake and omitted from results.*

| Strata and Wetland Class | Federal | State | Private | Tribal |
|---|---|---|---|---|
| **Great Salt Lake** | | | | |
| ***Land ownership*** | ***0.6%*** | ***98.9%*** | ***0.5%*** | ***0.0%*** |
| Aquatic Bed | 0.0% | 99.9% | 0.1% | 0.0% |
| Marsh | 3.7% | 96.2% | 0.0% | 0.0% |
| Meadow | 3.8% | 96.1% | 0.1% | 0.0% |
| Playa | 0.4% | 99.3% | 0.3% | 0.0% |
| Scrub-Shrub | 0.0% | 100.0% | 0.0% | 0.0% |
| **Sevier Basin** | | | | |
| ***Land ownership*** | ***64.8%*** | ***9.0%*** | ***26.2%*** | ***<0.1%*** |
| Aquatic Bed | 4.1% | 29.8% | 66.1% | 0.0% |
| Forested | 6.9% | 0.0% | 93.1% | 0.0% |
| Marsh | 9.8% | 59.3% | 30.9% | 0.0% |
| Meadow | 8.6% | 3.0% | 88.3% | 0.0% |
| Playa | 71.4% | 11.3% | 17.3% | 0.0% |
| Scrub-Shrub | 51.8% | 8.0% | 40.1% | 0.0% |
| **West Desert** | | | | |
| ***Land ownership*** | ***73.5%*** | ***8.1%*** | ***17.7%*** | ***0.7%*** |
| Aquatic Bed | 11.1% | 43.1% | 45.7% | 0.1% |
| Forested | 19.9% | 5.4% | 47.9% | 26.7% |
| Marsh | 20.9% | 18.9% | 60.3% | 0.0% |
| Meadow | 31.7% | 15.2% | 52.6% | 0.5% |
| Playa | 78.6% | 11.5% | 9.9% | 0.0% |
| Scrub-Shrub | 44.1% | 6.0% | 38.8% | 11.0% |

***Table 28.*** *Percent overlap between mapped wetland classes and land use classes by stratum. Forested class not present in Great Salt Lake and omitted from results.*

| Strata and Wetland Class | Aquatic or Riparian | Agriculture or Idle/Fallow | Hay/Turf or Pasture | Urban | Non-Agriculture Dryland | Not Mapped |
|---|---|---|---|---|---|---|
| **Great Salt Lake** | **91.0%** | **0.0%** | **0.0%** | **0.0%** | **0.2%** | **8.9%** |
| Aquatic Bed | 97.7% | 0.0% | 0.0% | 0.1% | 0.0% | 2.2% |
| Marsh | 79.4% | 0.0% | 0.0% | 0.0% | 0.0% | 20.5% |
| Meadow | 71.3% | 0.0% | 0.0% | 0.0% | 0.8% | 28.0% |
| Playa | 91.8% | 0.0% | 0.0% | 0.0% | 0.2% | 8.0% |
| Scrub-Shrub | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 100.0% |
| **Sevier Basin** | **34.2%** | **1.1%** | **3.6%** | **0.5%** | **19.6%** | **41.0%** |
| Aquatic Bed | 76.6% | 1.6% | 8.0% | 0.8% | 6.0% | 7.0% |
| Forested | 85.4% | 0.1% | 8.1% | 0.6% | 3.0% | 2.9% |
| Marsh | 59.0% | 4.2% | 13.0% | 0.0% | 9.9% | 13.8% |
| Meadow | 18.8% | 5.7% | 34.5% | 0.5% | 25.3% | 15.1% |
| Playa | 33.5% | 0.8% | 1.6% | 0.5% | 19.7% | 43.9% |
| Scrub-Shrub | 31.9% | 1.7% | 1.9% | 0.2% | 21.3% | 43.1% |
| **West Desert** | **97.8%** | **0.0%** | **0.5%** | **0.2%** | **0.4%** | **1.1%** |
| Aquatic Bed | 80.8% | 0.2% | 8.3% | 4.4% | 2.4% | 4.0% |
| Forested | 9.0% | 0.7% | 4.2% | 8.3% | 1.1% | 76.7% |
| Marsh | 64.2% | 0.6% | 25.2% | 0.8% | 8.3% | 0.9% |
| Meadow | 58.0% | 0.7% | 27.0% | 1.1% | 6.2% | 6.9% |
| Playa | 98.3% | 0.0% | 0.1% | 0.2% | 0.3% | 1.0% |
| Scrub-Shrub | 13.6% | 2.4% | 23.4% | 1.2% | 10.6% | 48.8% |

## Vegetation Condition

Vegetation condition was much poorer in the Great Salt Lake stratum than in other strata, driven by the presence and abundance of the noxious weed species Phragmites. We found Phragmites in greater abundance near Great Salt Lake in this study than in the Bear, Jordan, and Weber watersheds in other recent studies (Menuz, and others, 2016; Menuz and Sempler, 2018; Menuz and McCoy-Sulentic, 2019), even though our estimates of Phragmites prevalence and abundance were artificially lowered in this study because we excluded two sites that were inaccessible due to extremely high cover of Phragmites. Phragmites rapidly expanded around Great Salt Lake following flooding in the 1980s, which left behind bare soil and high-light conditions that allowed seeds and seedlings to thrive (Kettenring and others, 2020), conditions that are particularly prevalent on the exposed lakebed that comprises the Great Salt Lake stratum. The continued spread of Phragmites across the mudflats of Great Salt Lake may be primarily limited by the amount of freshwater inflow reaching the mudflats. If Great Salt Lake were to flood again as it did in the 1980s, it would likely wipe out Phragmites (and other vegetation) due to the hypersaline waters, providing managers with an opportunity to proactively work to limit reestablishment as lake levels decline. However, given the current trajectory of Great Salt Lake water levels, flooding of this nature seems unlikely without strong conservation efforts to allow more flow to reach the lake.

Phragmites is already the focus of concern and extensive control efforts by land managers due to its ecological and social impacts (Rohal and others, 2018). Though elimination of the species is unlikely due to the large area it occupies, control efforts have opened up habitat that was previously overrun with the species, and researchers are actively exploring the best methods for control and restoration (Rohal and others, 2017). While the most effective management for Phragmites is herbicide application followed by litter removal, livestock grazing is also used for Phragmites management since grazing can both reduce Phragmites biomass and break down litter through trampling, and ranchers will often either pay for the privilege to graze livestock within management areas or else spend their time and money managing cows to optimize Phragmites control (Duncan and others, 2019). Most if not all of the livestock-related stressors recorded at Great Salt Lake sites were due to management activities. Active restoration following treatment is necessary to reestablish wildlife habitat and create cover to limit germination of Phragmites seeds (Kettenring and others, 2020).

Noxious weeds and non-native species in general were a much smaller issue in the West Desert and Sevier Basin strata, with the exception of forested-shrubland sites, discussed below. The lack of noxious weeds and non-native species in the West Desert and Sevier Basin strata is likely at least in part driven by the high number of playa sites in these strata. Playas were often in remote locations and subject to less anthropogenic stressors like livestock grazing than other wetland types, and their high soil salinity levels greatly limit the number of species that are able to establish. The most common non-native species found in playas were *Bassia hyssopifolia*, *Ceratocephala testiculata* (curveseed butterwort), *Bromus tectorum* (cheatgrass), and *Halogeton glomeratus* (saltlover). Notably, the highly salt tolerant and introduced annual species *Frankenia pulverulenta* (European sea-heath), which has recently been documented on the eastern shore of Great Salt Lake, was not documented in any playas in the study (Kettenring and others, 2020). Non-native species including *Cardaria draba*, *Phalaris arundinacea* (reed canarygrass), *Puccinellia distans* (weeping alkaligrass), and *Agrostis gigantea* (redtop) were occasionally found with high cover in saline meadow, fresh meadow, and forested-shrubland sites, though we did not survey enough of these site types to determine how prevalent the species are in each wetland type.

Forested-shrubland sites all had very high cover of non-native species, though we only surveyed three of these sites, all in the Sevier Basin. *Tamarix chinensis* (five-stamen tamarisk) was present at all three sites. Species in the genus *Tamarisk* (tamarisk) were also found at several other sites in each stratum of the study area and were also very common and abundant at many of the sites we visited in the Sevier Basin that we determined were not wetland, especially along the Sevier River and in areas west of Deseret along Highway 50. Like Phragmites, hydrologic changes may also be at least partially responsible for the spread of tamarisk. Because tamarisk can tolerate salt, drought, and fire better than native riparian species such as *Populus* spp. (cottonwood) and *Salix* spp. (willow), dams, diversions, and other changes in flow regime that lead to drier and more saline conditions may disproportionately favor tamarisk over native species (Glenn and Nagler, 2005). Tamarisk is able to concentrate salt in leaf tissue, which can lead to increased soil salinity as the leaf litter accumulates, and the species can also fuel more frequent and intense fires (Bell and others, 2002); both increased soil salinity and fire cycles can reinforce the species' dominance once it establishes. The Northern tamarisk beetle (*Diorhabda carinulata*) was released around Delta in 2001 to help control tamarisk populations. The beetles colonize stands of tamarisk, feeding on leaves to the point of defoliation, and then emigrate to new stands, generally not killing the plants, but at least weakening them to limit their spread and allow other species to establish.

Phragmites and tamarisk are two of the most prevalent noxious weeds in the study area. Phragmites has been the focus of numerous Great Salt Lake-specific studies to determine optimal control methods and develop revegetation guidelines (Kettenring and others, 2020), whereas control efforts for tamarisk in the Central Basin appear to be mainly passive through tamarisk beetle defoliation. Active restoration is likely needed, in addition to continued monitoring and treatment, to successfully restore areas post-treatment (Shafroth and others, 2008; Kettenring and others, 2020). Alterations to hydrology likely represent the greatest impediment to successful restoration and habitat maintenance as these invaders are able to take advantage of hydrologic changes to push out native vegetation. In the Sevier Basin in particular, wetland or mesic vegetation is unlikely to be able to establish in many areas due to the impacts of water withdrawal (Shafroth and others, 2008).

## Hydrologic Condition

Hydrologic condition was poorest in the Great Lake stratum, intermediate in the Sevier Basin, and best in the West Desert. The causes and consequences of hydrologic stress varied considerably across strata. Surveyed wetlands in the Great Salt Lake stratum were mostly on the historical lakebed in places that now receive water from adjacent areas that are managed through impoundments, canals, and control structures for duck and other bird production; little if any water reaches these wetlands without passing through anthropogenic controls. Although these heavily managed areas are not in a "natural" condition, management is crucial to preserving wetland habitat in light of the drying lake, and also provides managers with the ability to manipulate water levels to create specific habitat types or facilitate Phragmites control (assuming there is water available to manage). In addition to hydroperiod manipulation, Great Salt Lake wetlands are subject to water quality stressors. Most of the water reaching wetlands in the stratum comes from the Jordan, Weber, or Bear Rivers, all of which pass through heavily urbanized or agricultural areas before reaching Great Salt Lake and are listed as impaired by the UDWQ (Utah Division of Water Quality, 2021). Excessive nutrients, pollutants, and sediment from these water sources could contribute to excessive algae blooms and impact aquatic wildlife and their food sources. Fortunately, Great Salt Lake and its contributing rivers are all focal areas for UDWQ work, including through development and implementation of TMDL plans and the development of wetland-specific water quality standards for Great Salt Lake (Utah Division of Water Quality, 2019).

While survey results indicate that hydrologic condition was better in the Sevier Basin than Great Salt Lake, this is probably an incomplete picture of conditions in the strata because survey results are based on sites that are still wetland, and there is strong evidence for widespread loss of wetlands and other aquatic habitat in the region. Furthermore, based on the NWI mapping, it seems possible that more heavily vegetated meadow wetlands have in some places been converted to playas. Examination of topographic maps from around Delta in the late 1800s show large areas that were mapped as impassable swamps and bayou that are now largely dry (appendix G). Though wetlands were likely over-mapped by NWI compared to typical conditions due to unusually wet conditions in the early 1980s, many of these over-mapped areas were likely wetland before settlers started diverting water for agriculture in the late 1800s. The Sevier River is one of the most used rivers in the nation (Natural Resources Conservation Service, 2006), only occasionally reaching its historical terminus in Sevier Lake, and on-going groundwater extraction has likely exacerbated water issues. Though concerted efforts to manage water use in the Sevier River Basin have been in place for some time, and advanced real-time monitoring has been in place since 1999 (Berger and others, 2003), continued declines in both groundwater levels and surface water extent suggest future adjustments to water management in the basin will be needed if wetlands are to be preserved with the added pressures of continued population growth and warmer temperatures. If declining trends continue, it is foreseeable that the only future wetlands left in the area will be those supported solely by agricultural return water. Appendix G contains a more detailed discussion of land cover changes in the Sevier Basin.

Hydrology of West Desert wetlands was largely unaltered, with a few exceptions. Wetlands at Locomotive Springs WMA are impacted by declining spring flow due to groundwater withdrawal (Smith and others, 2019), and wetlands both there and at Fish Springs NWR are subject to similar management via impoundments and control structures as wetlands adjacent to Great Salt Lake wetlands. Smaller-scale canals and dikes were also sometimes present to support agriculture and livestock production. Groundwater and surface water extent trends showed some areas of decline, though analysis was limited to many fewer wells compared to the Sevier Basin. Declines in surface water extent in Snake and Tule Valleys and in groundwater levels in Snake Valley (no wells in Tule Valley were included in analysis) could be cause for concern for several Utah SGCN species that rely on these wetland complexes. The West Desert is one of the few areas in Utah still open to new groundwater appropriations; increased hydrologic monitoring in Utah would be valuable to detect groundwater declines and wetland losses in a timely manner.

Water quality stressors are less prevalent in the Sevier Basin and West Desert than Great Salt Lake and are primarily related to the influence of direct livestock inputs and agricultural runoff, with the latter more common in the Sevier Basin. Direct livestock inputs were generally minor, and landowners and land managers should continue to sustainably manage grazing. Private landowners can receive technical and financial assistance from agencies such as the U.S. Natural Resources Conservation Service, the Utah Department of Agriculture and Food, and the Utah Department of Natural Resource's Watershed Restoration Initiative to support best management practices. While agricultural runoff may not be an optimal water source for wetlands, in some cases that water may be crucial for sustaining wetlands that may otherwise dry out.

## Wetland Function

Wetlands in our study area provide important anthropogenic benefits and ecological functions. The majority of wetlands in our study area are on state or federal land, and much of it is accessible for hunting, bird watching, and boating, including at the many areas managed for wildlife and hunting. Despite not conducting targeted species surveys, we documented wildlife at most sites. Wetland types that were least common across the study area—aquatic bed, marsh, and forested-shrubland—tended to have the highest number of unique taxa, though the majority of all surveyed sites in all wetland types had signs of wildlife.

Wetland potential to improve water quality is directly related to the extent to which wetlands receive water quality stressors, and as such Great Salt Lake wetlands had the highest potential to provide this function. As discussed above, these wetlands are located close to population centers and the associated development and pollution of urban environments, whereas wetlands in the Sevier Basin and, especially, West Desert, were much less impacted by these types of stressors. Notably, the majority of wetlands in each stratum had medium or high site potential to improve water quality, indicating that they could perform this function if they did receive stressors. The societal value component of the functional assessment focused on connectivity with impaired waterbodies, which was scored as low for most Sevier Basin and West Desert wetlands both because wetlands were often not connected to adjacent waterbodies and because many areas were either not assessed or incompletely assessed for water quality impairments. Water quality improvement functions for these wetlands may provide values not evaluated in this study, such as improved water quality for livestock and wildlife.

Of the functions evaluated by this study, surveyed wetlands were least likely to perform hydrologic functions of erosion control and flood reduction. Wetlands had some capacity to perform these functions, but generally had little surface water input, little to no storage depth, and no downstream structures to protect. The exception was the Sevier Basin, which had both the only large river in the study area as well as more human land use that could be impacted by flooding. Wetlands in the study area may also perform functions not evaluated in this study, including groundwater recharge, dust control, carbon storage, and temperature regulation.

Though updates were made to adapt the functional assessment method to wetlands in Utah, the remote location and arid nature of the majority of the study area complicated its use and interpretation. The questions in the evaluation are mainly focused on systems with surface water and assume the existence of water quality assessment data and planning documents to help with rating sites. In a remote region largely lacking population, water quality assessments, flood control plans, precipitation, and rivers, and with a large proportion of wetlands supported by groundwater, the assessment may not have adequately captured the functional value of these wetlands. We recommend continued use of the form with additional future refinements for use in Utah.

### Columbia Spotted Frog

We found very few locations within the study area that were deemed suitable for Columbia spotted frog breeding, and all suitable sites had at least some degree of disturbance. Furthermore, none of the suitable sites were within areas with known current or historical populations of the species, though historical distribution data are poorly understood (Bailey and others, 2006). Some of the suitable and marginal sites may be suitable targets for establishing refuge populations, which is one of the conservation elements listed in the species' conservation plan, though the plan also mentions the importance of conducting genetic studies and developing a plan to maintain genetic integrity and maximize genetic variability (Bailey and others, 2006). Three HUC8s within the study area are known to be occupied by Columbia spotted frog, including Hamlin-Snake Valleys, Southern Great Salt Lake Desert, and Tule Valley. Three sites were rated as marginal and none as suitable within these HUC8s. These included one each at Blue Lake Waterfowl Management Area, Fish Springs NWR, and Gandy Marsh in Snake Valley; the latter is a wetland complex where the species is already known to occur. Given the overall scarcity of suitable habitat, continued monitoring of the condition of known populations and of the impacts of stressors such as drought and groundwater development will play an important role in managing this SGCN.

## Least and Most Disturbed Condition

We were not able to examine differences between least and most disturbed sites for some wetland types due to low sample size and narrow range of disturbance. For the wetland types that we were able to evaluate, we saw strong differences in both URAP scores and vegetation metrics between least and most disturbed sites, which increases confidence in our evaluation methods. Although several of the vegetation metrics we examined were strongly correlated with one another, and thus could be considered redundant, it is useful to have a variety of ways to identify high quality sites in cases when species do not have assigned C-values or when a proportion of plant cover is attributed to unidentified species. The consistent and strong differences shown in a number of vegetation metrics support their potential use for identifying high quality sites with value thresholds determined by the population of least disturbed sites in each wetland type.

In some cases, sites classified as most disturbed had vegetation metric values that were close to the high end of the least disturbed values, particularly for mean C at playa and fresh meadow sites, and several least disturbed playas had cover-weighted mean C-values closer to values of the most disturbed sites. The outlier fresh meadow sites were located in a remote valley in western Utah and were heavily grazed with extensive pedestal formation. However, the grazing disturbances were not enough to eliminate characteristic fresh meadow species, and the remote location likely prevented more non-native species from invading. The lack of strong distinction for some playa sites may be due to two factors. First, even the most disturbed playa sites generally had lower stress impact values than most disturbed sites of other wetland types. Second, we observed more impacts to vegetation structure at impacted playa sites rather than vegetation composition; the remote location and high soil salinity prevented other species from establishing. Small sample sizes in water quality measurements due to the rarity of surface water prevented any substantive analysis of water quality data, and changes in lab methods prevented us from comparing some parameters across years. Despite not finding any significant differences between least and most disturbed sites, we recommend continued collection of water quality data where surface water is present to help establish baseline information about Central Basin wetlands and guide any future research into water quality and wetland condition.

# CONCLUSIONS

Water resources in arid regions like the Central Basin are scarce, creating conflict between municipal and agricultural water needs and the water needed to sustain aquatic resources. Wetlands in our study area are very vulnerable to the impacts of water diversion, from direct wetland loss in the Sevier Basin to increased invasion by introduced plant species on Great Salt Lake's drying lakebed. Although wetlands in the West Desert have not experienced widespread hydrologic impacts like those seen in other parts of the study area, impacts seen elsewhere should serve as a bellwether to what could happen if large amounts of new diversions are allowed without accounting for ecological impacts. Fortunately, we are not alone in recognizing these issues.

The 2019 Utah State Legislature passed a bill calling for solutions to address declining water levels in Great Salt Lake, which led to a 2020 report with 60 recommendations for addressing the issue (Great Salt Lake Resolution [HCR-10] Steering Group, 2020). Most of the Sevier Basin is closed to new groundwater appropriations and some areas in the basin have groundwater management plans that require future reductions in groundwater withdrawal to get to safe yield (Utah Division of Water Rights, 2011, 2021a, 2021b). Areas such as Snake Valley in the West Desert have been subject to over ten years of hydrologic monitoring in wetland complexes to better understand baseline conditions and provide input for water resource planning (Goodwin and others, 2021).

This study provides baseline data about wetlands in the study area and information about least disturbed conditions for a range of wetland types in the Central Basin. This information is a critical first step towards identifying and addressing issues of concern. Wetlands in our study area provide crucial functions, most obviously habitat for wildlife, but also recreational opportunities, water quality improvement, and, on a more limited basis, floodwater and erosion control, as well as additional functions not investigated in this study. Importantly, wetlands that are lost or severely impacted are unlikely to convert to intact upland communities. Instead, they might convert to systems such as cheatgrass-dominated annual grasslands that provide little ecological benefit and lead to altered fire regimes and increased dust production (Hahnenberger and Nicoll, 2014). Periodic assessment of wetlands in the Central Basin, whether through field assessments or remote sensing or a combination of the two, is critical for understanding trends in aquatic resources over time and identifying potential drivers of change.

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# APPENDIX A

## Utah Rapid Assessment Procedure User's Manual and Reference Material

Link to supplemental data download:

https://ugspub.nr.utah.gov/publications/open_file_reports/ofr-738/ofr-738-a.pdf

# APPENDIX B

## Utah Rapid Assessment Procedure Field Forms

Link to supplemental data download:

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# APPENDIX C

## Measurement of Soil Salinity in Wetlands: Methods and Seasonal Variability

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# APPENDIX D

## Evaluation of Methods for Assigning Hydrologic Functional Ratings to Wetlands

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# APPENDIX E

## Metrics Used to Compare Least and Most Disturbed Sites

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# APPENDIX F

## Central Basin Wetland Type Descriptions

Link to supplemental data download:

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# APPENDIX G

## An Abbreviated History of Wetlands in the Lower Sevier HUC8 Watershed near Deseret, Utah

Link to supplemental data download:

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