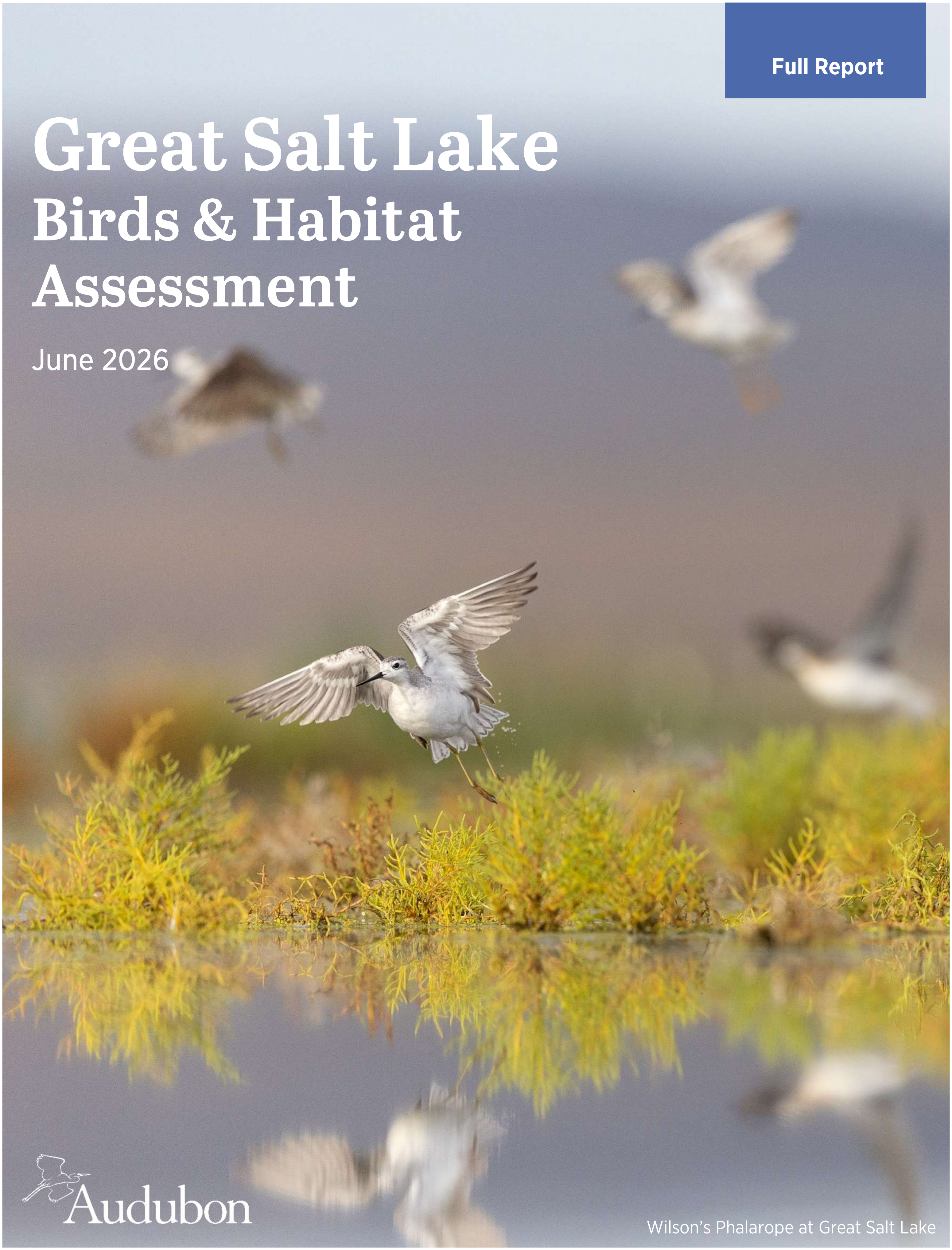
Full Report

Great Salt Lake
Birds & Habitat Assessment

June 2026



Audubon

Wilson's Phalarope at Great Salt Lake

Great Salt Lake Birds & Habitat Assessment:

Audubon's Analysis of Current and Future Habitat Conservation Priorities, Needs, and Opportunities for Great Salt Lake and Its Wetlands

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Partners looking to access the interactive web tool please contact
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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

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EXECUTIVE SUMMARY

The Great Salt Lake Birds and Habitat Assessment (Assessment) is a science-based analysis designed to inform conservation strategies in the Great Salt Lake watershed, with its core goal focusing on protecting birds and the places they need, today and tomorrow. Developed by National Audubon Society's (Audubon) team of scientists and habitat and water experts, this effort integrates data analyses from habitat, hydrology, and climate models into a unified, spatial framework.

As one of the largest saline lake systems in the Western Hemisphere, the Great Salt Lake ecosystem supports an estimated 12 million birds annually and hosts globally significant populations. Increasing water diversions, development, and climate stressors threaten Great Salt Lake's resilience and directly impact habitat quality and availability for priority birds.

To address these challenges, the Assessment offers an avian prioritization model to evaluate habitat suitability for waterbird species that depend on Great Salt Lake's diverse habitats across all seasons (breeding, nonbreeding, and migration). Avian habitat prioritization must consider both the intrinsic value of individual sites and their functional connectivity within the broader landscape. Isolated habitat patches may not support viable populations if they lack connectivity to other habitats or to essential water sources. A system-level perspective that accounts for hydrologic connectivity, habitat connectivity, and supports the full annual cycle needs of migratory birds at a hemispheric scale is necessary to guide effective conservation action. As part of this Assessment, Audubon utilized a complementary hydrologic model that depicts how wetland and agricultural return flows may contribute to lake inflows, providing system-wide context for potential water resource management.

The Assessment yields several key findings for conservation partners working in the Great Salt Lake watershed.

- The open water of Great Salt Lake and its surrounding wetland complexes—including Bear River Migratory Bird Refuge, Farmington Bay, Ogden Bay, and Willard Spur Waterfowl Management Areas—are of ongoing conservation priority because they provide essential habitat today that also are projected to persist under future climate conditions. Protecting water flows and preventing encroachment on these habitats offers the highest near-term conservation impact.
- Agricultural lands and degraded historical wetlands in the areas surrounding the lake represent conservation opportunities where climate suitability will remain high and where restoration or land protection can generate long-term conservation value.
- Maintaining and improving hydrologic connectivity—the network of streams, canals, and return flows that deliver water from across the watershed to the lake and its wetlands—is as essential to bird conservation as the wetland footprints themselves.

Conservation outcomes achieved through informed partnership will be most durable and most effective. In addition to state and federal managers, private landowners, agricultural operators, water rights holders and local governments are essential partners for taking advantage of the opportunity to maintain the necessary redundancy and ecological integrity that sustains the region's exceptional waterbird diversity.

Study Objectives

The Great Salt Lake Birds and Habitat Assessment was developed to provide a scientific spatial framework for prioritizing waterbird conservation efforts in the Great Salt Lake watershed. An interactive version of an accompanying map—displaying the avian habitat prioritization results, hydrologic inflows pathways, and relevant management classification layers across the study area—is available online for the conservation community and partners to use as a decision-support tool.

The specific objectives of this work were to:

1. Develop a spatial avian habitat prioritization model of Audubon Flight Plan indicator species that integrates multiple seasons and life-history stages.
2. Integrate habitat suitability, climate projection, and human modification data into a unified conservation framework that identifies priority conservation areas for waterbirds.
3. Evaluate habitat importance under both current conditions and projected mid-century climate scenarios to enable proactive conservation planning.
4. Model potential hydrologic contributions to Great Salt Lake from upstream wetlands and irrigated agricultural lands to identify opportunities for enhancing water delivery to the lake and its wetlands.
5. Provide spatial data that can inform restoration prioritization, water transactions, open space preservation, and land use planning and policy decisions.

By addressing these objectives, this Assessment provides local, state, regional, and national decision-makers, conservation partners, and resource managers with additional tools needed to assist informed choices about where and how to invest in conservation efforts, particularly when coupled with site-specific analyses. This Assessment is intended to complement other existing plans and studies underway in the region, including water delivery and measurement projects, integrated watershed planning, habitat and species monitoring, and more.

GREAT SALT LAKE ECOLOGY AND CONSERVATION CHALLENGES

Great Salt Lake is a Globally Important Ecosystem

Great Salt Lake, situated in northern Utah, is one of the largest saline lakes in the Western Hemisphere—spanning over 1,700 square miles on average—and provides multiple benefits across a variety of scales. Great Salt Lake plays a critical role in Utah's water cycle, providing lake effect precipitation that contributes about 5-7% of the snowpack in the Wasatch Mountains to its east. This ecosystem also serves as vital natural water infrastructure for human communities and wildlife, including food and habitat for millions of waterbirds. Great Salt Lake supports 7,700 local jobs and nearly $2.1 billion in annual economic output from minerals, fertilizers, brine shrimp industries, and recreation, and is a source of identity and heritage for nearby communities (Great Salt Lake Ecosystem Program, 2024; Great Salt Lake Advisory Council, 2025).

As a terminal lake, Great Salt Lake accumulates minerals and salts as water only exits the system through evaporation, creating a hypersaline aquatic environment that is the foundation of a globally important food web. The unique aquatic conditions supports large populations of highly adapted macroinvertebrates, such as brine shrimp *(Artemia franciscana*) and brine flies (*Ephydra* spp.). These invertebrates depend on the availability of primary producers (algae and cyanobacteria) and the associated microbial communities that are often present on microbialite structures throughout the lake (Utah Wildlife Action Plan Core Team, 2025). These primary producers are the foundation of the food web that sustains millions of migratory shorebirds, waterbirds, and waterfowl each year (Baxter & Butler, 2020; Wurtsbaugh et al., 2017). This food web has few analogs globally. Brine shrimp and brine fly populations occur in extraordinary densities during peak seasons, providing a superabundant food source for birds from across the hemisphere. Chironomid larvae (and associated taxa) also provide valuable protein and fatty acids for birds that forage in the moist to shallowly flooded mudflats of the lake and its wetlands. This extraordinary productivity makes the lake an irreplaceable resource for many birds during critical life history stages, particularly during migration when birds require substantial energy reserves to complete their journeys.

Great Salt Lake functions as both a vital ecosystem in its own right and as a keystone node within the Pacific Flyway, one of four major migratory bird corridors in the Americas (Figure 1). The expansive lake and its surrounding wetlands support a dynamic mosaic of habitats, which include natural and managed wetlands, salt marshes, wet meadows, deep and

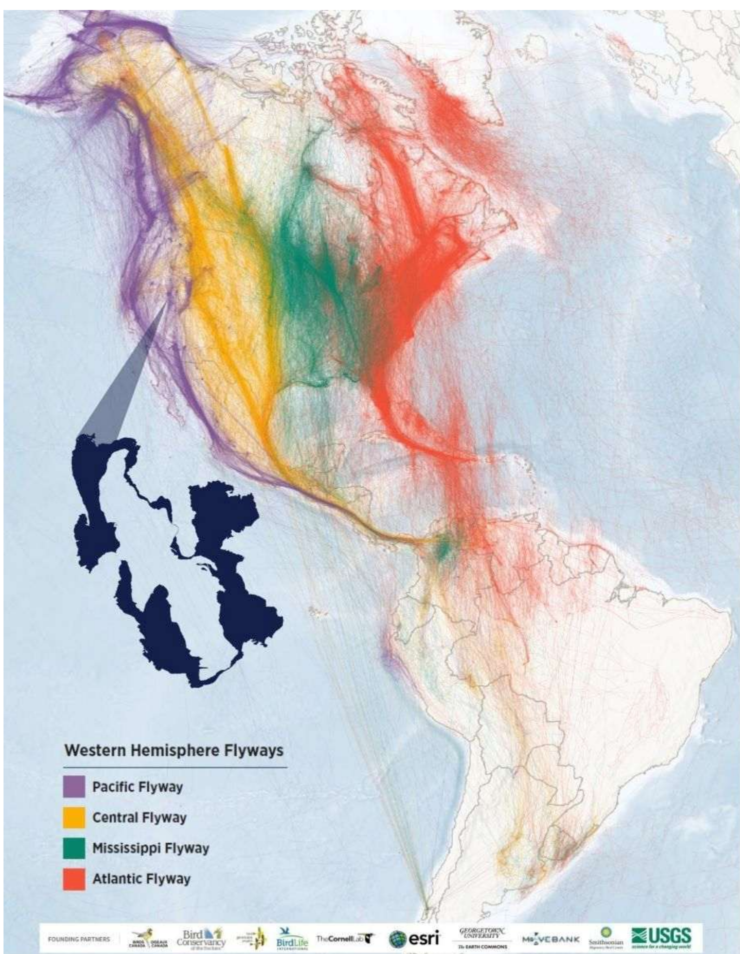

Figure 1. Western Hemisphere flyways.
Learn more about the Western Hemisphere flyways and bird movement with [Audubon's Bird Migration Explorer]

shallow water areas, islands, flooded mudflats, and playas with varying salinity—collectively providing essential resources for birds across multiple phases of their life cycles, serving as breeding grounds, stopover sites for migratory staging, and over-wintering refuges.

Great Salt Lake provides valuable habitat for some 12 million migratory birds annually, representing 339 species. As one of the most critical saline lake ecosystems for birds along the Pacific Flyway, Great Salt Lake supports species that travel as far as Alaska's Northern Slope and as far south as Patagonia (Wilsey et al., 2017). Several bird species appear in high numbers, representing large percentages of their Western Hemispheric populations, making the system a Western Hemisphere Shorebird Reserve Network Site of Hemispheric Importance—the network's highest tier. This reflects the lake's role as a major stopover and breeding site for roughly 1.4 million shorebirds each year at the time it was designated in 1991, with peak counts of species such as Wilson's Phalarope (*Phalaropus tricolor*) (~500,000 birds, exceeding 30% of the estimated global populations for that species), American Avocet (*Recurvirostra americana*) (~250,000 birds), and Black-necked Stilt (*Himantopus mexicanus*) (~65,000 birds) (Western Hemisphere Shorebird Reserve Network, 2025). Additionally, each of the major bays around the lake have distinct physiochemical and biological compositions that create their own unique aquatic environments and, collectively, provide a diverse and complementary set of habitat resources for different species. As a result, both Audubon and BirdLife International recognize the bays of Great Salt Lake as Globally Important Bird Areas (IBAs).

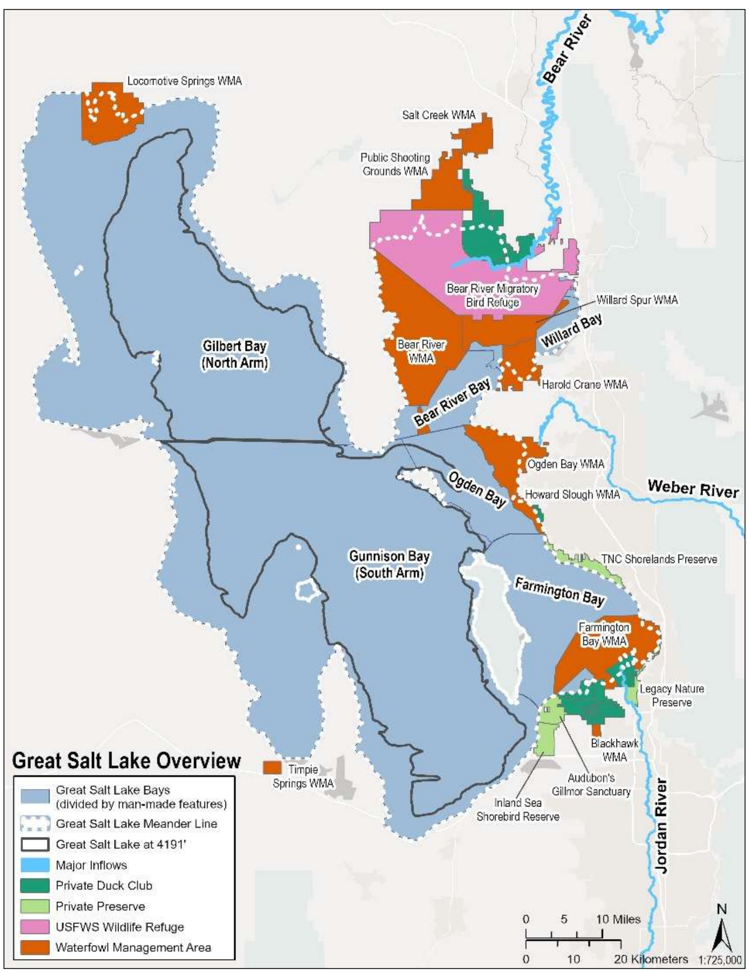

Figure 2. Great Salt Lake features (including major inflows, bays, and protected areas managed for birds).

Freshwater Inflows to Great Salt Lake

Freshwater inputs to Great Salt Lake stem from three major rivers (Figure 2) and several minor streams and seeps, groundwater sources, and precipitation. The Bear River is the major source of Great Salt Lake's water (contributing an estimated 46–64% of inflows to Great Salt Lake), flowing out of the Uinta Mountains of northeastern Utah, traveling through Wyoming and Idaho before re-entering Utah and dispersing through the Bear River Migratory Bird Refuge and, eventually, Bear River Bay at the northeastern extent of the lake (Great Salt Lake Strike Team, 2026; Great Salt Lake Advisory Council, 2025). The Weber River contributes an estimated 14–17% of inflows to Great Salt Lake. It flows from the Uinta Mountains and converges with the Ogden River, which drains from the Wasatch Range, becoming a major source of water for Harold Crane, Ogden Bay, and Howard Slough Waterfowl Management Areas, and indirectly to Willard Spur Waterfowl Management Area on the eastern shore of the lake (Great Salt Lake Strike Team, 2026; Great Salt Lake Advisory Council, 2025). The Jordan

River flows into the southern end of Great Salt Lake (contributing an estimated 8–20% of inflows), discharging to both Farmington and Gilbert Bays. Jordan River pathways to Farmington Bay include those flowing through Farmington Bay Waterfowl Management Area and several privately managed duck clubs before water moves into the un-impounded area of Farmington Bay. Water diverted out of the Jordan River at the Surplus Canal at 2100 South can also flow directly into Gilbert Bay via the Goggin Drain (Turney et al., 2025).

These perennial freshwater inflows mix with the lake's saline water, creating estuarine-like conditions that sustain a highly diverse and productive food base for birds including macroinvertebrates, mollusks, snails, salt-tolerant vegetation, and algae with a range of salinity tolerances. Bear River Bay, Ogden Bay, and Farmington Bay (Figure 2) typically receive the most freshwater inflows, providing a nursery habitat for aquatic life and birds. The absence or presence of freshwater inputs affect salinity levels of the lake body and its bays, which allows for a diversity of aquatic organisms with varying tolerance to salinity. When salinity increases too much in Gilbert Bay, invertebrate health and abundance declines and can have a cascading effect, collapsing the food web (Brown et al., 2023). However, while rising salinity from low water levels (Figure 3) threatens keystone invertebrate populations, excessively low salinity can also present challenges, such as the encroachment of invasive species in mudflat/playa habitats. Balancing salinity through adaptive management is therefore essential. The State of Utah has implemented proactive efforts to manage waterflow between the North and South Arms of the lake, which are separated by a railroad causeway, to balance salt exports and imports. Managing the Union Pacific Railroad causeway opening to change inflows and outflows has resulted in maintaining salinity levels within a suitable range (Figure 3) despite the low water levels being experienced in 2025 and 2026 (U.S. Geological Survey, 2026; Brown, et al., 2023).

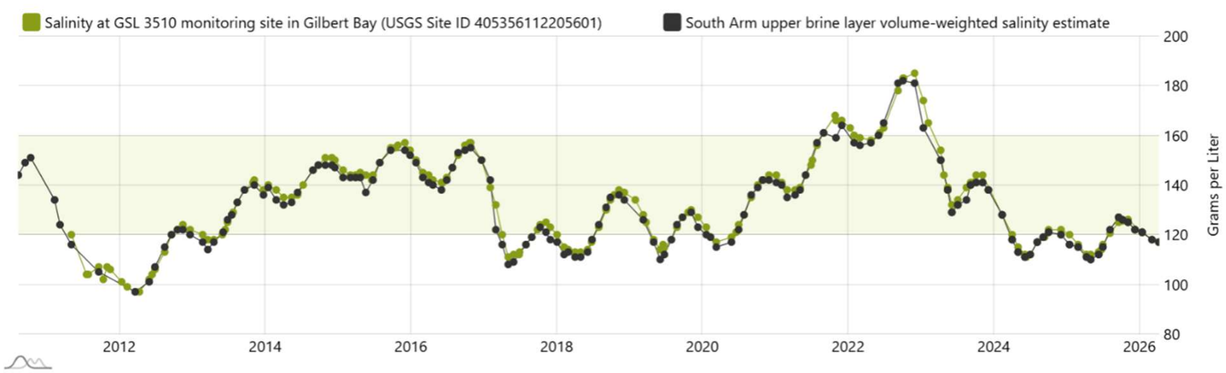

Figure 3. Great Salt Lake North and South Arm salinity in grams per liter between 2012 and 2026. The shaded green area between 120 –160g/L represents the salinity range to support the beneficial uses of the lake's ecology. (Great Salt Lake Hydromapper; U.S. Geological Survey, 2026)

The ecological significance of Great Salt Lake is closely tied to the wetlands concentrated around the eastern perimeter of the lake, as well as along its north and south shores. The wetland complex surrounding the open waters of Great Salt Lake encompasses both managed and naturally occurring seasonal to perennial wetlands, totaling approximately 350,000 acres (Downard et al., 2017). Many of these wetlands and wetland complexes are protected, including the Bear River Migratory Bird Refuge managed by the U.S. Fish and Wildlife Service, numerous

Waterfowl Management Areas owned by the State of Utah, Antelope Island State Park, private refuges and conservation areas owned by Audubon and The Nature Conservancy, and multiple privately owned duck clubs. In addition to supporting important functions—nutrient cycling, water filtration and purification, groundwater recharge, reliable shelter and forage for birds and other wildlife—these wetlands provide varied microhabitats with different water depths and availability, vegetation types, and salinity levels. This diversity supports a wide array of species with differing ecological requirements.

Shallow wetlands and mudflats provide foraging and nesting habitat for shorebirds, while deeper water supports diving ducks and grebes (Sorensen et al., 2020). Emergent vegetation offers nesting substrate and cover, while open water areas—both in freshwater wetlands and on the open water of Great Salt Lake—are essential for species such as phalarope, grebes, waterfowl, etc. (Conover & Bell, 2020). Islands within the lake body provide critical nesting habitat for colonial waterbirds, including California Gull (*Larus californicus*) and American White Pelican (*Pelecanus erythrorhynchos*). Together, with the open water of Great Salt Lake, these habitats form an integrated landscape that serves the full spectrum of wetland bird guilds.

Importantly, not all wetland types within this mosaic are permanent or structurally uniform. Ephemeral wetlands—including playa habitats that flood seasonally and dry completely between wet periods—represent a vital and often underappreciated component of the system. These features support species and ecological functions that are distinct from managed impounded wetlands. Their variable hydroperiods mean that habitat availability and quality can shift substantially across years and seasons. This variability underscores the need for conservation strategies that account for the full spectrum of wetland types beyond consistently inundated areas.

Birds and wildlife utilize a variety of habitats, emphasizing the importance of habitat connectivity within this system. Birds move among wetlands, riparian areas, agricultural lands, and upland areas throughout their annual cycles and even within single days (Donnelly et al., 2024; Downard et al., 2017). Breeding birds may nest in managed wetlands but forage in nearby agricultural fields, and vice versa. Migratory birds stage in different wetlands depending on water levels and food availability. The connectivity between these habitat areas—and critically, between wetlands and their upstream water sources—determines the functional capacity of the entire system to support bird populations (Haig et al., 1998). Connectivity in this context does not require direct physical linkage between every wetland patch; rather, it reflects the degree to which birds can access and move among a sufficient variety and abundance of habitats distributed across the landscape. Wetland birds with diverse habitat requirements—such as the American Avocet, which uses shallow freshwater wetlands for chick-rearing but forages in more saline, open-water settings during other life stages (Ackerman et al., 2020; Plissner et al., 2000)—depend on a mosaic of habitat types within a reachable, connected landscape.

Conservation Challenges and Urgency

Great Salt Lake faces unprecedented conservation challenges that threaten its ecological integrity and cause a variety of cascading impacts that are difficult to reverse and costly to mitigate. These challenges are characterized by their complexity as well as the interconnected nature of the watershed's system—where natural processes and human development are deeply intertwined—

creating urgent conservation priorities that demand coordinated action. A collapsing Great Salt Lake ecosystem would have continent-wide ecological consequences, jeopardize important economic activities for the state and nation, and lead to public health hazards from dust emissions.

Declining Lake Levels and Climate Change

The most visible threat to Great Salt Lake is its declining water level. The lake has experienced dramatic reductions in volume over recent decades and hit its lowest recorded lake level in 2022 (Figure 4), driven by a combination of factors including historic and increased water diversions, extended periods of drought, and warming temperatures associated with a changing climate (Bigalke et al., 2025). And now in the 2026 water-year, the lowest snowpack on record (Utah Division of Water Resources, 2026*b*) combined with below-average runoff and persistent drought are driving Great Salt Lake's water levels to near record lows once again (Utah Department of Natural Resources, 2026; Great Salt Lake Strike Team, 2026). Lower lake levels have led to the loss of nesting islands, exposed formerly submerged lakebed, reduced the extent of aquatic habitat, and disrupted the food web dynamics that support bird populations. This often occurs in conjunction with the exposure and desiccation of microbialite structures and the algal microbiomes they support. When the lake is at a critically low water level, salinity (if not managed through engineered solutions) spikes can threaten keystone aquatic invertebrate populations that are critical avian food sources. In addition, when water levels are low, more lakebed becomes exposed and contributes to dust emissions and stresses wetland habitats.

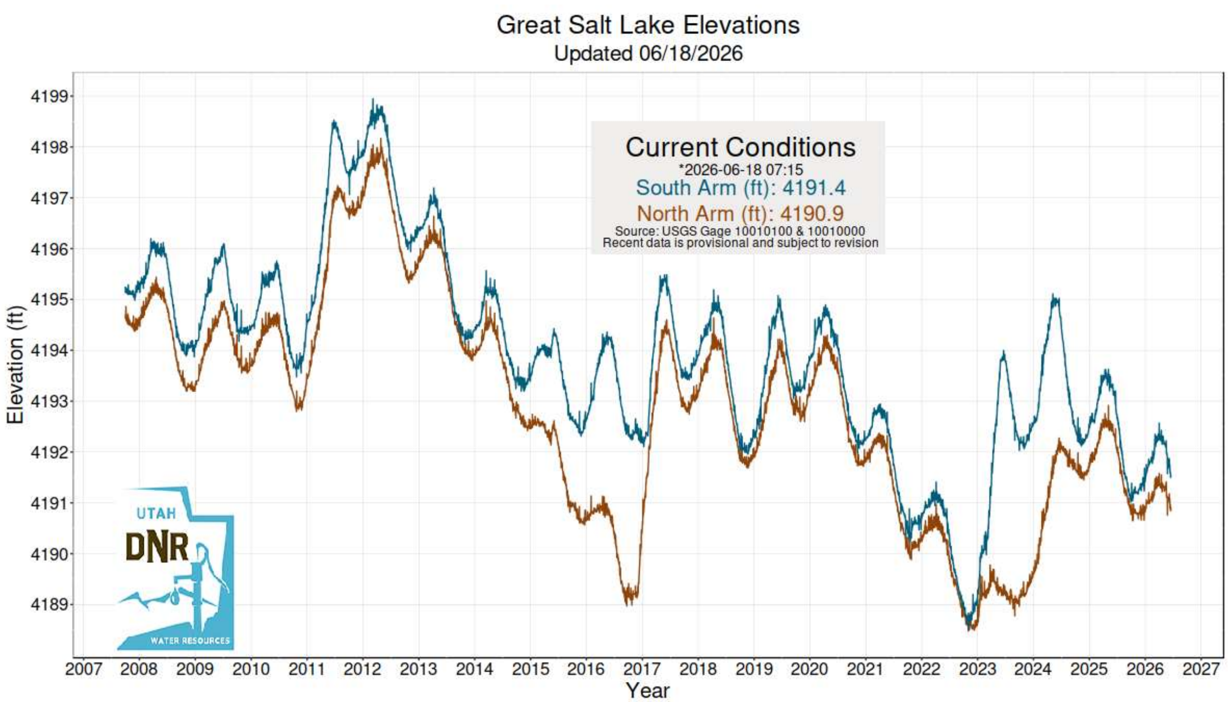

Figure 4. Great Salt Lake North and South Arm elevation in feet between 2007 and 2026. (Great Salt Lake Commissioner's Office, 2026)

Climate change projections indicate that conditions in the Great Salt Lake basin will continue to degrade, with models predicting warmer temperatures, altered precipitation patterns, and increased evaporation rates (Baxter & Butler, 2020; Hassan et al., 2023). These changes will impact both the lake itself as well as the surrounding wetlands and upland areas that provide complementary habitat for birds. The climate modeling being undertaken as part of the Great Salt Lake Integrated Basin Plan will provide updated and important information to inform the anticipated effects of climate change scenarios in the Great Salt Lake Basin (Utah Division of Water Resources, 2026*a*).

Water Diversions and Competing Water Demands

Water flowing into Great Salt Lake is heavily managed and allocated through Utah's prior appropriation water rights system. Upstream diversions for agricultural, municipal, and industrial uses, along with other upstream ecological uses, reduce inflows to the lake and its wetlands. As Utah's human population continues to grow and development expands, competition for water resources intensifies. Agricultural practices, particularly irrigation, play a dual role: while irrigation diverts water from the system, return flows from flooded agricultural fields contribute to inflows to Great Salt Lake and its wetlands and the flooded agricultural fields provide wetland-like habitats and food resources for birds (Donnelly et al., 2024). Municipal and industrial water uses also decrease inflows to Great Salt Lake and can degrade water quality (Great Salt Lake Strike Team, 2026).

Balancing these competing water demands while maintaining sufficient inflows to support the lake's ecological functions is a fundamental challenge. Policy changes in Utah now recognize that water rights can be used for the "reasonable preservation or enhancement of the natural aquatic environment" in places like Great Salt Lake (H.B. 33, 2022; Utah Code Section 73-3-30), increasing opportunities for water to be secured for the benefit of the lake, which improves water levels and wetland habitat through increased and secured inflows. The scale of water needed to stabilize and restore the system is substantial, requiring strategic prioritization, when possible, in the timing and location of water deliveries.

Habitat Loss and Fragmentation from Development

The Great Salt Lake watershed is experiencing rapid urbanization and growth pressure. The expanding Wasatch Front urban corridor is encroaching upon essential wetland and upland habitats, converting them to residential, commercial, and industrial uses (Figure 5; Wasatch Front Regional Council, 2026). As urban development encroaches further alongside open lands, the ability for birds to access and move among a variety of habitats erodes. Each converted parcel of wetland, wet meadow, or agricultural land reduces the number of viable habitat alternatives to birds reliant on Great Salt Lake and its wetlands, narrowing movement corridors, and diminishing the ecological integrity of the watershed as a functioning system. These land use changes not only eliminate habitat directly but also fragment remaining habitats, disrupt ecological connectivity, and introduce hard edges that degrade habitat and water quality, as well as convert water from agricultural to municipal use. This can reduce or eliminate the buffer between the built landscape and natural settings, significantly reducing the presence of sensitive species such as Long-billed Curlew (*Numenius americanus*).

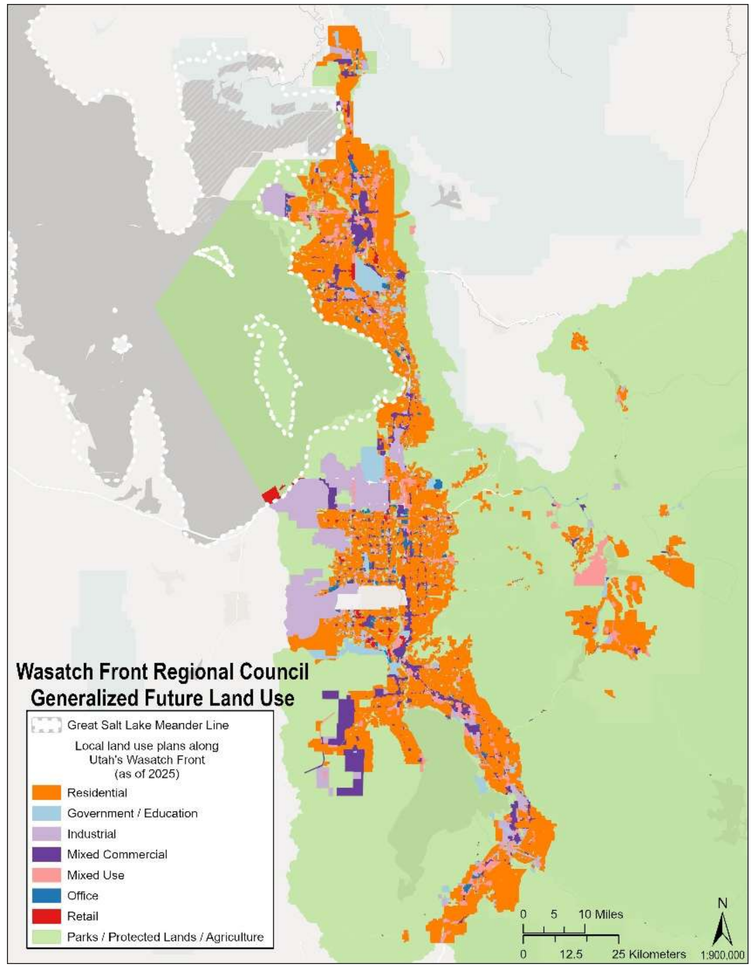

Figure 5. Generalized local land use plans along Utah's Wasatch Front, based on individual cities general plans in late 2024 and early 2025. The Wasatch Front Regional Council interpreted these plans to develop a set of best match/simplified land use codes as represented as the individual colors shown in this figure. (Wasatch Front Regional Council, 2026).

Additionally, conserving hydrologic connectivity for freshwater inflows into Great Salt Lake is not simply a water management concern, but a foundational bird conservation priority (Pringle, 2001). When hydrologic pathways are severed or degraded (whether by water diversion, infrastructure, or land conversion) the downstream wetlands they supply may lose the critical timing of inundation, duration, and associated biochemical pathways that make them functional waterbird habitat.

Agricultural lands—which can provide important supplemental habitat for birds, especially when flooded or fallowed, as well as groundwater recharge in some cases—are also being converted to municipal and industrial uses. In the Great Salt Lake Basin, it is estimated that agricultural to urban land conversion between 2024 and 2059 will range from between 58,400 acres to 87,600 acres of land and 77,000 acre-feet to 115,700 acre-feet of water (Utah Division of Water Resources, *personal communication*, May 26, 2026). These lands are effectively removed from potential conservation or restoration opportunities once converted to impervious surfaces. The pace of this conversion is accelerating, intensifying the need to preserve habitats before they are permanently lost.

<u>Displacement of Habitat by Invasive Phragmites</u>

The invasive common reed, *Phragmites australis* (Phragmites), established its foothold in exposed moist sediment of Great Salt Lake and its wetlands in the 1980s. Phragmites, which can grow well over 3 meters tall, has a higher tolerance to soil salinity and soil contaminants relative to other native wetland vegetation, allowing it to spread rapidly (Hoven & Richards, 2018). By 2016, more than 90 square kilometers of lakebed and managed wetlands were invaded by the robust reed, dominating and transforming formerly open, productive bird habitat into dense monocultures of little value to those species (Long et al., 2017*a*; Long et al., 2017*b*).

Phragmites stands impound sediment, obstructing natural water flow. Phragmites also has nearly double the water consumption of native saltgrass (*Distichlis spicata*) (Inkenbrandt et al., 2026). It has now become well accepted that removing dense stands of Phragmites can increase inflows to Great Salt Lake significantly (Utah Division of Forestry, Fire and State Lands, 2024). Awareness of the need for coordinated, watershed-scale control efforts focused on invasive plants along freshwater inflow areas is gaining traction. In recent years, significant investments have been made in research into control measures, impacts on habitat and water availability, and regional-scale management.

These converging threats create an imperative for strategic, science-based habitat prioritization. Not all areas of the watershed are equally important for bird conservation, nor are they equally vulnerable to loss or equally amenable to restoration. Conservation resources—whether financial, political, or organizational—are limited and have the greatest impact when deployed strategically to achieve maximum benefit.

Traditional approaches to habitat conservation often focus on protecting existing high-quality habitats. While this remains important, the dynamic nature of climate change and development pressure requires a more forward-looking approach. Areas that currently provide marginal habitat may become increasingly important as conditions shift. Understanding these trajectories is essential for making informed conservation decisions.

Habitat prioritization must consider both the intrinsic value of individual sites and their functional connectivity within the broader landscape. Isolated habitat patches, no matter how high-quality, may not support viable populations if they lack connectivity to other habitats or to essential water sources. A system-level perspective that accounts for hydrologic connectivity, habitat connectivity, and supports the full annual cycle needs of migratory birds at a hemispheric scale is necessary to guide effective conservation action.

METHODS

Audubon developed two frameworks as part of this Assessment: an avian prioritization model to evaluate bird species and habitat importance under current and projected climate conditions, and a hydrologic model to depict how wetland and agricultural return flows may contribute to lake inflows.

Avian Prioritization Framework

Audubon scientists conducted a series of optimization analyses to identify priority areas using Zonation Conservation Planning software (Moilanen et al. 2024). Analyses were conducted for both present and midcentury (year 2050) timesteps based on focal bird suitability and relative abundance using the methods described in Deluca et al. (2023). The features being optimized are listed on the left side of each box (Figure 6) and include present and future habitat and climate suitability models for the breeding and nonbreeding seasons (Wilsey et al. 2019) as well as relative abundance models for fall and spring migration seasons (Fink et al. 2024, Meehan et al. 2022), for all indicator species in all seasons in which they are present in the watershed. The right side of each box (Figure 6) indicates the landscape degradation attributes the model aims to avoid.

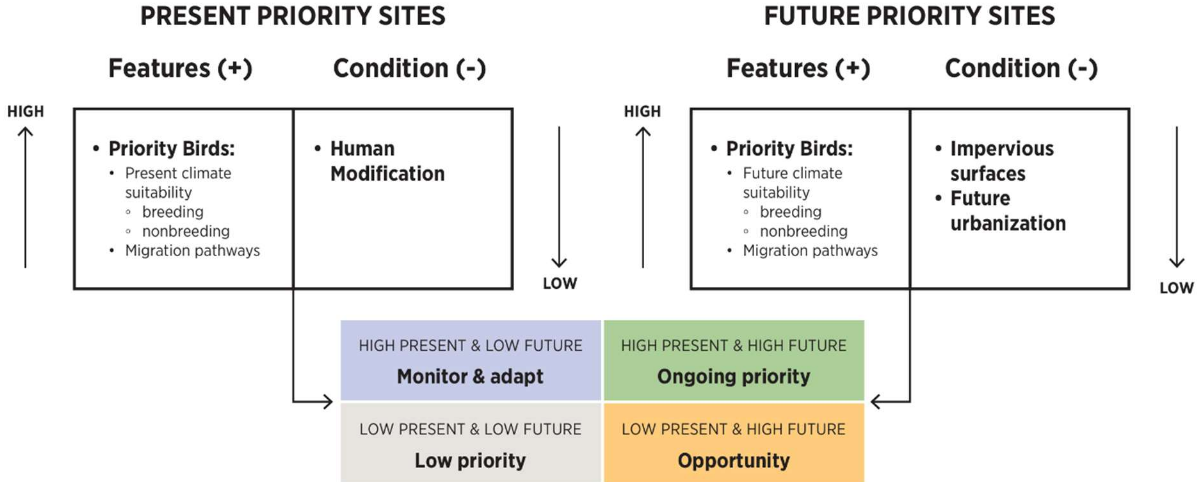

Figure 6. Conceptual model and process for identifying priority sites for conservation action in the Great Salt Lake watershed.

Locations with the highest suitability/relative abundance for any species in each season are represented in the highest ranks of the prioritization if habitat degradation is low. Locations with high levels of human modification today (e.g. agriculture, urban, roads; Kennedy et al., 2019) are ranked lower, regardless of suitability. In the future model, the ranks of locations with high suitability are lowered only by impervious surfaces (Dewitz, 2021) and predicted urban growth (U.S. Environmental Protection Agency, 2017) rather than total human modification. We used this approach because reasonable restoration or mitigation strategies exist for most other forms of degradation, while areas already converted to impervious cover (e.g. highways, dense urban development) are treated as effectively permanent for planning purposes given the extremely high costs and low likelihood of large-scale removal or restoration. This reflects a practical assumption for identifying realistic future conservation opportunities. Excluding non-impervious land uses (e.g. agriculture) from the future condition layer allows the model to identify those areas as opportunities if they have high climate suitability in the future.

The present and future prioritizations were combined into a single classified raster with four management classes as shown in Figure 6 and described below. The classified raster was derived by thresholding the present and future prioritizations at the top 20% (reclassifying all cells with a rank >= 0.8 as high, and all cells with a rank < 0.8 as low) and combining them as follows:

Ongoing Priority: high rank in both the present and future
Opportunity: low rank in the present, high rank in the future
Monitor & Adapt: high rank in the present, low rank in the future

<u>**Spatial Extent**</u>

The avian analysis focused on the eastern Great Salt Lake Basin (Figure 7). We excluded the wetted north arm of the lake body, which provides unsuitable habitat for wetland birds due to the high salinity, as well as all subbasins located west of the Great Salt Lake meander line. We recognize that there may be valuable waterbird habitat within the West Desert watershed but excluded this region to produce results targeted to our main focal areas surrounding the lake. We constrained the results to a 5-kilometer radius around wetlands documented in the Intermountain West Joint Venture wetland resilience and hydroperiod dataset. Limiting results to these areas allowed us to focus on water-

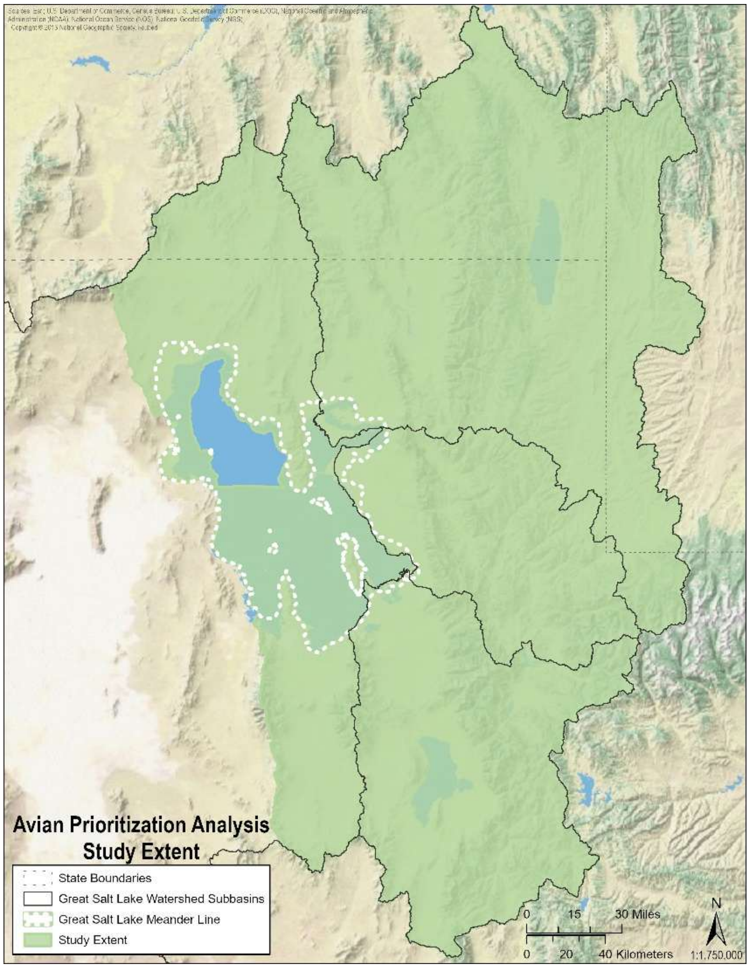

Figure 7. Avian habitat prioritization study area extent with subbasin boundaries.

dependent systems (including wetted upland or agricultural habitats) and gain an understanding of where development encroachment or land conversion may have the most immediate impact. Although our primary interest was in wetland systems, we also sought to understand broader patterns of habitat use across the watershed.

Indicator Species

Indicator species were selected based on their sensitivity to specific habitat conditions and their ability to represent larger guilds or species groups. We used Audubon's Survival by Degrees (Wilsey et al., 2019) suitability models (1 km resolution) to represent the present and future suitability for all indicator species in the breeding and nonbreeding seasons based on the worst-case climate scenario (RCP 8.5). For species present in the watershed during spring and fall migration, we used Audubon's Migratory Bird Initiative's Merged Migration Maps (Meehan et al., 2022) which integrate tracking data with eBird relative abundance models and are considered the best available representation of migration distributions for the present day. We used the original eBird Status and Trends (Fink et al., 2024) models for the migration season distributions of two species that did not have Merged Migration Maps available (Lesser Yellowlegs (*Tringa flavipes*) and Western Sandpiper (*Calidris mauri*).

All indicator species in the analysis are included in Audubon's Flight Plan indicator species list (Table 1). To account for the species that are not on the list, we considered Wetland Climate Strongholds (both relatively intact and vulnerable), which were derived from 117 wetland bird species including the four 'Non-Flight Plan Indicator Species' listed in Table 1. Note that this product does not include migration season information therefore the Non-Flight Plan Indicator Species that are present in the Great Salt Lake only during migration are not well represented in Wetland Climate Strongholds.

Table 1. Indicator species included in the avian prioritization analysis.
* species not included in Audubon's Strategic Flight Plan
† species present in the Great Salt Lake watershed only during spring and fall migration

Indicator Species
American Avocet
American White Pelican
Black-necked Stilt *
California Gull

Cinnamon Teal
Eared Grebe
Lesser Yellowlegs †
Long-billed Curlew
Long-billed Dowitcher †
Marbled Godwit †
Northern Pintail
Redhead *
Ruddy Duck *
Snowy Plover
Tundra Swan *
Western Grebe
Western Sandpiper †
White-faced Ibis
Wilson's Phalarope

It is important to note that while indicator species were used for the avian prioritization, the areas identified support a much broader suite of bird species and life-cycle stages that are not included in this model. For example, the open water habitat of the lake body that is important to indicator species such as Eared Grebe (*Podiceps nigricollis*) also supports significant populations of Red-necked Phalarope (*Phalaropus lobatus*) (approximately 10% of the North American population) (Paul, 1982) and tens of thousands of overwintering Common Goldeneye (*Bucephala clangula*) (J. Luft, *personal communication*, June 29, 2026). The indicator species are a subset of the remarkable diversity of shorebirds, waterfowl, and other waterbirds that spend time on Great Salt Lake and its wetland habitats.

We did not include riparian birds or upland bird species that are found in the Great Salt Lake watershed in order to focus on waterbirds using wetlands and the lake itself. Inclusion of riparian and upland species would have redirected model rankings toward high-quality riparian corridors and upland grasslands rather than the wetland and open-water habitats central to this analysis. Practitioners working in riparian or upland contexts within the watershed should be aware that those systems are not represented in the prioritization outputs and require a separate analysis.

Prioritization Versions

We ran four versions of the avian prioritization model using Zonation conservation planning software and the Core Area Zonation algorithm (CAZ).

1. All indicator species
2. Open water of Great Salt Lake indicator species
3. Deep water/freshwater wetland indicator species
4. Shallow/near shore wetland indicator species

The CAZ algorithm minimizes biological loss by iteratively removing the cell that is least critical to its most dependent species, where dependency is measured by how much of a species' remaining distribution occurs in that cell. A cell ranks highly if even one species relies heavily on it relative to its other available habitat (Moilanen et al. 2005, Moilanen et al. 2007). By running multiple versions of the analysis, we ensure that the distinct conservation needs of open water, deep water wetland, and shallow water bird communities are each captured precisely, and that the results are applicable to the management decisions most relevant to each habitat and species group. The species and seasons included in each version are listed in Table 2.

We weighted species equally in all versions using a 0.0–1.0 scale. Because the number of seasons in which each indicator species is present in the watershed, equal weighting requires normalization. Each species received a total weight of 1.0, divided equally across seasons in which it is present on the landscape. A resident species, for example, present in all four seasons (breeding, nonbreeding, pre-breeding migration, post-breeding migration) received a weight of 0.25, while a species present during only one season received a 1.0. This ensures that migratory specialists (i.e., species present for a brief but ecologically critical window) receive equivalent representation to year-round residents. This decision was made to avoid prioritizing resident birds over migratory birds to achieve equal habitat representation for all indicator species.

Table 2. Species included in each habitat-specific prioritization version.

Habitat Type	Description	Species	Season
Open Water	Open water areas of Great Salt Lake and its bays. These areas provide foraging habitat required for species foraging on brine shrimp and brine flies during staging, and island breeding habitat.	American White Pelican	Breeding
		California Gull	Breeding Nonbreeding
		Eared Grebe	Migration
		Wilson's Phalarope	Migration
Deep Water Wetlands	Deep water wetland included managed / natural wetlands with reliable freshwater sources and deep-water zones. These support breeding species and provide staging habitat during migration for many species.	American White Pelican	Breeding Migration
		California Gull	Breeding Nonbreeding
		Cinnamon Teal	Breeding Migration
		Eared Grebe	Breeding
		Northern Pintail	Breeding Nonbreeding Migration

		Western Grebe	Breeding Migration
		White-faced Ibis	Breeding
		Wilson's Phalarope	Breeding
Shallow Water / Near Shore Wetlands	Shallow wetlands include seasonal wetlands and the extensive mudflats that develop around the margins of Great Salt Lake and tributary wetlands. These areas are essential for species that forage in shallow water or on exposed substrates and nest on exposed substrate or the wet meadow fringes. These habitats range in salinity and provide an assortment of macroinvertebrates if there is periodic hydrologic connectivity that maintains salinity levels below tolerance thresholds for invertebrates.	American Avocet	Breeding Nonbreeding Migration
		California Gull	Breeding Nonbreeding
		Cinnamon Teal	Breeding Migration
		Lesser Yellowlegs	Migration
		Long-billed Curlew	Breeding Migration
		Marbled Godwit	Migration
		Northern Pintail	Breeding Nonbreeding Migration
		Snowy Plover	Breeding Migration
		Western Sandpiper	Migration
		White-faced Ibis	Breeding Migration
		Wilson's Phalarope	Breeding Migration

Hydrologic Inflows Analysis

The hydrologic inflows model is a customized geospatial assessment with the goal of understanding potential flow pathways into Great Salt Lake from either natural or managed wetland environments. Inflows are the most sensitive cause of lake volume fluctuation in Great Salt Lake (Mohammed & Tarboton, 2012) and therefore an important area of opportunity for conservation action across the watershed. Flooded agricultural fields temper seasonal inflow variability, returning a portion of applied irrigation water to the lake (Null & Wurtsbaugh, 2020). These agricultural return flows are important water sources for the lake while flooded fields offer surrogate wetland and riparian habitats that are important for birds (Berkowitz & Evans, 2014; Moulton et al., 2022).

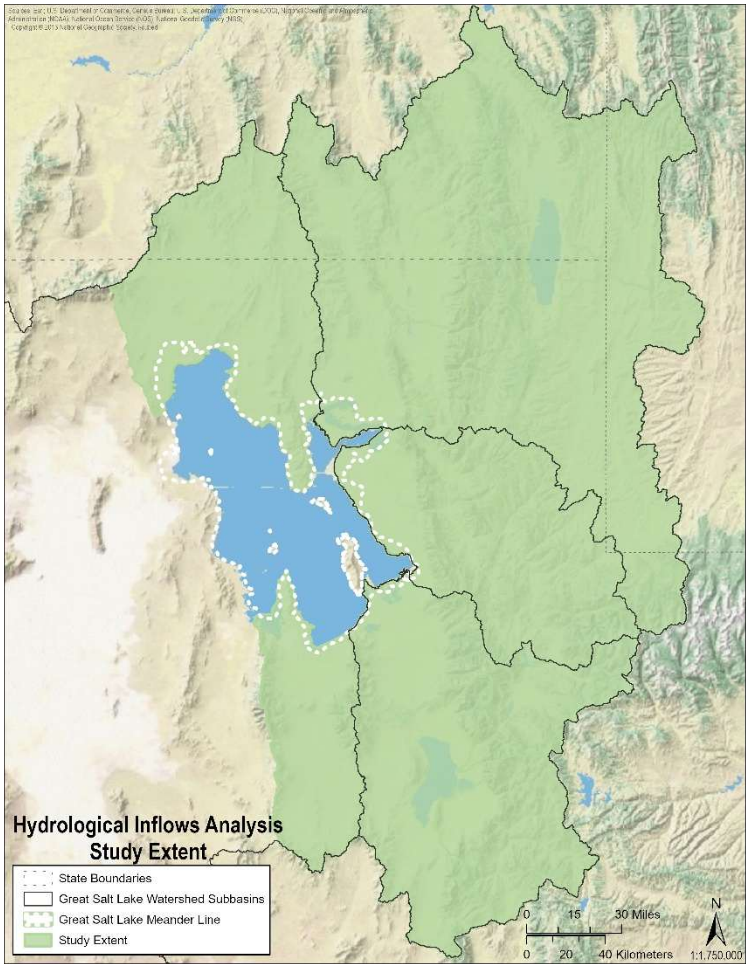

Figure 8. Hydrologic inflows analysis study area extent with subbasin boundaries.

Spatial Extent

The extent of the inflow analysis was restricted to inflows from level 12 Hydrologic Units north, south, and east of the Great Salt Lake (Figure 8). We excluded the west desert for the reasons outlined above.

Wetland Data

High resolution, vectorized, wetland data were not available across the entire study area any time in the past 5 years. Instead, we used high resolution remotely sensed data from the Intermountain West Joint Venture documenting wetland resilience and hydroperiod across the west (Donnelly, et al. 2022). Wetland resilience, a measure of water cover trend, was calculated as a monthly trend over the period 1984–2021 and averaged across all 12 months to produce a mean annual resilience trend. Hydroperiod, flooding time in an area, was aggregated over multiple time periods; for this analysis we used 2015–2022. The wetland resilience and hydroperiod rasters were then combined to capture all wetlands identified across both datasets.

Flooded Agricultural Data

Flooded agriculture data was acquired from the Utah Geospatial Resource Center, Utah Water Related Land Use dataset (2015, with data having been updated and accessed June 2025). The Utah Division of Water Resources collects and maintains data on land uses that impact water consumption across the state and publishes water usage-related maps annually that depict the types and extent of irrigated crops, as well as information concerning vegetation, wet/open water areas, and residential/industrial areas. The water related land use dataset categorizes irrigation methods as “Drip,” “Flood,” “Sub-irrigated,” and “Dry Crop.” All polygons where the irrigation method is listed as “Flood” were retained in the analysis, while the “Drip” and “Dry Crop” irrigation methods in the dataset were not included because they do not provide significant amounts of potential return water flows to Great Salt Lake's ecosystem, nor do they provide comparable high-quality habitat for wetland birds (Burke, 2020; Moulton et al., 2022). Given rapid changes in agricultural land use and optimization practices, results should be interpreted with the awareness of this data limitation.

Stream Data

High resolution (1:24,000/1:12,000 scale) stream data from the National Hydrologic Dataset that were modified by the Utah Geographic Resource Center (Utah Geographic Reference Center, 2015) were used as the base data for streams.

Potential reach contribution to Great Salt Lake was quantified by acres as a surface area measurement of water either from flooded agricultural fields or wetlands. Streams were buffered by 12 meters—a spatial resolution corresponding to the high-resolution quality of the stream data. This was based on expert opinion to address uncertainty in the delineation and width of actual streams—and joined to the flooded field dataset and the wetland dataset where they intersect. We ran a downstream flow network analysis to visualize the entire hydrologic network surrounding the lake. The downstream flow analysis mapped the flow path from the top 80% potential contribution reaches flowing from either wetlands or flooded fields. We chose the top 80% of potential contribution to exclude single cells and small fields and wetlands unlikely to yield large contributions to lake levels.

Caveats and Limitations

Both the avian prioritization and the hydrologic inflows analyses are geospatial in nature and carry uncertainties that should be considered when interpreting results. We used the best available data and data layers, including information gathered from peer scientists and experts. However, results are not ground-verified, and that unquantified uncertainty should be acknowledged when applying findings to on-the-ground decisions. Additional caveats and limitations to note:

- As we did not have projected migration distribution maps for the future scenario in the prioritization modeling, we used the present day to represent both time periods. This is a known limitation of this analysis: under worst-case climate conditions, migratory patterns may shift in ways that could alter the relative importance of stopover sites. Potential future refinements of this Assessment should incorporate projected migration distributions as that modeling capacity develops.
- A consequence of normalizing species weights in the CAZ algorithm is that species with strong year-round site fidelity contribute proportionally less per season than species present for a single season. Professionals making management decisions for a specific species of concern should consult the underlying species-specific models, which are not normalized this way, rather than solely on the aggregated prioritization output.
- The avian prioritization model is limited to a one-kilometer resolution, which does not provide fine-scale results at the site level. This may designate some developed areas as habitat. The results, however, help inform the next phase of on-the-ground detail.
- Audubon is not suggesting any infringement on private property rights.
- As noted above, we did not include riparian birds or upland bird species that are found in the Great Salt Lake watershed in order to focus on waterbirds using wetlands and the lake itself.

RESULTS

Avian Prioritization

The avian prioritization analysis produced three sets of outputs for each of the four prioritization versions (all species, open water, deep-water wetlands, shallow wetlands): present landscape rankings, future landscape rankings, and management classification layers.

Present and Future Landscape Rankings

The present landscape rankings (Figure 9a) identify areas of highest current conservation value based on habitat suitability for indicator species and current levels of human modification. Lighter colors in the rank maps indicate higher conservation priority. The highest-ranked areas represent the set of locations that contain the highest habitat suitability values for all individual species, rather than high total species richness, and where human modification is relatively low.

The future landscape rankings (Figure 9b) show projected conservation priorities under the worst-case climate scenario (RCP 8.5), assuming degraded non-impervious surfaces are restored (e.g. agricultural land). Notable spatial shifts appear between present and future rankings, reflecting anticipated changes in habitat suitability driven by climate change, urban growth, and hypothetical restoration. Some areas that currently rank high are projected to decline in value, while other areas that are currently degraded or of moderate importance are projected to increase in conservation value.

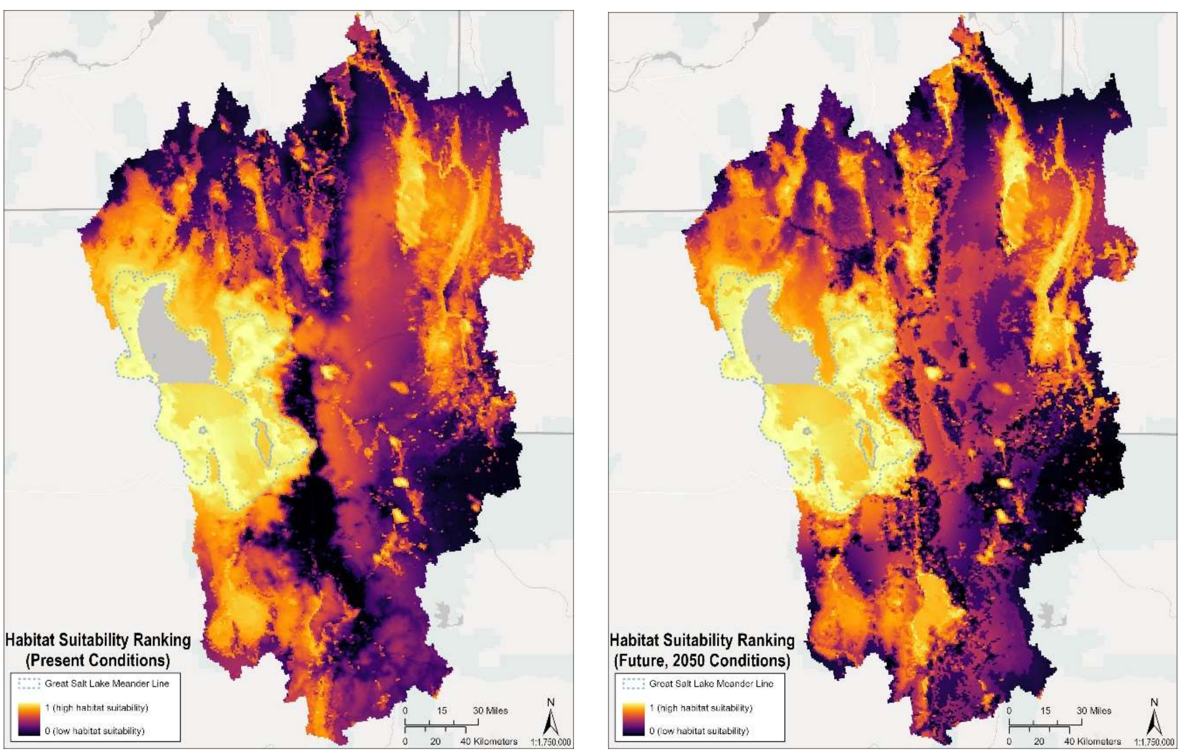

Figure 9. Present landscape ranking (**a**) and future landscape ranking (**b**) for the 'all indicator species' version. Lighter colors indicate higher habitat suitability rankings.

The comparison between present and future rankings reveals important patterns:

- Core wetland complexes surrounding Great Salt Lake, and the open water of the lake itself, generally maintain high ranks in both time periods, indicating their fundamental and enduring importance.
- Some portions of the watershed show increased future suitability, suggesting the potential for climate-driven habitat shifts.

Management Classification

The management classification outputs (Figure 10) synthesize present and future rankings into actionable categories. The four classes are distributed across the landscape as follows:

Ongoing Priority areas (high present rank, high future rank) are concentrated around the open water of the lake body and existing wetland complexes, particularly managed wetlands and state waterfowl management areas. These areas represent the stable core of the conservation landscape and warrant protection, continued management, and potentially enhancement. They include key sites such as the Bear River Migratory Bird Refuge, Farmington Bay Waterfowl Management Area, Audubon's Gillmor Sanctuary, and Bear Lake (which is an important facet of the watershed).

Opportunity areas (low present rank, high future rank) represent the most significant opportunities for proactive conservation. These areas are primarily:

- Agricultural lands and open water predicted to maintain or gain climate suitability.
- Degraded but restorable historical wetlands with high predicted future climate suitability for one or more indicator species.
    - For example, Utah Lake shows increased future suitability, suggesting high value if water quality and habitat are improved. This finding warrants careful interpretation. Utah Lake is an important water storage and distribution node that contributes substantially to Great Salt Lake inflows. The model flags it as a potentially significant habitat under future conditions—reflecting the presence of water sources and high bird use. Utah Lake is currently degraded, with eutrophic conditions and land-use-driven water quality issues limiting its ecological function despite continued bird use. Its long-term value is restorable, and the model's future projections reflect that habitat could be enhanced now making conditions more suitable amid climatic changes.
- Undeveloped areas projected to become more suitable as climate conditions shift, if such areas remain undeveloped.

It is important to clarify what "Opportunity" means in this framework: these are areas where the current condition is degraded in a non-permanent way—meaning restoration is possible. The model does not indicate that conditions are already improving; it indicates

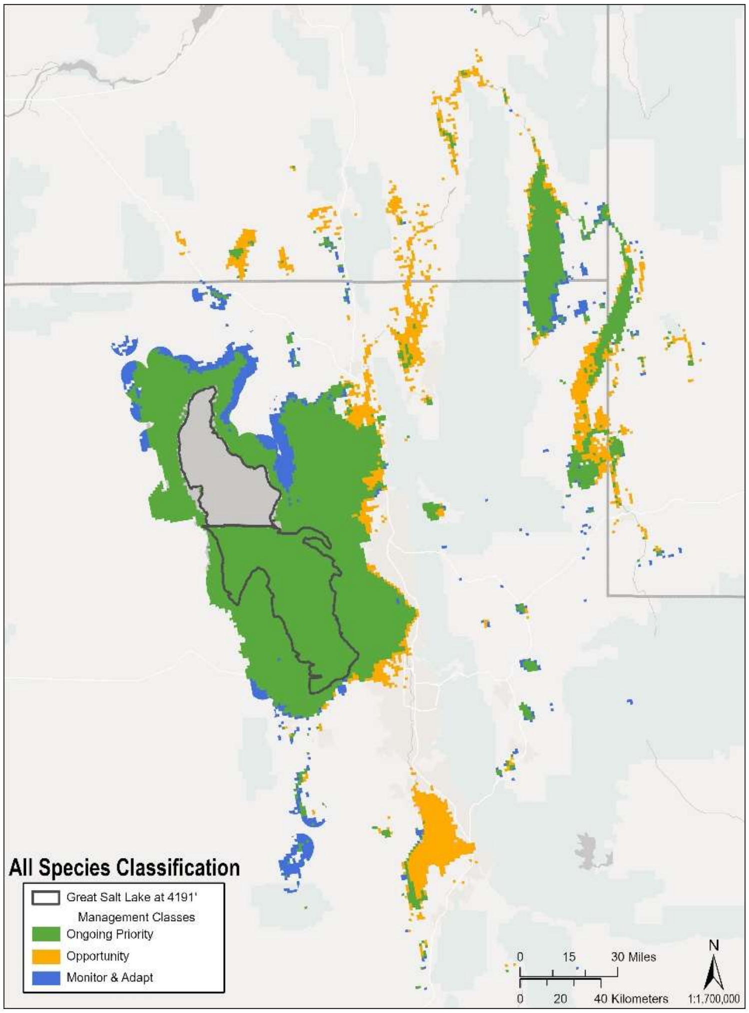

Figure 10. Management classification layers based on the top 20% thresholds for all indicator species and equal species weighting (all seasons summed to 1).

that the climate will be suitable for indicator species when the habitat is restored or revitalized. This distinction is critical for interpreting the layer appropriately.

Monitor & Adapt areas (high present rank, low future rank) are scattered throughout the watershed, often in locations where current climate and habitat suitability are high, but projected climate conditions suggest future challenges. Management strategies can focus on enhancing climate resilience through water or vegetation management. It should be noted that the designated areas of Monitor & Adapt are largely driven by particular bird species in particular locations. For example, areas to the west of Utah Lake around Rush Valley and areas to the North of Great Salt Lake are the result of current uses by breeding Long-billed Curlew, which are projected to become less amenable habitats with climate change. Monitor & Adapt areas to the east of Bear Lake are currently priorities for Eared Grebe and Wilson's Phalarope, and such habitats are projected to be less suitable for the respective species in future years.

The identification of classified areas is particularly valuable in guiding conservation investment in areas that will provide long term value, potentially providing supplemental habitat to areas in the "Ongoing Priority" category. Many classified habitat areas are currently in agricultural use, particularly flood-irrigated fields that already provide some wetland function and could be enhanced to provide dedicated wildlife habitat.

Unprioritized areas (low present ranking, low future ranking) constitute the matrix between conservation priorities. While these areas may not be central to indicator bird habitat conservation, they may serve other important ecological functions or have value for different conservation objectives.

<u>Habitat Specific Patterns</u>

Open water species priority areas concentrate on the open water areas of Great Salt Lake itself (Figure 11). These areas provide the saline, open water foraging habitat required for species like Eared Grebe and Wilson's Phalarope during staging, and island breeding habitat for California Gull and American White Pelican.

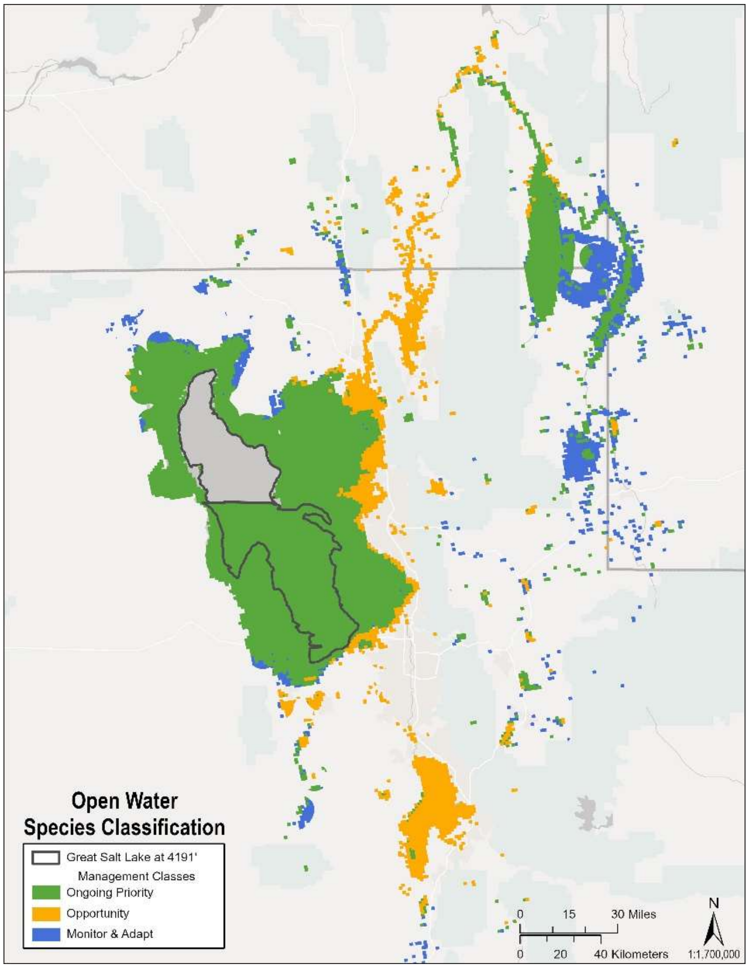

Figure 11. Management classification layer for the open water species group.

Deep water wetland priorities emphasize managed wetlands with reliable freshwater sources and deep water zones (Figure 12). These support breeding species including Northern Pintail and Cinnamon Teal, foraging habitat for waterbirds like Western Grebe and White-faced Ibis, and provide needed habitat during migration for many species.

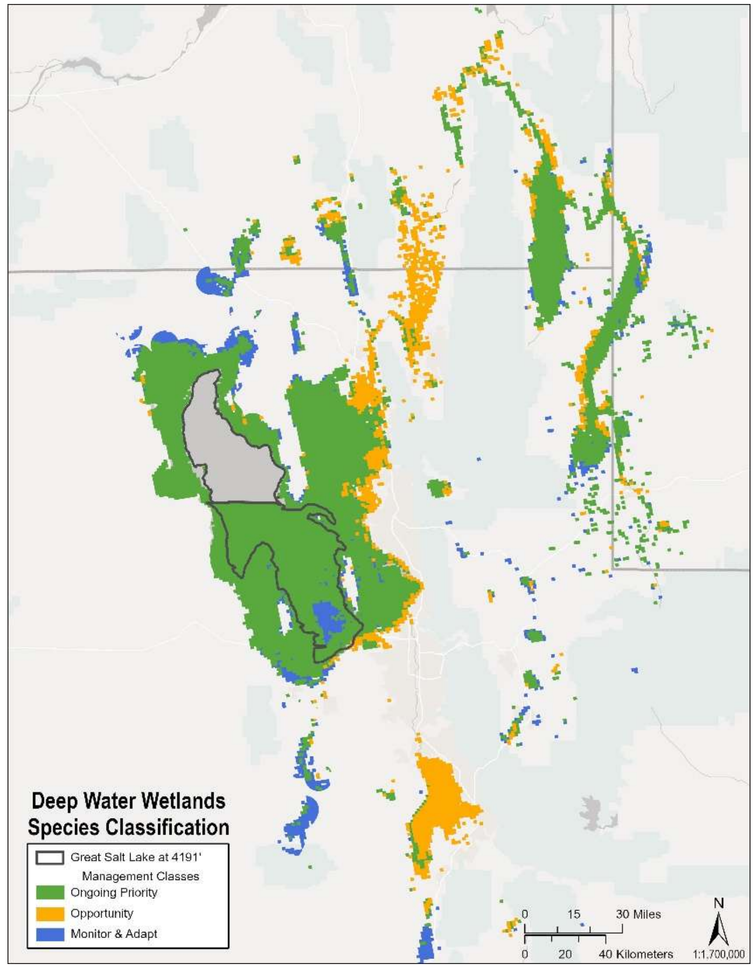

Figure 12. Management classification layer for the deep water wetlands species group.

Shallow wetland priorities are more variable, including seasonal wetlands and the extensive mudflats that develop around the margins of Great Salt Lake and tributary wetlands (Figure 13). These habitats are essential for breeding shorebirds, like Snowy Plover, which depend on seasonal shoreline-mudflats and playas, and other species such as American Avocet, and Black-necked Stilt, which forage in shallow water or on exposed substrates and nest in fringing the wet meadows. These habitats range in salinity from freshwater, to brackish and saline and provide an assortment of macroinvertebrates as long as there is periodic hydrologic connectivity that maintains salinity levels below tolerance thresholds for invertebrates.

The spatial complementarity embedded within the prioritization process underlying these habitat-specific maps highlights the importance of maintaining landscape-scale heterogeneity. No single habitat type can support the full suite of focal species; rather,

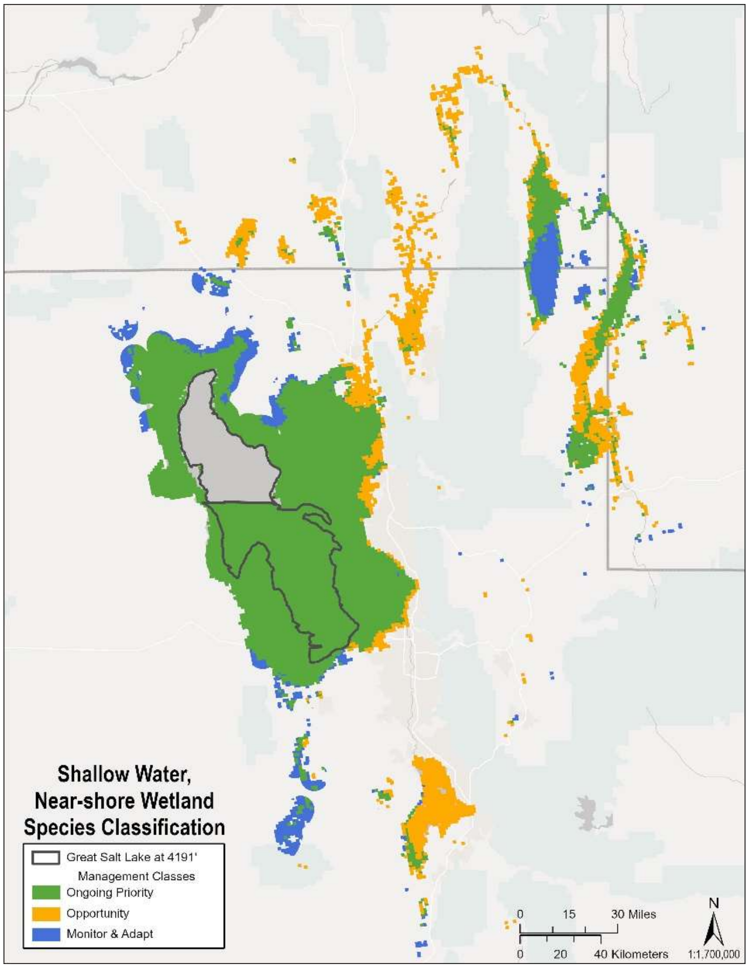

Figure 13. Management classification layer for the shallow water / near-shore wetlands species group.

the mosaic of habitats distributed across the watershed provides the diversity needed to sustain the region's incredible bird diversity and abundance.

Interpreting Overlap Across Prioritization Versions

Several indicator species appear in more than one habitat-specific version of the analysis—Wilson's Phalarope in all three, California Gull and Northern Pintail in two. This reflects genuine ecological behavior, as waterbird species use different habitat types during different seasons and life stages, and each version captures a distinct aspect of that habitat relationship using only the seasonal data relevant to its focus. As a result, the same geographic areas may rank highly in more than one habitat-specific version. This overlap is meaningful. When a site ranks as Ongoing Priority across multiple versions, it is important to multiple bird guilds using different habitats—a signal of broad conservation value. Conversely, sites that rank highly in only one version have specialized rather than lesser importance: they are critical to a specific group for which no equivalent alternative exists nearby, and the habitat-specific versions are designed to highlight that targeted importance.

Habitat Connectivity Patterns

The prioritization results reveal critical patterns of habitat connectivity that are essential for maintaining functional landscapes for birds across their annual cycles. Several key themes emerge:

Vital Corridors Between Wetlands and Uplands

This analysis identifies areas where high-priority wetland habitats maintain connectivity to adjacent or near-by upland areas that provide complementary ecological functions. These wetland-upland interfaces are particularly important for:

- Breeding waterbirds that nest in wetlands but forage in surrounding agricultural lands or upland grasslands, such as White-faced Ibis.
- Breeding waterbirds that forage in wetlands and nest in surrounding uplands, such as Willet and Long-billed Curlew.
- Species that require different habitat types during different life stages, such as Wilson's Phalarope and Eared Grebe.

- Maintaining natural transitions between aquatic and terrestrial ecosystems that support diverse ecological communities.
- Providing a buffer from anthropogenic disturbances associated with the human-built landscapes and associated predators such as raccoons and rodents.

Classified areas showing strong wetland-upland connectivity are concentrated where managed wetlands border agricultural lands or grasslands that remain undeveloped. These areas provide landscape-scale habitat mosaics essential for species with diverse habitat requirements, and in many cases represent opportunities for the restoration.

Connectivity Among Wetland Complexes

The prioritization also highlights the importance of connectivity among multiple wetland sites. Birds regularly move among wetlands in response to changing water levels, food availability and seasonal requirements. Areas that maintain functional connectivity among multiple high-priority wetlands enable:

- Movement of birds among staging areas during migration
- Flexibility in habitat use as conditions fluctuate seasonally and annually

Key corridors connect major wetland complexes including the Bear River Migratory Bird Refuge, Farmington Bay, Ogden Bay, Willard Spur and the wetlands surrounding Utah Lake. Maintaining these connections is critical for landscape-scale functionality. Additionally, important riparian resources along hydrologic corridors within the watershed—including major rivers, tributaries, and canals that connect upstream lakes such as Bear Lake and Utah Lake with Great Salt Lake—cannot be overlooked.

Fragmentation Risks and Conservation Opportunities

When overlain with anticipated growth patterns, the analysis reveals fragmentation risks where high-priority habitats are becoming isolated by development, infrastructure, or habitat degradation. Areas of particular concern include:

- Wetland complexes increasingly surrounded by hard-scaped development
- Loss of connectivity between agricultural lands and wetlands due to land conversion pressures
- Decreasing hydrologic connectivity due to water diversions for urban uses

The integration of connectivity considerations into the prioritization framework ensures that conservation investments support not just individual high-quality sites, but also functional landscape networks that sustain bird populations across their full annual cycle.

Hydrologic Inflows Analysis

The hydrologic inflows analysis identified connectivity between both wetlands and flood-irrigated agricultural fields and the stream/canal network flowing to Great Salt Lake.

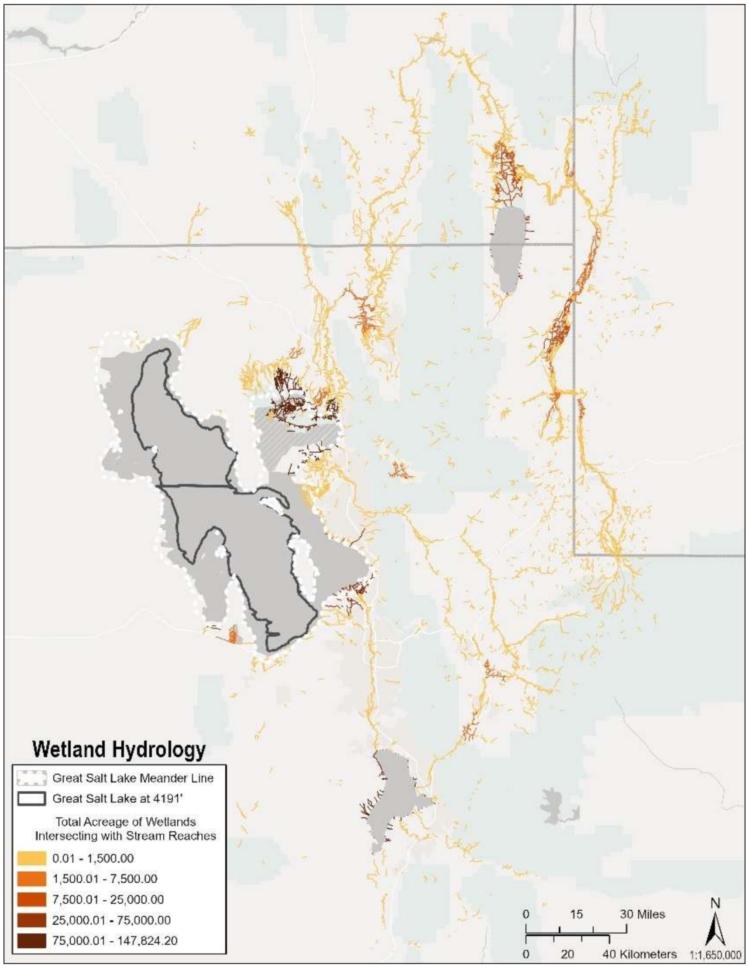

Figure 14. Total acreage wetland parcels intersecting individual flow pathways.

Wetland Connectivity Patterns

The wetland inflows analysis (Figure 14) shows the spatial distribution of stream reaches with connected wetlands and quantifies the total wetland acreage accessible to each reach. Several patterns emerge:

- High concentrations of connected wetlands occur along major tributary systems including the Bear River, Weber River, and Jordan River. These river corridors support extensive riparian and floodplain wetlands that maintain hydrologic connectivity to the stream flow network.
- Many hydrologically connected wetlands are actively managed for waterfowl and other waterbirds and typically have reliable water sources and water rights associated with their management and practices, which are strategically aimed at facilitating water delivery to important habitats.
- Beyond the berms and dikes of managed areas, there are both areas of open water and vast complexes of sheetflow wetlands—which are areas of shallow, overland waterflow— that are fed by water flowing out onto the lakebed. These wetlands gradually shift from freshwater emergent vegetation to salt-tolerant vegetation as surface water disperses and mixes with salt water. These wetlands support foraging and nesting resources for many species of wading birds, waterfowl and shorebirds. Eventually the sediment and water becomes too saline for vascular plants to tolerate, but the shallowly flooded mudflats, connected to other wetlands areas, are vitally important habitat providing highly productive food resources for many species of shorebirds and other waterbirds.
- Many highly productive foraging areas are found in areas where freshwater and saline water mix, creating estuarine transition zones that are distinctive in the Great Salt Lake Basin, and act as a nexus between freshwater inflows and Great Salt Lake's bays.

Agricultural Return Flow Connectivity

The flooded agricultural field analysis (Figure 15) reveals widespread connectivity between flood-irrigated agriculture and the stream network. Key findings include:

- Flooded agricultural fields are extensively connected to streams throughout the lower elevations of the watershed, particularly in areas of intensive agriculture in the valleys surrounding Great Salt Lake.
- The highest concentration of connected agricultural lands occurs in the same areas as high wetland connectivity—around Great Salt Lake, Utah Lake, and along

major river corridors. This overlap indicates that these are key zones where both natural wetlands and agricultural water use contribute to potential inflows.

- Many flood-irrigated fields provide incidental wetland habitat for birds during irrigation season, effectively functioning as seasonal wetlands within the agricultural landscape. The connectivity of these fields to the stream network also suggests that management of agricultural water may have direct implications for downstream wetland habitats and lake inflows. And the present threat of conversion of these agricultural fields to residential development fractures this connectivity.

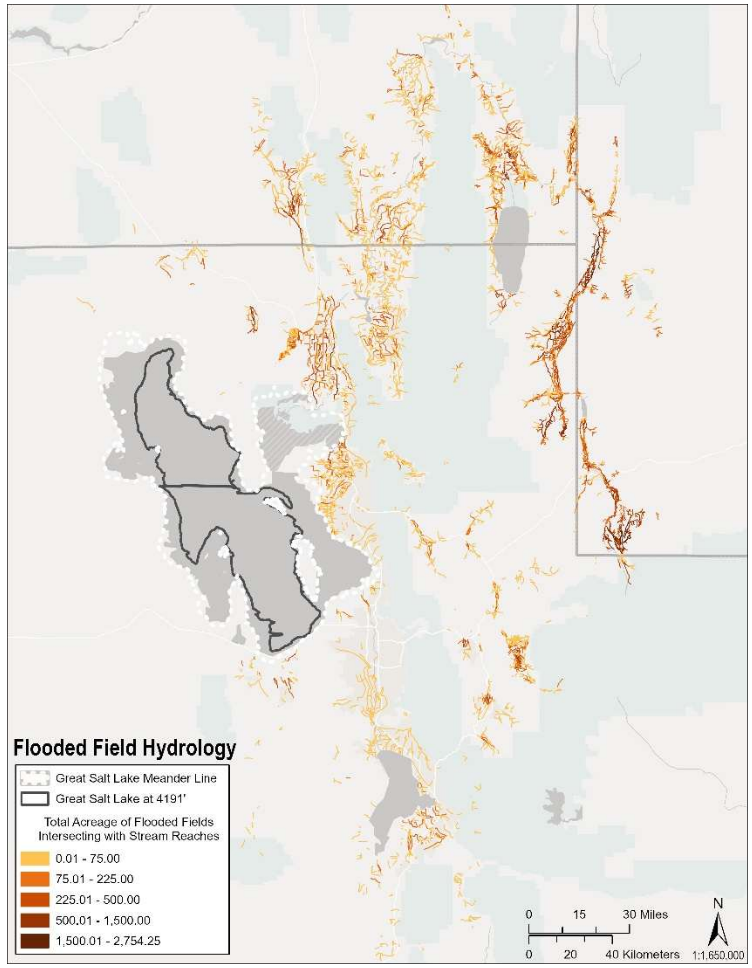

Figure 15. Total acreage flooded agricultural field parcels intersecting individual flow pathways.

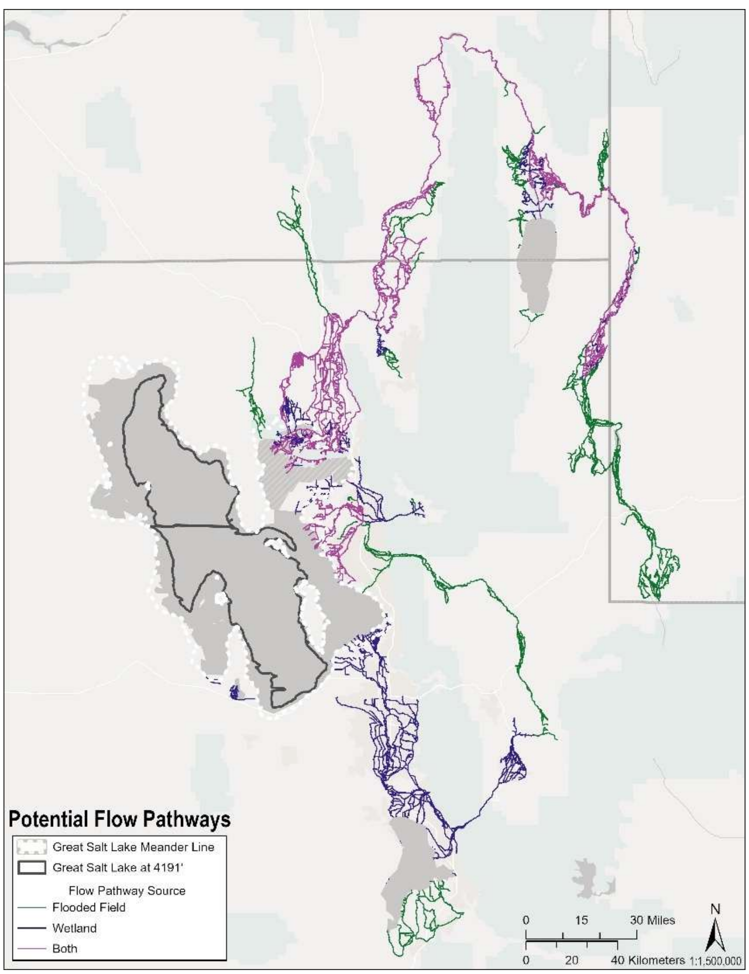

Figure 16. Potential pathways for return flows to Great Salt Lake from flooded agricultural fields and wetlands.

Downstream Flow Network

The downstream flow analysis (Figure 16) visualizes potential complete flow pathways from source wetlands and agricultural fields to Great Salt Lake. This analysis reveals:

- Multiple flow pathways converge on Great Salt Lake from different portions of the watershed, representing the integrated hydrologic system that sustains the lake and its wetlands.
- High spatial clustering of flooded fields and wetlands results in overlap of flow paths, particularly in key tributary valleys. These convergence zones represent critical hydrologic functions where water management decisions can have a disproportionate impact on downstream habitats.
- The network analysis demonstrates the functional connectivity between upland water sources, mid-elevation wetland and agricultural

lands, and terminal habitats. This system's perspective is essential for understanding how water conservation efforts, land use changes, or restoration projects in one location may affect habitats and bird populations elsewhere in the watershed.

DISCUSSION

Conservation Implications and Strategic Applications

The integration of the avian prioritization and hydrologic connectivity analyses offers insights applicable to multiple scales and decision contexts, from watershed-scale planning to site-specific project design.

This Assessment addresses climate change through its dual-timeframe approach, evaluating both present and future habitat priorities. Areas identified as Opportunity areas represent climate adaptation opportunities—places where investments in avian habitat made now could provide increasing returns as climate conditions evolve, and management or restoration activities are supportive. Ongoing Priority areas primarily represent areas with known conservation value with relatively low uncertainty. Areas identified as Monitor & Adapt signal where active management will be needed to maintain habitat values despite climate pressures.

Landscape-scale Conservation Planning

The emphasis on habitat connectivity—both ecological connectivity among habitat patches and hydrologic connectivity between water sources and wetlands—represents a systems-level approach to conservation. Individual wetlands do not function in isolation; they are embedded within broader landscapes where their ecological value depends on connectivity to other habitats and water sources. Conservation science increasingly emphasizes the importance of landscape-scale processes, functional connectivity, and ecosystem resilience (Anderson et al., 2023; Rudnick et al., 2012).

Scale Trade-offs

Landscape-scale connectivity conservation may achieve broader ecosystem benefits but requires larger investments and coordination. Site-specific conservation is more readily achievable but may not address landscape-scale processes.

Land Use Planning and Development Decisions

The rapid pace of urbanization in the Great Salt Lake watershed makes land use planning a key factor in conserving important habitats (Utah Division of Water Resources, 2021; Utah Population Committee, 2025). The Assessment provides information that can support local government planning processes, which can be coupled with site specific investigation to identify areas where land use changes could have particularly significant impacts on bird habitat and ecosystem function (Figure 17).

Areas classified as Ongoing Priority or Opportunity areas warrant special consideration in land use planning and open space protection. Development in these areas could result

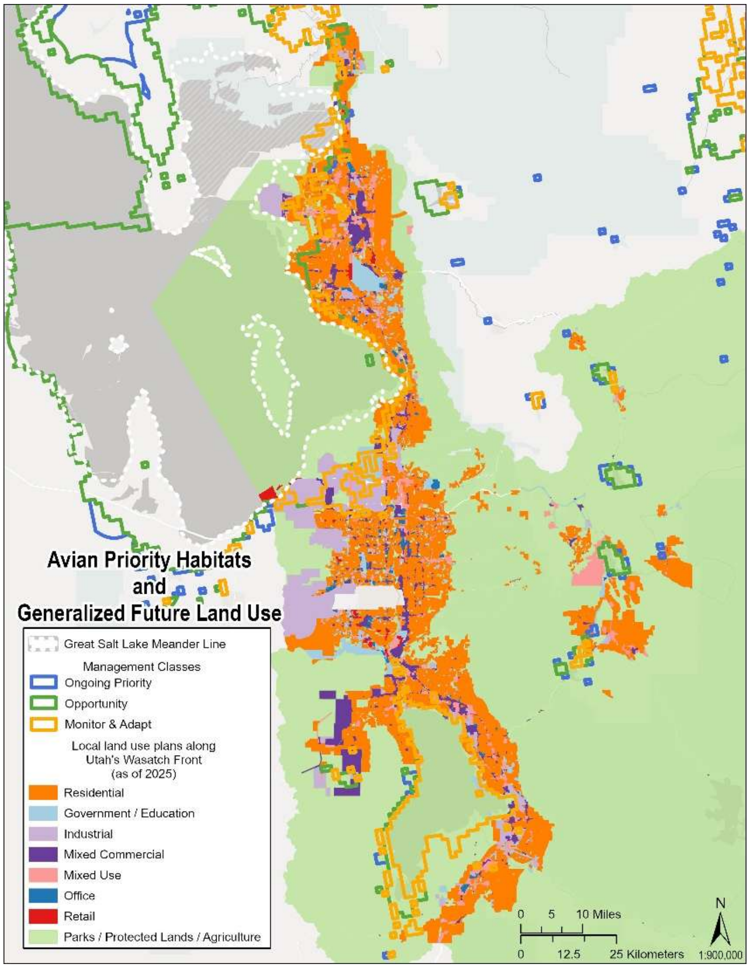

Figure 17. Generalized local land use plans along Utah's Wasatch Front, based on individual cities general plans in late 2024 and early 2025. (Wasatch Front Regional Council, 2026). Management classes from the all species avian prioritization model are overlaid, indicating priority habitat as color-coded boundaries.

in permanent loss of habitats that are projected to remain climatically suitable or become increasingly important for bird conservation. Conversely, unclassified areas may be more appropriate for development, though all land use changes should be evaluated for their cumulative effects throughout the watershed.

The recognition that ecosystem modifications do not occur in isolation is crucial for land use planning in the Great Salt Lake basin. At this stage in the progression of climate and land use change across the Great Salt Lake watershed, both “positive” and “negative” changes carry the potential to ripple through the broader ecosystem and affect populations of birds that depend on each facet of the system. A wetland restoration in one sub-basin may alter downstream hydrology; actions that modify lake levels may shift salinity gradients in the lake’s bays that impact the invertebrate prey base; and the conversion of agricultural land to urban uses—however incrementally—not only eliminates potential wildlife habitat at that site but may also reduce return flows to downstream wetlands, fragment movement corridors and ecological processes across larger areas. This interconnectedness does not counsel against action, but rather, it points to the need for conservation and land use decisions alike to be evaluated with full awareness of their systemic effects. A landscape perspective that accounts for these broader implications is essential for sustainable, bird-focused land use planning around Great Salt Lake.

Proactive Conservation in the Face of Climate Change

Climate change poses fundamental challenges to traditional conservation approaches that assume relatively stable environmental conditions. The Great Salt Lake watershed is particularly vulnerable to climate impacts given its position in an arid landscape where small changes in temperature and precipitation can have outsized effects on water availability and ecosystem function (Affram et al., 2025; Baxter & Butler, 2020).

Building climate resilience into conversation planning requires flexibility and adaptive management. Conservation strategies should not assume that future conditions will mirror the present. Instead, they should anticipate change and position conservation efforts to succeed across a range of potential futures. The Assessment’s framework supports this approach by explicitly modeling climate trajectories and identifying areas likely to remain important to birds across different scenarios.

The Assessment's identification of restoration priorities is particularly valuable for proactive conservation. Rather than only protecting existing high-quality habitats, this framework identifies areas that may not currently rank highly but are projected to become important as climate conditions shift. Restoring these areas now, before extensive land use changes occur or land values rise substantially, provides long-term conservation benefits at potentially lower costs.

Conservation Approaches and Key Actions

When the avian prioritization and hydrologic connectivity analyses are considered together (Figure 18), several strategic conservation opportunities emerge. These key findings can inform and help prioritize conservation actions and investments in the Great Salt Lake watershed.

1. Protect and Enhance Open Water and Core Wetland Complexes: Wetland complexes identified as Ongoing Priority areas that have strong hydrologic connectivity should be prioritized for preserving water flows. The open water of Great Salt Lake and its surrounding wetland complexes—including Bear River Migratory Bird Refuge, Farmington Bay, Ogden Bay, and Willard Spur Waterfowl Management Areas—are of Ongoing Priority because they provide essential habitat today that also are projected to persist under future climate conditions. Ensuring reliable and adequate water supplies to these high-quality, core habitats will preserve their long-term conservation values. This could support stabilizing current breeding and staging populations, preventing further habitat loss, and maintaining landscape-scale habitat networks. Preventing degradation or the loss of wetlands typically requires less intervention than restoring wetlands after they have been degraded. Key actions can include:

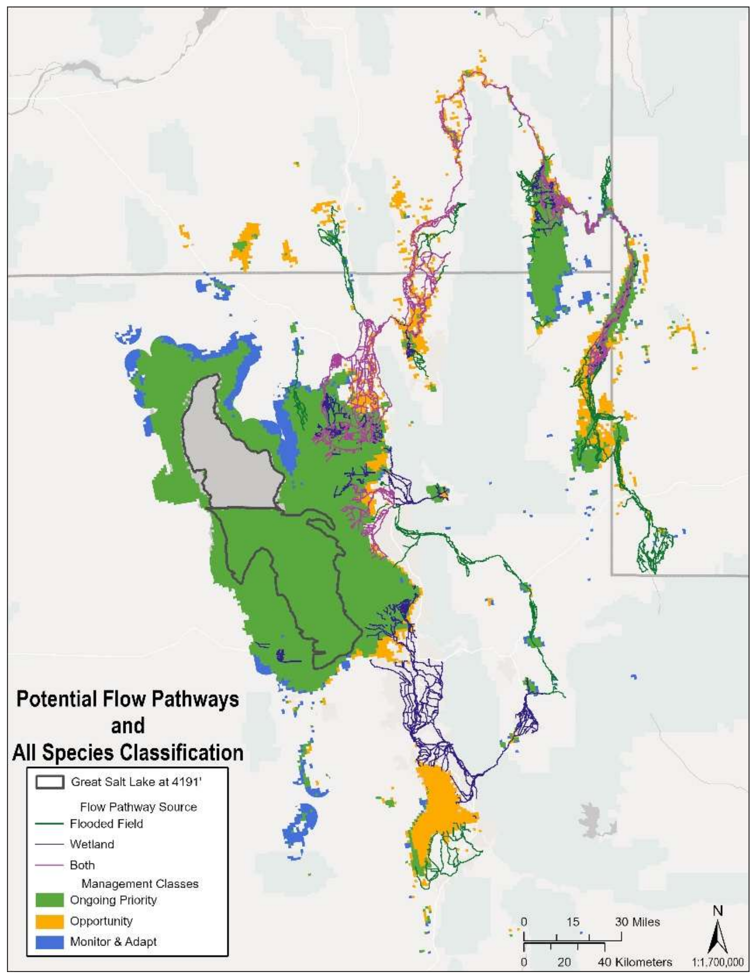

Figure 18. Management classification layers for all indicator species with the overlay of potential pathways for return flows to Great Salt Lake from flooded agricultural fields and wetlands.

- Securing inflows and continuing water deliveries to major wetland complexes and Great Salt Lake bays
- Enhancing habitat through water management, vegetation management, and water delivery and infrastructure improvements
- Strategically timing water delivery to wetlands identified as Ongoing Priority areas
- Incentivizing the improvement and preservation of wetland habitats
- Strengthening management resources at key sites

2. Invest in Future Priority Areas: Proactive restoration of future priority areas—classified as Opportunity in Figure 18—positions conservation ahead of climate-driven habitat shifts. Opportunity areas in the avian analysis that also show high connectivity to the stream network represent particularly valuable conservation opportunities. These areas have both the ecological potential to support important waterbird populations in the future and the hydrologic infrastructure to receive and convey water. Proactive restoration may compensate for losses elsewhere, enhance habitat functions, and protect key areas before development pressure increases. Agricultural lands and degraded historical wetlands in the areas surrounding the lake represent conservation opportunities where climate suitability will remain high and where restoration or land protection can generate long-term conservation value. Key actions can include:
    - Restoring degraded wetlands predicted to maintain climate suitability, including vegetation management
    - Incentivizing voluntary land preservation and conservation easements on working lands that provide current and future habitat values
    - Identifying opportunities to strategically protect undeveloped areas projected to become suitable
    - Enhancing hydrologic connectivity and improved water conveyance infrastructure to ensure water delivery to restoration sites

3. Integrate and Enhance Wetland and Water Connectivity: Enhancing landscape-scale connectivity, especially between wetlands and water sources, would reduce habitat fragmentation and increase resilience to environmental variability. Strategic land protection or restoration in key connectivity areas can maintain or restore landscape functionality even as surrounding areas develop. Undeveloped lands between existing protected wetlands or strategic conservation protections that provide contiguous habitat should be priority locations for enhancing connectivity. Key actions can include:
    - Incentivizing land conservation to connect existing wetland complexes and protect riparian zones and wetlands near urban areas to improve water quality and habitat function
    - Developing opportunities for agricultural conservation easements that maintain working landscapes while preserving connectivity
    - Removing barriers to hydrologic and ecological connectivity

In summary, the integration of ecological prioritization and hydrologic connectivity analyses equips conservation practitioners, land managers, and other partners with a flexible, science-based tool to support decision-making. Rather than prescribing a single course of action, this Assessment supports a range of conservation approaches that can be applied individually or in combination, depending on local need, partner capacity, and site-specific conditions.

The most effective conservation strategy likely involves elements of all conservation scenarios, applied strategically across the landscape based on local opportunities, partner capacity, and site-specific conditions. Given the vast extent of Ongoing Priority areas in this region, overlaying the hydrologic priorities (Figure 18) allows for more targeted prioritization of these areas. The key insight is that strategic, science-informed prioritization enables conservation investments to achieve greater impact than opportunistic approaches.

Partner Implementation and Active Project Integration

The value of this Assessment lies in its use as a tool to aid land use planning decisions and projects. Multiple pathways exist for integrating the Assessment's findings into ongoing conservation efforts. Examples of key applications include:

- **State and Federal Alignment and Public Funding Guidance:** The Assessment supports state and federal efforts to manage, restore and sustain Great Salt Lake, including through planning, prioritizing, and funding conservation efforts and management of the watershed's wildlife areas, state parks, and the Bear River Migratory Bird Refuge. The Assessment can also support the implementation of Utah's State Wildlife Action Plan by (1) identifying specific sites for habitat protection or restoration projects, (2) supporting the development of habitat management plans and restoration on state lands, and (3) informing land use planning decisions that affect wildlife habitat. Furthermore, multiple state and federal agencies administering wetland or habitat protection and enhancement grants, wildlife and research grants, and water conservation grants can use the Assessment as an additional tool that can be used to support criteria for grant eligibility, assist review panels in assessing which projects are likely to provide the greatest ecological benefits, and guide applicants in identifying strategic opportunities and articulating the conservation significance of their proposals.
- **Water Resource Planning and Decision-making:** Agencies and organizations working on water conservation in the Great Salt Lake basin can use the Assessment's findings to prioritize their efforts and evaluate opportunities for collaboration. For example, the Great Salt Lake Commissioner's Office and Great Salt Lake Watershed Enhancement Trust can use the Assessment to strategically target water deliveries for maximum habitat benefit, while the Utah Geological Survey wetlands program can apply it to prioritize wetland restoration sites and guide invasive species mapping and removal efforts. Utah State University's Functional Flows research examining the environmental flows required by rivers and wetlands to maintain ecological health can be informed by the Assessment's identification of important habitats. Their effort will result in waterway-specific predictions of healthy flow ranges that can be used to set initial targets and to justify water transactions and additional monitoring and gaging. Utah State University is also conducting research specifically on smaller inflows around Great Salt Lake to better

understand both the quantity of water delivered to the lake from these inflows and their sources. The Assessment is a useful tool for this work to align approaches for locating permanent in situ gages or environmental tracer analyses.

Future Research Direction and Model Applications

The Assessment represents a first iteration of a living framework—one that is designed to be refined, expanded, and connected to ongoing datasets as new information becomes available.

One potential area for future development is the integration of active bird monitoring data. Audubon and its partners conduct systematic avian surveys across the Great Salt Lake ecosystem, tracking abundance, distribution, and habitat use for indicator species across seasons. As these survey datasets accumulate, they offer a critical ground-truthing opportunity for the habitat suitability models underlying this Assessment. Systematically linking survey observations to the prioritized areas identified here could allow managers to evaluate model performance, detect emerging shifts in bird distribution, and update conservation priorities as conditions shift. This feedback loop between predictive modeling and empirical monitoring is essential for adaptive management.

The hydrologic inflows model also warrants further refinement and updating. Incorporating real-time flow monitoring data—including gaging stations, isotopic tracers, and remote sensing products—would improve the precision of inflow contribution estimation and help identify which hydrologic pathways are functionally important for sustaining wetland habitat in drought years versus wet years. Collaboration with Utah State University's Functional Flows research and other ongoing hydrologic monitoring and groundwater research efforts in the watershed can help build this capacity.

Perhaps most significantly, this Assessment is not a standalone product. Great Salt Lake is a node in a broader network of saline lakes and semi-arid wetland systems across the western United States, including Mono Lake (California), the Salton Sea (California), the Lahontan Valley wetlands (Nevada), Lake Abert (Oregon), and others. Many of these systems are experiencing similar pressures—declining inflows from increasing water demands, climate-driven habitat shifts, and habitat loss and fragmentation from development—and the birds that rely on Great Salt Lake are often the same species that depend on these other lakes at similar phases of their annual cycles. The Assessment's methodological framework was designed with transferability in mind that has direct applicability to saline lakes across the Intermountain West. Any future iterations of this work should explicitly position Great Salt Lake conservation priorities within the context of this regional network. Understanding how habitat quality in the Great Salt Lake ecosystem interacts with conditions at other saline lakes—and how loss or degradation at any one site affects the broader system—is an essential next step for hemispheric shorebird and waterbird conservation.

CONCLUSIONS

Great Salt Lake sits at the intersection of multiple converging crises: a decades-long decline in lake levels, accelerating pressure from encroaching development across the greater Salt Lake City urban area along the Wasatch Front, increasingly variable precipitation driven by a changing climate, and unrelenting competition for a finite water supply. Against this backdrop, the millions of birds that depend on the Great Salt Lake ecosystem annually have little margin for further habitat loss.

This science-based Assessment was developed to prioritize responses to that urgency by identifying where conservation actions will have the greatest impact. By integrating habitat suitability modeling, climate change, and hydrologic connectivity analysis into a spatial prioritization framework, the Assessment can align efforts and provide conservation partners, water and land managers, restoration practitioners, and decision-makers with actionable, defensible guidance for where to focus their efforts.

Several key themes warrant emphasis. First, the Great Salt Lake watershed is defined by its heterogeneity of habitat types that range in varying levels of salinity to freshwater. The wetland types surrounding the lake range from permanently inundated, heavily managed impoundments to ephemeral playa habitats that may only hold water briefly. Collectively, this diverse mosaic of habitat and its varied levels of interdependency on hydrologic connectivity, including the lake itself, support birds and ecological functions that the system as a whole cannot afford to lose. Conservation strategies must account for the need of diverse habitat types and their vulnerability to system-wide threats.

Second, hydrologic connectivity is not peripheral to bird conservation at Great Salt Lake—it is central to it. Wetlands that become cut off from their water sources—whether by upstream diversion, infrastructure barriers, or land conversion that severs return flows—cannot reliably provide the timing of inundation, water depth, and food resources that waterbirds require. Such areas may retain their footprint while losing much of their functional habitat value. Protecting and restoring the stream reaches, return flows, and water delivery pathways that sustain this system is as important as protecting the wetland and lake footprints themselves.

Third, the interconnectedness of this ecosystem requires a systemic perspective on conservation and development decisions. At this moment in the Great Salt Lake Basin's ecological trajectory, no change occurs in isolation. Audubon's interest in this Assessment is not to compel any particular land use outcome or to advocate for involuntary changes to private property or wetland management structures. Rather, it is to ensure that decision-makers at every level—from individual landowners to state legislators—have the best available information about the downstream and system-wide consequences of the choices before them. The goal is simple: improve habitat where possible and prevent further degradation where it can still be avoided.

Finally, the work described here is incomplete. Great Salt Lake is one node in a network of saline lake ecosystems across the western United States and hemisphere. The birds that rely on this system depend on the integrity and redundancy of that whole network. Further refinement of this avian prioritization framework—through ongoing bird surveys, expanded hydrologic monitoring, and collaboration with partner institutions across the region—will strengthen its utility and extend its reach.

Bird and habitat conservation at Great Salt Lake must consider the dynamic nature of climate change and development pressure in a forward-looking and coordinated approach with multiple partnerships. Every area of quality habitat today warrants attention and protection, and as habitat conditions are predicted to shift in the future, many opportunities to improve the health of the lake and its wetlands have been identified and described in this Assessment. More conservation resources and efforts—strategically aligned—are needed to address the challenges facing Great Salt Lake, its habitats, and surrounding communities to have the greatest beneficial and durable impact.

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