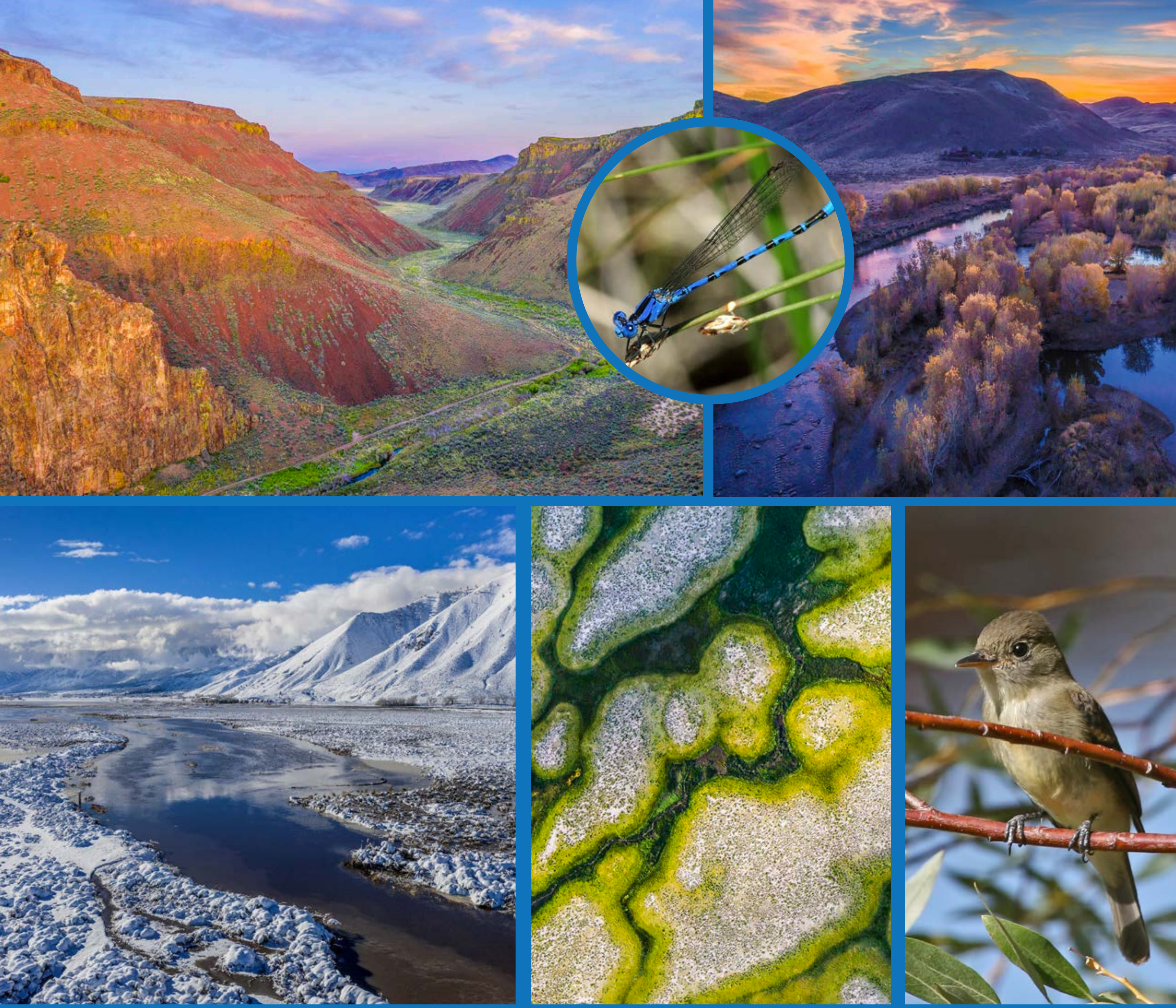


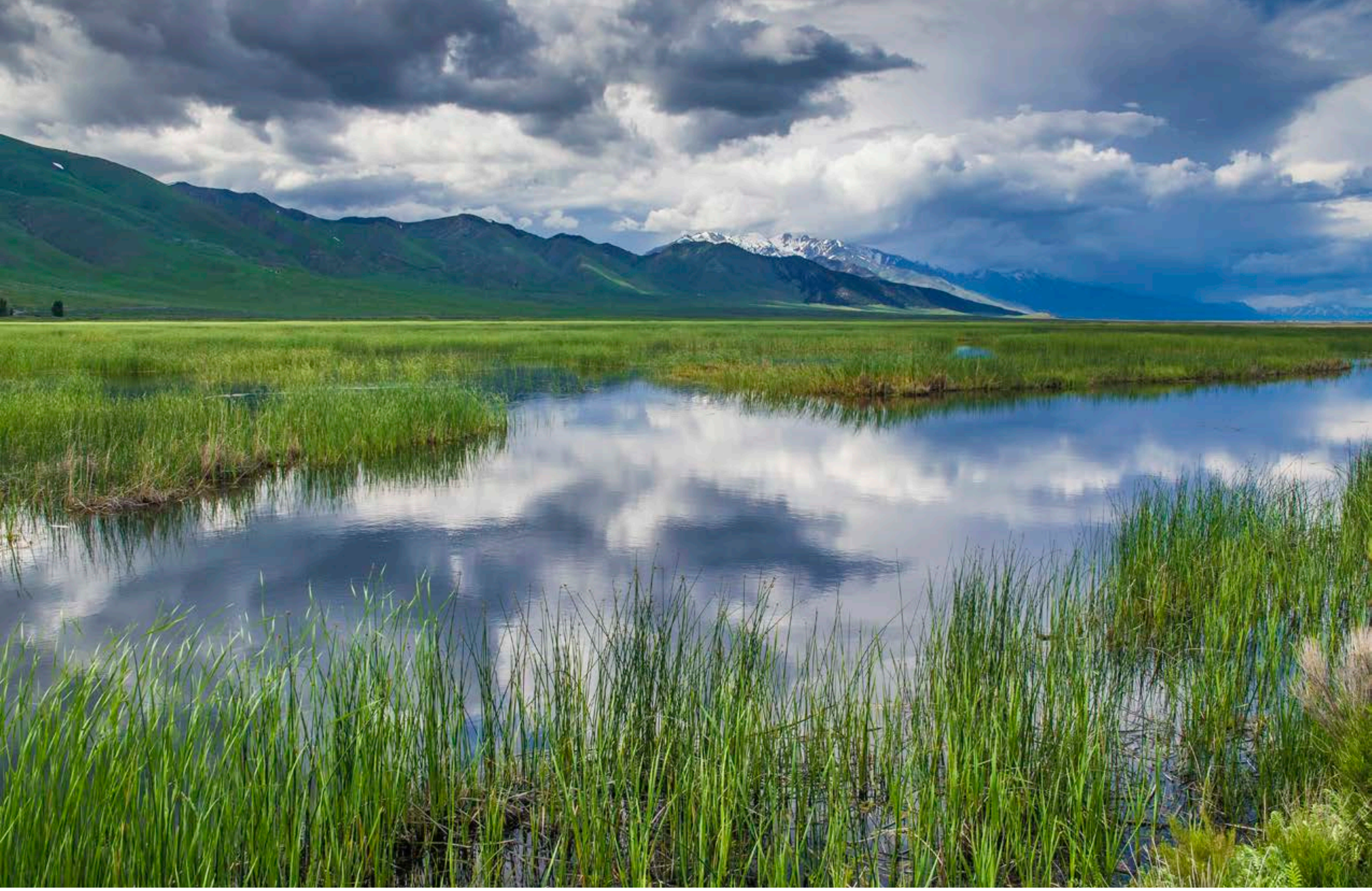
STRATEGIES FOR MANAGING AND SUSTAINING

Groundwater-Dependent Ecosystems in Nevada

Laurel Saito and Liz Munn

December 2023

The Nature Conservancy



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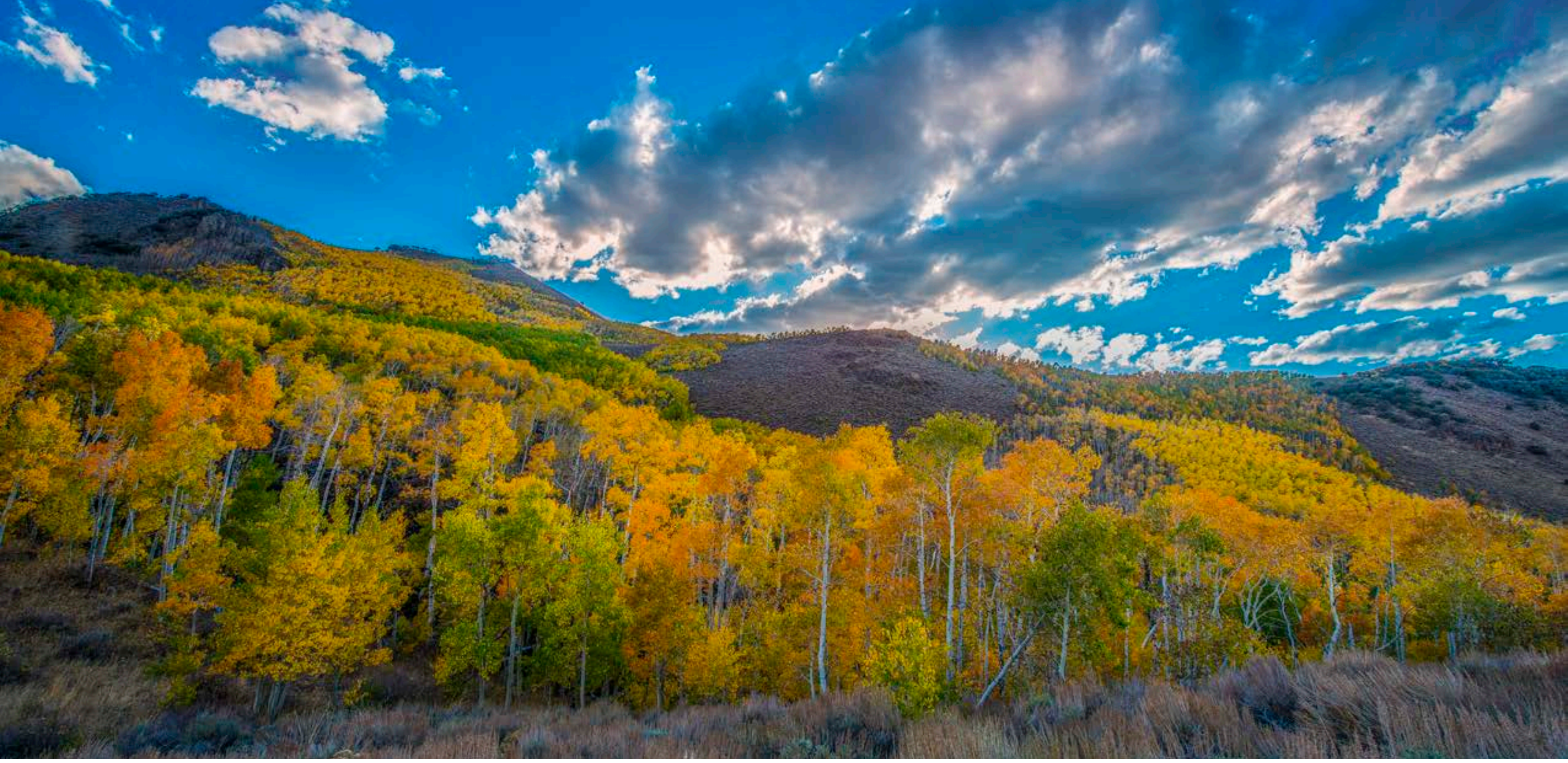


Introduction and Purpose

Groundwater dependent ecosystems (GDEs) are ecosystems that rely on groundwater for all or part of their water needs, including wetlands, seeps, springs, lakes, playas, rivers, and streams. According to a database of indicators of groundwater dependent ecosystems, more than 10 percent of Nevada's landscape is likely to be a GDE (Saito et al. 2020). In Nevada's water-limited environment where less than 250 mm (10 inches) of precipitation occur each year on average, GDEs are extremely important to plants and wildlife (Keleher and Sada 2012), with almost half of Nevada's endemic species (those found nowhere else in the world) associated with GDEs. GDEs are also critical for human uses, including drinking water, agriculture, water quality improvements, and recreation (Brown et al. 2011; Griebler and Avramov 2015; Saito et al. 2020).

Recently, an assessment of 12 stressors and threats to GDEs in Nevada found GDEs across the state are projected to have less water available from the atmosphere in the future (2022-2060), which will compound other stressors and threats they face (Saito et al. 2022a; Box 1). Stressors were considered things that are currently impacting GDEs whereas threats were things that could potentially impact GDEs in the future. Strategies are needed to provide direction and prioritization for reducing the risks of these stressors and threats to ensure that GDEs are managed and sustained for future generations. The purpose of this report is to share 10 strategies that collectively can address most of the 12 stressors and threats to achieve the goal of reducing impacts and improving sustainability of GDEs in Nevada. Ideal strategies for this purpose should have the following **"SUP"** characteristics:

- **Specific** (i.e., strategy should address the goal and lead to actions that connect to the strategy, but it is not an action itself)
- **Useful** (i.e., for communicating to leadership, articulating the need for funding or capacity, or choosing actions to implement)
- **Plausible** (i.e., rational, logical, and realistically achievable)

The strategies were developed by 1) having discussions with many organizations and entities about the GDE stressor and threat report (see list in Appendix A); 2) literature review; 3) several meetings between The Nature Conservancy (TNC) and Bureau of Land Management (BLM); and 4) a survey of staff from TNC Nevada. The survey involved evaluating proposed strategies and their qualitative linkages to each of the 12 stressors and threats. Respondents were also asked to comment on possible barriers to each strategy.

Box 1. Summary of stressor and threat assessment of Nevada groundwater dependent ecosystems (Saito et al. 2022a).

In 2022, The Nature Conservancy completed an assessment of 12 stressor and threat risk factors to Nevada's groundwater dependent ecosystems. Each risk factor was rated on a scale of 0.0 (lowest risk) to 1.0 (high risk) using available data across the state. Stressor risk factors (hereafter called "stressors") were considered things that currently are impacting GDEs, whereas threat risk factors (hereafter called "threats") were considered things that have the potential to impact GDEs in the future. Key findings from this assessment are as follows (see Figures B.1 and B.2 for results and the full report at https://www.groundwaterresourcehub.org/where-we-work/nevada/nevada-gde-stressor-threat/).

Stressor S1 - Groundwater pumping status: Nevada has 256 hydrographic areas (administrative groundwater units), and almost 20% had more groundwater withdrawn annually (i.e., are over-pumped) than the estimated available water according to data from 2017 (Wilson 2019). About 20% of GDEs are in hydrographic areas that are over-pumped, which can put them at risk of having groundwater they use captured by excessive groundwater withdrawals.

Stressor S2 – Declining groundwater trends: Declining trends in groundwater levels can lead to reduced flows to springs, rivers, and lakes, and detach groundwater from vegetation, which can result in extirpation of native plants and animals (Fleishman et al. 2006). 39% of 6,536 analyzed wells had significantly falling groundwater level trends over water years (WY) 1984-2021.

Stressor S3 – Current climate: Ecosystems fed by local groundwater flow paths are more likely to respond quickly to variations in temperature and recharge than larger systems with longer groundwater flow paths (Kløve et al. 2014; Toth 1963) and thus are more susceptible to current climate stresses. Over 10,000 springs and over 3,700 miles of groundwater-dependent rivers and streams are at high risk from current droughts and climate stresses because they are located in recharge areas with short flow paths.

Stressor S4 – Ungulates[1]: Ungulates such as cattle, domestic sheep, horse, burro and elk outside native range[2] can affect GDEs through trampling and unsustainable grazing (Armour et al. 1991; Naumburg et al. 2005; NRC 2002). The majority of springs and groundwater-dependent rivers and streams are in areas that ungulates are expected to access, so they were rated at high risk, but in some of these areas the stressor is being mitigated.

Stressor S5 – Non-native species presence: Non-native species can displace natural species, affect natural foodwebs (Kolosovich et al. 2012; Vitousek et al. 1996), affect the local water balance and soil, nutrient, and light dynamics (Stevens et al. 2020), and increase fire frequency (Provencher et al. 2020). Based on reported data on non-native species well-known to negatively affect GDEs in Nevada (see Saito et al. 2022a for a list), over 60% of lakes and playas are at high risk from the presence of non-native species; springs had the lowest percentage (7%) at high risk which contradicted literature that has found non-native species to affect springs-dependent taxa, so this result may reflect a low rate of monitoring and reporting of non-native species at springs.

Stressor S6 – Nearby surface diversions: Surface water diversions can impact GDEs such as riparian zones along rivers by altering interactions between surface water and groundwater (Rohde et al. 2021) and they are common at springs to enable use of water for irrigation, drinking water, or livestock watering (Sada and Nachlinger 1998). Based on locations of surface water points of diversion in the Nevada Division of Water Resources database, over 60% of phreatophyte communities and groundwater-dependent lakes and playas are at high risk for the surface water points of diversion stressor risk factors, which can lead to the decline and elimination of GDE species.

Stressor S7 – Urbanization (proxy: housing density): Urbanization can impact GDEs by disturbing them, fragmenting them, covering up areas that would naturally provide recharge for groundwater, and altering local air temperature patterns (Marchionni et al. 2020), as well as contaminate groundwater (Cantonati et al. 2020). Using housing densities for 2010 in the Bureau of Land Management's Rapid Ecological Assessment (Comer et al. 2013) as a proxy for urbanization, about 10% of lakes and playas are at moderate to high risk for the housing density stressor risk factor.

1. Ungulates were considered both a stressor and threat in Saito et al. (2022a), but the method for estimating was the same for both and therefore results were the same, so for this report ungulates were considered as stressor only.
2. Ecosystems where elk are native are adapted to interactions with elk.

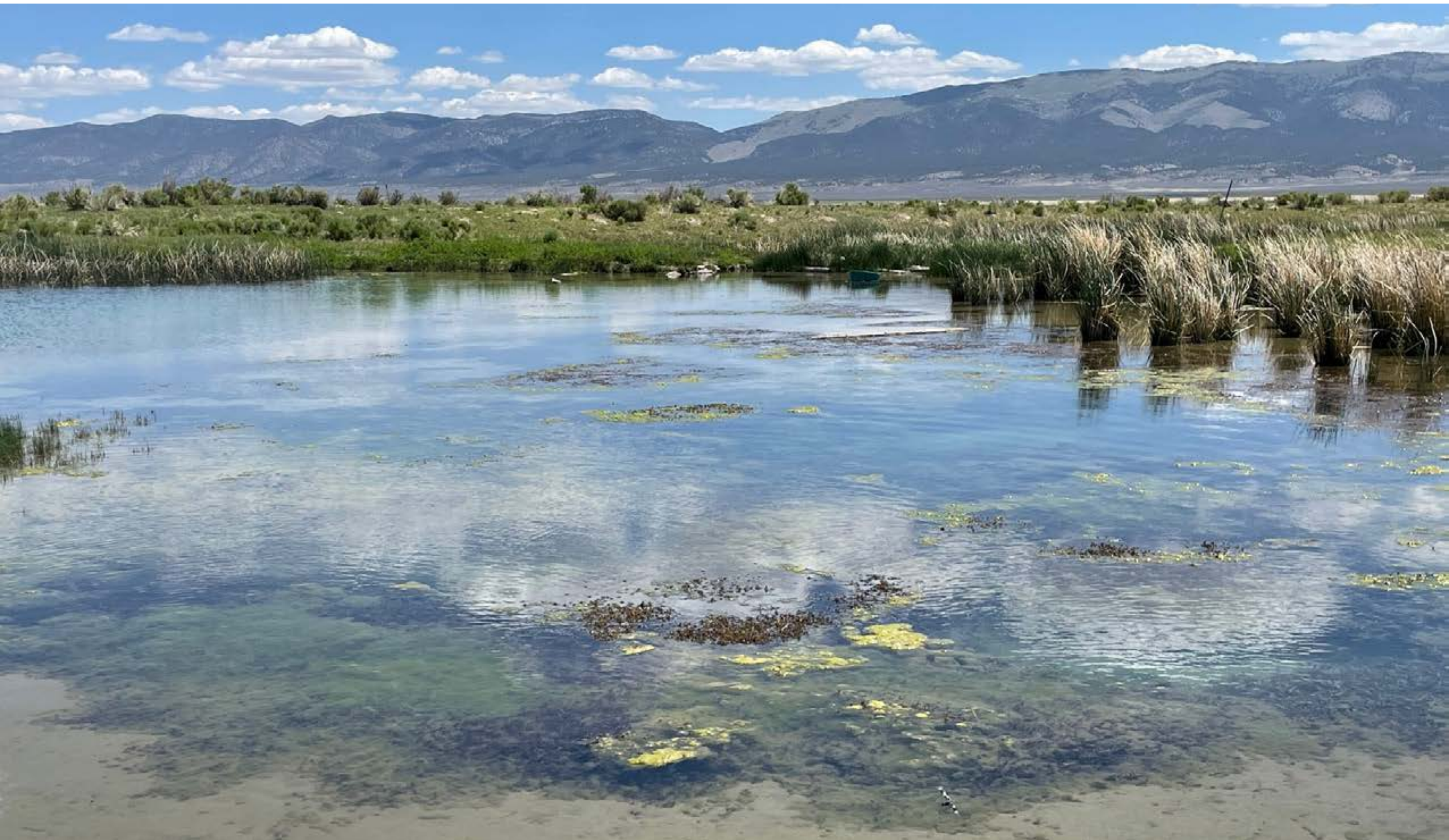
Threat T1 – Groundwater appropriation status: About 50% of hydrographic areas are fully- or over-appropriated, which means that water rights were committed at or above the estimated available groundwater (Wilson 2019), so if all water rights were used, theoretically no water could be left for GDEs. At least 40% of all GDE types are in hydrographic areas that have more water rights committed than available groundwater.

Threat T2 – Potential withdrawal proximity to GDEs: There is always a decline in water levels at and near a well that is withdrawing groundwater (Alley et al. 1999), so GDEs that exist where the water table is fairly shallow are likely to be affected if water withdrawals are nearby (Patten et al. 2008). Using data on groundwater levels from Lopes et al. (2006) to identify areas with shallow water tables, over 70 percent of wetlands, phreatophyte communities, and lakes and playas are at high risk for threats from potential groundwater withdrawals; loss of access to groundwater can lead these GDEs to transition to more fire-prone systems (Provencher et al. 2020).

Threat T3 – Future climate: The future climate in Nevada is likely to be warmer which could increase evapotranspiration and reduce recharge (Somers and McKenzie 2020), thereby affecting the availability of groundwater to GDEs. Using downscaled data from global climate models, all hydrographic areas are projected to have more droughty conditions in the future (2022-2060), which means that all of Nevada's GDEs are likely to encounter less water availability from the atmosphere; GDEs in Southern Nevada are at especially high risk.

Threat T4 – Non-native species spread (proxy: road density): Human activities often increase populations of non-native species (Bart et al. 2020; Nielson et al. 2019; Sada and Pohlmann 2006; Stevens et al. 2020) in part because people may knowingly or unknowingly transport non-native species from one system to another (Fleishman et al. 2006). Using road density data from the TIGER database of the U.S. Census Bureau as an indicator of possible spread of non-native species, very few GDEs are at moderate to high risk of the road density non-native species threat risk factor because many GDEs are in rural areas where the normalized road density values are low.

Threat T5 – Future urbanization (proxy: housing density increase): See Stressor S7 for impacts to GDEs. Based on projected increased housing densities between 2010 and 2060 in the Bureau of Land Management's Rapid Ecological Assessment (Comer et al. 2013) as a proxy for increased urbanization, about 6% of lakes and playas are at moderate to high threat risk for the increased housing density stressor risk factor.



Strategies

Strategies to manage and sustain groundwater-dependent ecosystems and the services they provide involve knowledge, governance, management, and awareness (Rohde et al. 2017; United Nations 2022). We therefore developed the following strategies:

SCIENCE AND MONITORING

Knowledge and data can reduce uncertainty, increasing the likelihood that other strategies will be successful.
Strategy 1: Increase understanding of co-benefits of healthy and restored GDEs, including carbon dynamics
Strategy 2: Increase monitoring and reporting over space and time

POLICY

Policy changes can refine governance structures at the federal, state or local level that support GDE management.
Strategy 3: Enact policies to reduce current excessive groundwater withdrawals and overappropriation to protect GDEs
Strategy 4: Enact policies to prevent future groundwater withdrawals that would negatively affect GDEs
Strategy 5: Include requirements for maintaining or protecting GDEs in regulations, codes, and laws for land and water management and economic development

MANAGEMENT

Management commitments can bolster informed decision-making and on-the-ground action to conserve GDEs.
Strategy 6: Include consideration of GDEs in permitting, guidance and large-scale planning documents to identify and prioritize areas for protection and management of GDEs
Strategy 7: Increase the pace and scale of restoration of GDEs in time and space
Strategy 8: Incorporate collaboration, including public-private partnership, to manage and sustain GDEs

EDUCATION AND OUTREACH

Awareness and communication can foster collaboration to implement successful strategies.
Strategy 9: Increase awareness of the value of GDEs and the need to protect and reduce impacts to them
Strategy 10: Increase communication among water users, administrators, managers and academics about GDEs

Conservation, science, and policy staff from The Nature Conservancy in Nevada were surveyed to provide a qualitative assessment of the ability of each strategy to address impacts to GDEs from each of the 12 stressors and threats. Qualitative ratings were Highly Likely, Somewhat Likely, or Unlikely to have the ability to address impacts to GDEs from each stressor or threat. Staff were asked to rate each strategy in relation to each stressor or threat, and then all responses were aggregated to obtain the overall ratings shown in the tables throughout this document as follows: Highly Likely indicates that most respondents felt the strategy was Highly Likely or Somewhat Likely to have the ability to address impacts of a particular stressor or threat, and Highly Likely was the most frequently chosen option by respondents; Somewhat Likely indicates most respondents felt the strategy was Highly Likely or Somewhat Likely to have the ability to address impacts, but Highly Likely was not the most frequently chosen option by respondents. In addition to rating each strategy, staff were asked to provide reasoning for their ratings, thoughts on barriers for implementing a strategy, and any additional comments about the strategy.

STRATEGY 1

Increase understanding of co-benefits of healthy and restored GDEs, including carbon dynamics

Why this strategy is needed

In addition to being valuable to plants and wildlife in Nevada, GDEs are important resources for human uses, including drinking water, agriculture, water quality improvements, and recreation (Brown et al. 2011; Saito et al. 2020). Quantification of co-benefits of healthy GDEs can be valuable for effective management, as well as for funding restoration and management efforts. For example, an area where very little data exist is carbon dynamics in relation to water availability and GDEs. The Nevada Division of Environmental Protection (NDEP) prepares an annual report on greenhouse gas emissions in Nevada, but only includes forests for natural area carbon sequestration. In arid and semi-arid regions like Nevada, GDEs like springs, wetlands, wet meadows, and riparian areas may have a disproportionately large carbon sequestration role compared to the rest of the landscape, and probably also compared to forests per unit area (Reed et al. 2021). Research in Sierra meadows and Central Nevada riparian ecosystems has indicated that healthy and restored areas can significantly enhance carbon sink potential (Morra et al. 2023; Reed et al. 2021). Restoration and conservation of GDEs may be important opportunities for nature-based solutions with co-benefits for carbon dynamics, water security, and critical habitat for plants and wildlife, but more data and analysis are needed at different GDE types across Nevada.

Examples of actions associated with this strategy

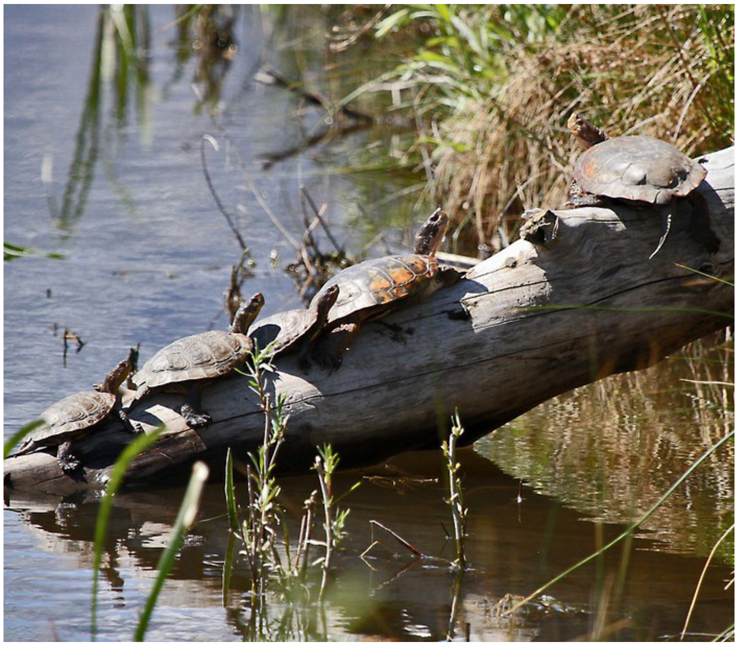
- Gather and analyze data on carbon dynamics in GDEs in Nevada
- Develop models and framework tools to estimate co-benefits
- Quantify ecosystem services of GDEs
- Project novel ecosystem states[3] for GDEs to understand effective management options

Challenges and considerations

Actions associated with this strategy alone will not have much impact, but they can be used to support management activities, policies, or increased funding to implement actions based on this science. The need to pair science with other management activities through this strategy may enable more partnerships between researchers and land stewards. Also, education can contribute to modified behavior. Studies to implement this strategy will likely require considerable funding and time (e.g., understanding carbon benefits in GDEs may require $0.5-1M over 3-5 years) and the translation of study results to action will be needed. Importantly, there may be pushback specifically on natural climate solutions if they are perceived to enable continued polluting operations.

Qualitative assessment of the effectiveness of Strategy 1's ability to reduce the impacts of each GDE stressor and threat.

STRESSOR RISK	EFFECTIVENESS
S1: Groundwater pumping status	Somewhat Likely
S2: Declining groundwater level trends	Somewhat Likely
S3: Current climate	
S4: Ungulate impacts	Somewhat Likely
S5: Non-native species presence	Somewhat Likely
S6: Surface diversions	Somewhat Likely
S7: Urbanization	
THREAT RISK	**EFFECTIVENESS**
T1: Appropriation status	Somewhat Likely
T2: Potential withdrawal proximity to GDEs	Somewhat Likely
T3: Future climate	Somewhat Likely
T4: Non-native species spread	Somewhat Likely
T5: Future urbanization	Somewhat Likely



3. Novel ecosystems are ecosystems that have transitioned to an entirely new state with new species combinations and changes in ecosystem functions because of human actions (Hobbs et al. 2006; Seastedt et al. 2008). For example, changes in climate may shift species distributions as new ecosystems are created and historic ecosystems disappear, requiring changes in conservation objectives (Pecl et al. 2017).

STRATEGY 2

Increase monitoring and reporting over space and time

Why this strategy is needed

Lack of data (including indigenous knowledge; Fillmore 2017) can make it difficult to understand dynamics, threats, and best approaches for management to sustain GDEs (Saito et al. 2021). Access to data can reduce conflict and confusion while also informing management decisions (Christian-Smith and Abhold 2015; Mawdsley et al. 2009). For example, the assessment of stressors and threats to Nevada GDEs (Saito et al. 2022a) noted the lack of sufficient groundwater data to assess any groundwater trends in almost 10% of Nevada's 256 administrative groundwater basins. Furthermore, <1% of springs and <22% of phreatophyte communities in Nevada were within 800 m of wells with sufficient data to be analyzed for an assessment of groundwater levels between 2002 and 2021 (Saito et al. 2022b). Another study estimated that ~44% of probable GDE areas may be associated with significant groundwater level declines between 1985 and 2021 (Saito et al. 2022c), but this was based on a small fraction of sites that had sufficient monitoring data near GDEs. Monitoring and reporting data are also needed for non-native species. Studies have reported that the introduction of non-native species at springs had resulted in extirpation of native species (Miller et al. 1989; Williams and Sada 2021), but only 7% of springs were assessed at high risk for non-native species presence in Saito et al. (2022a) based on reported data. Increasing the availability of data through monitoring and reporting over space and time can be useful for more strategic management actions.

Examples of actions associated with this strategy

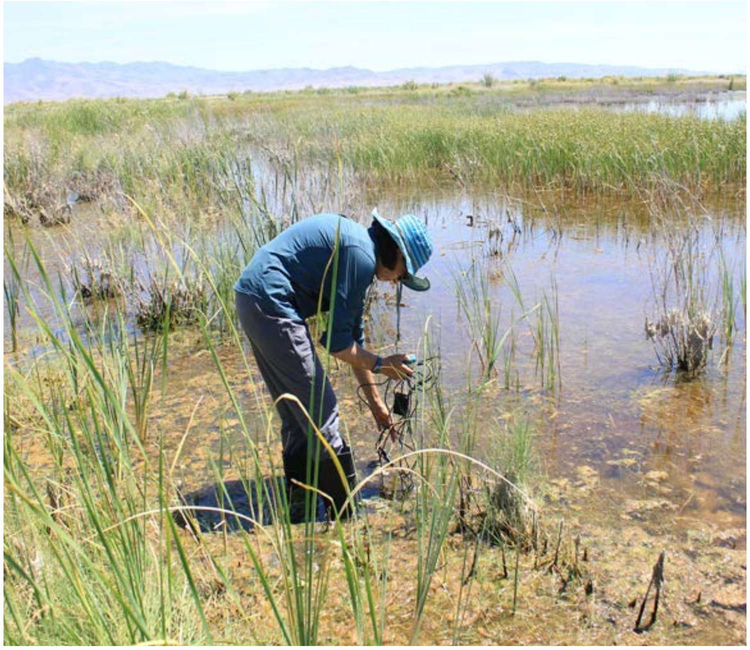
- Improve monitoring and reporting of non-native species at springs and other GDEs, including repeat measurements
- Increase monitoring of groundwater levels throughout Nevada, especially at GDEs, including permanent monitoring networks and repeated measures
- Use Nevada Indicators of Groundwater Dependent Ecosystems (iGDE) database (available here) to inform Assessment, Inventory, and Monitoring (AIM) for lotic and lentic systems
- Use bioblitzes and citizen science monitoring

Challenges and considerations

Monitoring and reporting requires funding and commitment from agencies and NGOs where staff capacity is often a limiting factor. Monitoring and reporting alone will not result in reduced impacts to GDEs; the data need to be translated to action by being used with management, policy, and education strategies. Importantly, coordination of data collection and management is challenging, and an open-sourced platform for data reporting and dissemination could be helpful for making this strategy more effective. In addition, monitoring and reporting protocols are needed for data to be consistent, respect privacy issues, and be reported in a timely and effective manner. Where resources are limited, a phased approach with prioritization could be used, and remote sensing or other technologies may be more appropriate. California's Sustainable Groundwater Management Act could be considered as an example for how to implement a statewide monitoring strategy in Nevada.

Qualitative assessment of the effectiveness of Strategy 2's ability to reduce the impacts of each GDE stressor and threat.

STRESSOR RISK	EFFECTIVENESS
S1: Groundwater pumping status	*Somewhat Likely*
S2: Declining groundwater level trends	*Somewhat Likely*
S3: Current climate	
S4: Ungulate impacts	*Somewhat Likely*
S5: Non-native species presence	*Somewhat Likely*
S6: Surface diversions	*Somewhat Likely*
S7: Urbanization	
THREAT RISK	**EFFECTIVENESS**
T1: Appropriation status	*Highly Likely*
T2: Potential withdrawal proximity to GDEs	*Somewhat Likely*
T3: Future climate	*Somewhat Likely*
T4: Non-native species spread	
T5: Future urbanization	



STRATEGY 3

Enact policies to address current excessive groundwater withdrawals and overappropriation

Why this strategy is needed

Administration of groundwater in Nevada is the responsibility of the Nevada Division of Water Resources (NDWR) and is managed by hydrographic area, with each of the 256 hydrographic areas across the state having an assigned perennial yield (PY) that is used as general guidance for evaluating water available for use in each hydrographic area (Nevada State Engineer Order 1308). Most PYs were estimated in the 1950s to 1970s and were based on groundwater discharge, which Bredehoeft (2002) noted is mostly evaporation from playas and evapotranspiration of phreatophytic plants. Thus, withdrawals can theoretically be allowed to the rate of natural discharge, which is water used by GDEs, so GDEs could be progressively eliminated as water stored in an aquifer reaches a new equilibrium. Nevada's total PY is ~2.5×10^9 m^3 (2 million acre-feet (af)), of which ~2.0×10^9 m^3 (1.6 million af) was used for human purposes in 2015 (Dieter et al. 2018). According to Wilson (2019), 50% of the hydrographic areas were fully- or over-appropriated, which means that water rights were committed at or above the PY in those hydrographic areas. Of these, 62 were over-appropriated by more than 200%, and 49 of the hydrographic areas had more groundwater withdrawn than the PY (Wilson 2019). Saito et al. (2022a) found that 20% of Nevada GDEs are in over-pumped hydrographic areas, and at least 40% of each GDE type (i.e., springs, wetlands, phreatophyte communities, rivers and streams, and lakes and playas) are in hydrographic areas that are over-appropriated. To reduce risks to GDEs, overuse and overappropriation of groundwater needs to be brought back to sustainable levels. In addition, policies that affect land management agencies such as the BLM may help address excessive groundwater withdrawals by land uses such as mining.

Examples of actions associated with this strategy

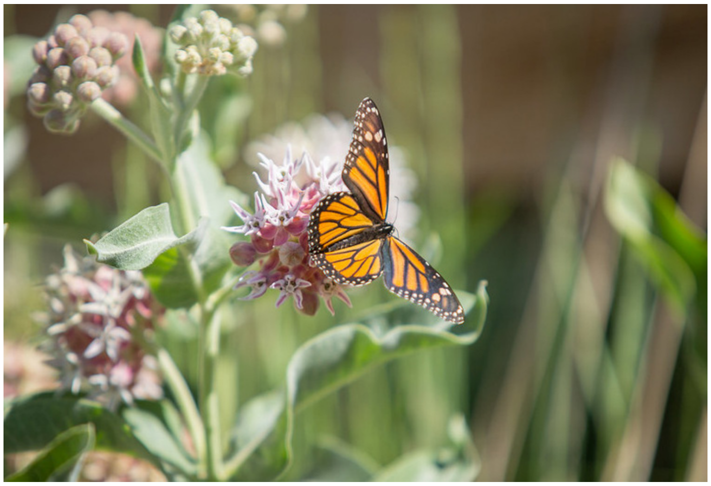
- Enable voluntary permanent retirement of groundwater rights, especially those that protect GDEs
- Incentivize the protection of GDEs in policies to reduce excessive groundwater withdrawals and overappropriation
- Set limits or allocations for groundwater consumption
- Enact policies to facilitate or incentivize reduction in water demands (e.g., water conservation, crop switching, new technologies, etc.)

Challenges and considerations

Changing water law or regulations is inherently difficult, particularly when focusing on issues of overappropriation and excessive withdrawals, as there are existing economic systems built on the current structure. However, stakeholders and legislators working together may be able craft policies that include protections for GDEs that have a higher likelihood of success. Through this process, it may be hard to get buy-in from senior water right holders if potential actions might appear to challenge prior appropriation and litigation against policies that restrict existing water rights should be anticipated. To be effective, policy design processes will require time and persistent dialogue amongst stakeholders that may have very different perspectives, including those prioritizing conservation aspects and others focused on economic growth opportunities. Science and education strategies will be important to incorporate along with this policy strategy as part of this process. Despite these challenges, because there could be lag times between when pumping is reduced to seeing reduced impacts at GDEs, these policies should be implemented as soon as possible.

Qualitative assessment of the effectiveness of Strategy 3's ability to reduce the impacts of each GDE stressor and threat.

STRESSOR RISK	EFFECTIVENESS
S1: Groundwater pumping status	*Highly Likely*
S2: Declining groundwater level trends	*Highly Likely*
S3: Current climate	
S4: Ungulate impacts	
S5: Non-native species presence	
S6: Surface diversions	
S7: Urbanization	
THREAT RISK	**EFFECTIVENESS**
T1: Appropriation status	*Highly Likely*
T2: Potential withdrawal proximity to GDEs	*Somewhat Likely*
T3: Future climate	*Somewhat Likely*
T4: Non-native species spread	
T5: Future urbanization	



STRATEGY 4

Enact policies to prevent future groundwater withdrawals that could negatively affect GDEs

Why this strategy is needed

To protect GDEs and the services they provide for future generations, policies are needed that guide GDE management going forward. Within NV water law, there are only a few protections for water for wildlife, and even fewer for ecosystems. Water for wildlife is a beneficial use in limited circumstances, agricultural water rights can be temporarily used for wildlife purposes (§NRS 533.0243), a de minimus collection of precipitation for wildlife guzzlers is allowed (§NRS 533.027) and interbasin transfers of water must be "environmentally sound" in the basin of origin (§NRS 533.370.3(c)), but environmentally sound is not defined. The State Engineer may require an environmental study (§NRS 533.368) before making a decision on an application, but this is discretionary. The State Engineer can approve temporary applications for environmental permits to avoid pollution or contamination of a water source (§NRS 533.437, §NRS 533.4373, §NRS 533.4375, §NRS 533.4377). Also, the State Engineer makes decisions in the public interest (§NRS 533.345, §NRS 533.370.2, §NRS 533.371, §NRS 533.372, §NRS 533.375, §NRS 533.436.4, §NRS 533.4375, §NRS 533.500, §NRS 533.504, and §NRS 534.320), but how ecosystems fit into the public interest is not described in statute. Over 70% of groundwater-dependent wetlands, phreatophyte communities, and lakes and playas are at high risk for threats from potential groundwater withdrawals (Saito et al. 2022a), which can lead these GDEs to transition to more fire-prone systems with less ecological value (Provencher et al. 2020), so regulations and laws are needed to reduce the threat of groundwater withdrawals that could impact GDEs.

Examples of actions associated with this strategy

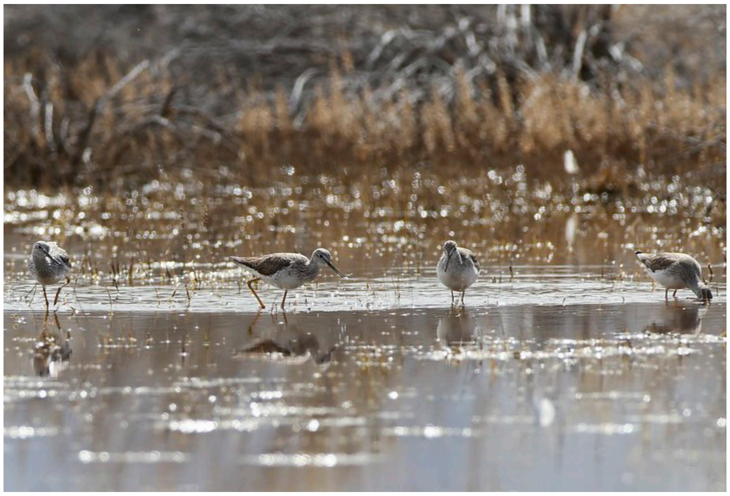
- Enable voluntary permanent retirement of groundwater rights, especially for over-pumped or over-appropriated hydrographic areas
- Use conservation easements and land withdrawals to protect areas with important GDEs.
- Incorporate considerations for GDEs (e.g., environmental rights for groundwater that allow for local protections of GDEs or groundwater withdrawals for ecological needs [Nelson 2022]) in Code of Federal Regulations and Nevada water law

Challenges and considerations

Political will and agreement among stakeholders will be needed to make policy changes to prevent future groundwater withdrawals near GDEs and it may be hard to get buy-in from senior water right holders if potential actions might appear to challenge prior appropriation. However, there could be trade-offs between economic growth and conservation of GDEs that may be alleviated through incentives or grant programs. Because of the nature of groundwater and uncertainty in its dynamics, identifying the best places to protect from future groundwater withdrawals could be challenging. For example, more information on short versus long groundwater flow paths and how the dynamics of pumping and water available to GDEs interact is important at the local and regional levels to make decisions. It will also be hard to measure success of this strategy since it is aimed at preventing future withdrawals. A framework to assist decision-makers when justifying a policy that limits future groundwater withdrawals could be useful.

Qualitative assessment of the effectiveness of Strategy 4's ability to reduce the impacts of each GDE stressor and threat.

STRESSOR RISK	EFFECTIVENESS
S1: Groundwater pumping status	*Highly Likely*
S2: Declining groundwater level trends	*Somewhat Likely*
S3: Current climate	
S4: Ungulate impacts	
S5: Non-native species presence	
S6: Surface diversions	
S7: Urbanization	
THREAT RISK	**EFFECTIVENESS**
T1: Appropriation status	*Highly Likely*
T2: Potential withdrawal proximity to GDEs	*Highly Likely*
T3: Future climate	*Somewhat Likely*
T4: Non-native species spread	
T5: Future urbanization	*Somewhat Likely*



STRATEGY 5

Include requirements for maintaining or protecting GDEs in regulations, codes, and laws for land and water management and economic development

Why this strategy is needed

As the Nation's driest state, Nevada has limited water resources. Groundwater in many of Nevada's hydrographic basins is either fully allocated or overallocated and almost all of the State's surface waters are fully appropriated and administered by civil, federal or state decrees (Legislative Counsel Bureau 2017). Nevada's continued growth and industrial development create additional demands and recent appropriations by the U.S. Congress to accelerate the nation's transition to "green energy" puts pressure on renewable energy expansion with associated transmission infrastructure (The Nature Conservancy 2023), and mineral extraction to support the transition. For example, Nevada is estimated to have enough lithium to supply the world at current rates for over 80 years (Parker et al. 2022). On top of that, drought conditions threaten the sustainability of existing water supplies, with all of Nevada's 256 hydrographic areas projected to be more droughty in the future (2022-2060; Saito et al. 2022a). The coordination of land and water use is critical for healthy communities, ecosystems, and future generations of Nevadans.

Examples of actions associated with this strategy

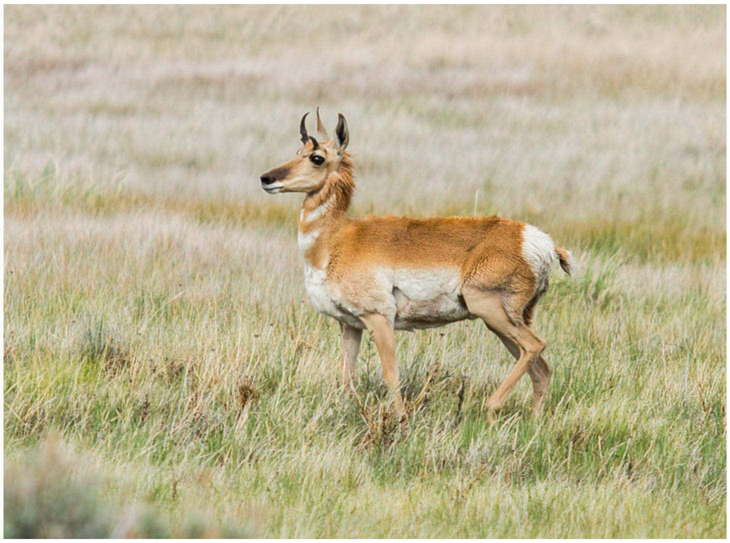
- Enact policies to apply Smart-from-the-Start planning to prioritize areas where development can have minimal or no impacts to GDEs
- Enact policies that require and implement management plans for federal or state listed or sensitive species
- Include protection for vulnerable GDE species in zoning codes and Federal, State or local codes, regulations or other policies

Challenges and considerations

To be effective, policies that maintain or protect GDEs will need to be coordinated across a wide range of federal, state, and local regulations, which would be challenging and there would likely be pushback from developers as well. As with other policy-related strategies, it may be hard to get buy-in from senior water right holders if potential actions might appear to challenge prior appropriation. Education and training about the implementation of new code is also paramount to avoid inconsistent applications, confusion, and inefficiency. In addition, for regulations, codes, and laws that target invasive species treatment and/or require monitoring, care should be taken to ensure consistent funding and sustained efforts over time. Integrating more groundwater components into management and development plans and frameworks, such as Smart-from-the-Start, will be helpful for getting these ideas to a broader audience and including ecosystem values provided by GDEs into management and development decisions. The Sustainable Groundwater Management Act in California and its implementation may be a helpful example for designing solutions for Nevada.

Qualitative assessment of the effectiveness of Strategy 5's ability to reduce the impacts of each GDE stressor and threat.

STRESSOR RISK	EFFECTIVENESS
S1: Groundwater pumping status	*Somewhat Likely*
S2: Declining groundwater level trends	*Somewhat Likely*
S3: Current climate	
S4: Ungulate impacts	*Somewhat Likely*
S5: Non-native species presence	*Somewhat Likely*
S6: Surface diversions	*Somewhat Likely*
S7: Urbanization	
THREAT RISK	**EFFECTIVENESS**
T1: Appropriation status	*Somewhat Likely*
T2: Potential withdrawal proximity to GDEs	*Highly Likely*
T3: Future climate	*Somewhat Likely*
T4: Non-native species spread	*Somewhat Likely*
T5: Future urbanization	*Highly Likely*



STRATEGY 6

Include consideration of GDEs in permitting, guidance and large-scale planning documents to identify and prioritize areas for protection and management of GDEs

Why this strategy is needed

Groundwater-dependent plant communities cover at least 10% of Nevada, and many of Nevada's endemic species rely on GDEs (Saito et al. 2020). Nevada has >25,000 documented springs, and most of its rivers, streams and lakes are groundwater-dependent (Saito et al. 2020), with almost 90% of springs and >70% of rivers and streams in areas ungulates are expected to access (Saito et al. 2022a). Furthermore, all of Nevada is projected to be more droughty in the future, so all of Nevada's GDEs are likely to encounter less water availability from precipitation in future decades (Saito et al. 2022a), increasing the importance of groundwater as a buffer for less reliable surface water. Protection tools like conservation easements and land acquisitions should consider groundwatersheds (i.e., contributing areas of shallow local groundwater flow to a protected area or feature of interest) because human actions in these areas can impact distribution, availability or quality of groundwater for GDEs (Huggins et al. 2023). To prioritize effective GDE conservation, management perspectives are needed that consider conserving ecosystem function while reducing stresses on species such as non-native species and habitat loss (Lawler 2009; Mawdsley et al. 2009). Adaptive management should balance multiple uses (e.g., mining, geothermal, and solar) while conserving GDEs. Land management blueprints like the BLM's Resource Management Plans establish goals and objectives to guide land resource management actions (Federal Register 2016) and can incorporate consideration of GDEs during the planning assessment phase (§CFR 1610.4; Smyth 2014). Permits and guidance documents for more localized applications of management and protection can include direction for incorporating best management practices and restoration approaches that improve GDE resiliency to disturbances.

Examples of actions associated with this strategy

- Incorporate a Smart-from-the-Start approach to managing GDEs facing pressures from renewable energy development, mining, water use, and urbanization
- Include Nevada iGDE database in BLM GIS layers and GIS layers used by field- and state-level staff engaged in planning projects
- Use the Nevada iGDE database to prioritize management and conservation of GDEs (e.g., land acquisition, easements, land exchanges, permitting, travel management, etc.)
- Prepare programmatic environmental impact statements/assessments (EISs/EAs) to specify actions that can conserve or improve resiliency for GDEs
- Incorporate best management practices (e.g., for grazing, non-native species, etc.) in permit issuances and renewals that help sustain GDEs
- Prepare guidance for design criteria to sustain or minimize impacts to GDEs

Challenges and considerations

Plans provide important guidance but are not compulsory. Staffing and funding to prepare guidance and planning documents are needed, and permitting staff need to be aware of approaches for reducing impacts to GDEs and mapping resources on GDEs. Adding another thing to consider in planning documents could make the approval process more difficult, which might not be popular. Adaptive management would likely be appropriate in updated permits, guidance, and plans, but can require substantial coordination between stakeholders on an ongoing basis and challenging commitments to long-term monitoring. Successful implementation of other strategies could help management approaches be more effective at protecting GDEs: policy changes could strengthen consideration of GDEs in planning; increased monitoring and science could inform management and adaptive approaches; education and outreach could help decision makers and permitting and field staff be aware of this strategy. A broader Programmatic EIS focused on GDEs would be a valuable way to look at cumulative impacts to GDEs from a variety of land uses. We note that the iGDE database is best as a guiding document; additional work to better describe specific recommendations for certain GDEs is needed.

Qualitative assessment of the effectiveness of Strategy 6's ability to reduce the impacts of each GDE stressor and threat.

STRESSOR RISK	EFFECTIVENESS
S1: Groundwater pumping status	Somewhat Likely
S2: Declining groundwater level trends	Somewhat Likely
S3: Current climate	
S4: Ungulate impacts	Highly Likely
S5: Non-native species presence	Somewhat Likely
S6: Surface diversions	Somewhat Likely
S7: Urbanization	
THREAT RISK	**EFFECTIVENESS**
T1: Appropriation status	Highly Likely
T2: Potential withdrawal proximity to GDEs	Highly Likely
T3: Future climate	Somewhat Likely
T4: Non-native species spread	Highly Likely
T5: Future urbanization	Highly Likely

STRATEGY 7

Increase the pace and scale of restoration of GDEs in time and space

Why this strategy is needed

Land and water management can disturb or alter groundwater-dependent ecosystems and their functions. For example, roads can alter hydrology, groundwater recharge, fish passage, wildlife habitat, water quality, and spread of non-native species (NRC 2005; Coffin et al. 2021). The stressor and threat assessment of Nevada GDEs found that 39% of the over 6,500 wells analyzed had significantly falling groundwater level trends between 1984 and 2021 (Saito et al. 2022a), which means that already there are many areas in Nevada where groundwater levels are declining. While many of those declines are likely due to groundwater pumping, stream incision resulting from land use and water management can also cause groundwater level declines in riparian areas (Miller et al. 2011a). The assessment also found that >10,000 springs and >3,700 miles of groundwater-dependent rivers and streams are associated with short groundwater flow paths (Saito et al. 2022a), so they are sensitive to changes in hydrology and are less resilient to drought (Miller et al. 2011b). Stressors and threats like these are contributing to precipitous declines in freshwater biodiversity, with freshwater species declining more than twice as fast as terrestrial or marine species (WWF 2014; Tickner at al. 2020). Tickner et al. (2020) point out that wetlands are vanishing 3 times faster than forests and restoring critical habitats is an important part of bending the trajectory of biodiversity loss. Nature-based solutions like managed aquifer recharge and restoring floodplains and riparian areas can provide important co-benefits to people and nature that make systems and species more resilient and adaptable to changing climates and other disturbances (Seddon 2022; United Nations 2022). For example, research in Sierra meadows with shallow groundwater tables has indicated that healthy meadows sequester more carbon than equivalent areas of forest, but degraded meadows emit carbon, and restoration may turn emitting meadows back into locations of sequestration (Reed et al. 2021). To improve resiliency and retain multiple benefits of healthy GDEs, restoration of GDEs is needed.

Examples of actions associated with this strategy

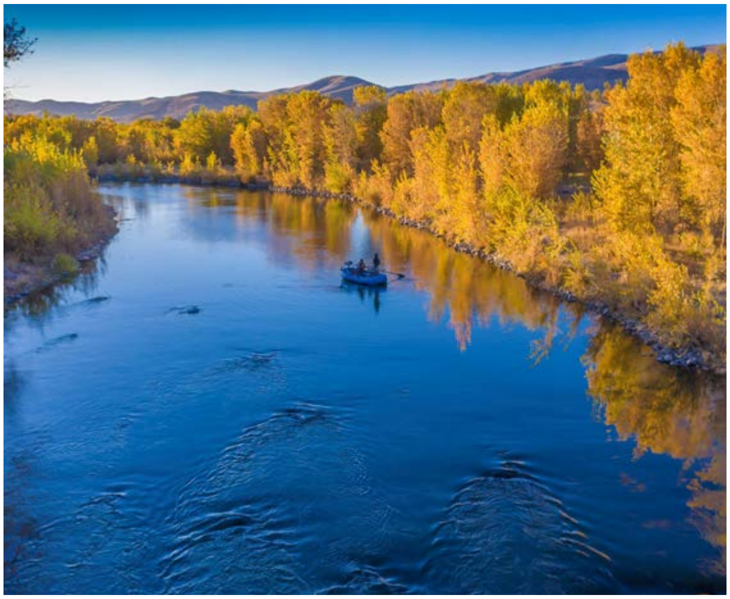
- Prepare programmatic environmental impact statements/assessments (EIS/EAs) to specify actions that can conserve or improve resiliency for GDEs
- Invest in or fund GDE restoration projects
- Integrate incentives for restoring GDEs in land or water management funding opportunities

Challenges and considerations

Funding for restoration work is often limited, and new environmental impact statements or assessments will likely be needed for much of the work on public lands. Guidance for where the most effective restoration can be done will be helpful (see Chambers et al. (2021) for an example on geomorphic conditions), including under specific circumstances like non-native fish presence or ungulate overuse. Identifying and quantifying the full suite of ecosystem services from restoration projects may unlock new funding streams for this work, but likely require additional science. While restoration may be able to address impacts of stressors and threats in the short term, the strategy needs to be done in conjunction with other strategies that address causes of GDE degradation (e.g., Policy Strategies and other Management Strategies) to ensure long-term benefits.

Qualitative assessment of the effectiveness of Strategy 7's ability to reduce the impacts of each GDE stressor and threat.

STRESSOR RISK	EFFECTIVENESS
S1: Groundwater pumping status	
S2: Declining groundwater level trends	*Somewhat Likely*
S3: Current climate	*Somewhat Likely*
S4: Ungulate impacts	*Highly Likely*
S5: Non-native species presence	*Highly Likely*
S6: Surface diversions	*Somewhat Likely*
S7: Urbanization	
THREAT RISK	**EFFECTIVENESS**
T1: Appropriation status	
T2: Potential withdrawal proximity to GDEs	
T3: Future climate	*Highly Likely*
T4: Non-native species spread	*Somewhat Likely*
T5: Future urbanization	



STRATEGY 8

8

Incorporate collaboration, including public-private partnerships, to manage and sustain GDEs

Why this strategy is needed

Agencies that manage and restore GDEs have limited staff and funding capacity (Iftekhar et al 2016), yet management decisions and actions are needed now because all GDEs in Nevada are threatened by future climate and most have many additional stressors and threats (Saito et al. 2022a). Collaboration among agencies as well as with non-governmental and private entities may help to overcome capacity and funding barriers by mitigating some of the financial risks while incentivizing desired outcomes (Mendel and Brudney 2012; Iftekhar et al. 2016). In Florida, Higgins et al. (2007) found that collaboration between The Nature Conservancy, local, state, and federal agencies, and private landowners was effective for implementing actions to reduce or eliminate undesirable non-native species. Examples of public-private partnerships include numerous mitigation efforts, the US Forest Service's work to improve and restore forest health in the Truckee River watershed, the Watershed Restoration Initiative in Utah, and several programs run through the Natural Resource Conservation Service. Another tool that involves collaboration between non-federal landowners and governments to provide net conservation benefits to species is Candidate Conservation Agreements with Assurances (CCAAs). An example is the Nevada-Utah Springsnail Conservation Agreement (Springsnail Conservation Team 2020).

Examples of actions associated with this strategy

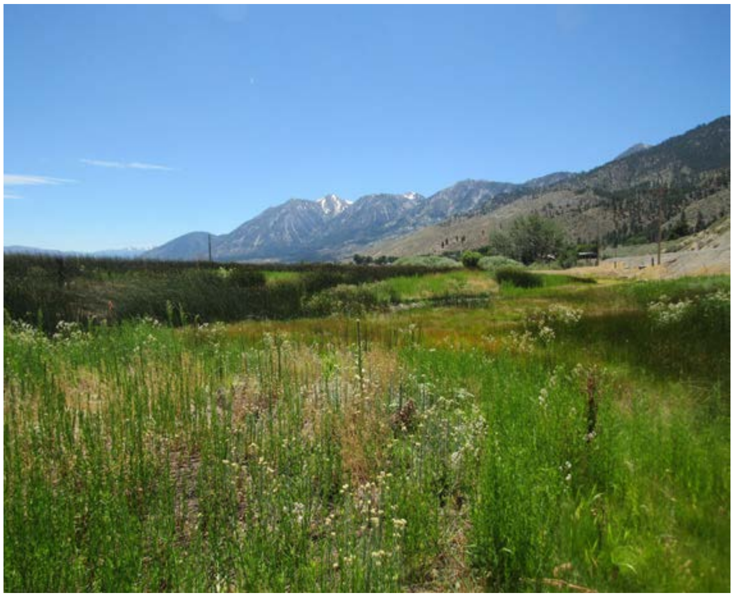
- Identify and promote incentive and disincentive programs to manage and sustain GDEs through public-private partnerships
- Implement Candidate Conservation Agreements with Assurances (CCAAs) to conserve GDE habitat for at-risk species
- Implement partnerships and co-management to leverage and prioritize work to manage and sustain GDEs

Challenges and considerations

Finding agreement and building and sustaining trust among partners are critical and can take time and effort, particularly where there are conflicting values (e.g., conservation as opposed to development) that must be overcome. Collaborative efforts are often born in response to either an incentive program that requires collaboration, or a crisis, and usually are successful when championed by a well-respected, long-term member of the community. In addition, neutral facilitators can help discern common ground, but can be hard to find. Buy-in from agencies may also be challenging depending on their mandates and capacities. Once established, there will still be effort and funding needed to sustain coordination. Despite these challenges, collaboration at some level (formal or informal) will likely strengthen the likelihood of success and the durability of outcomes of many other strategies.

Qualitative assessment of the effectiveness of Strategy 8's ability to reduce the impacts of each GDE stressor and threat.

STRESSOR RISK	EFFECTIVENESS
S1: Groundwater pumping status	*Somewhat Likely*
S2: Declining groundwater level trends	*Somewhat Likely*
S3: Current climate	*Somewhat Likely*
S4: Ungulate impacts	*Somewhat Likely*
S5: Non-native species presence	*Somewhat Likely*
S6: Surface diversions	*Somewhat Likely*
S7: Urbanization	
THREAT RISK	**EFFECTIVENESS**
T1: Appropriation status	*Somewhat Likely*
T2: Potential withdrawal proximity to GDEs	*Somewhat Likely*
T3: Future climate	*Somewhat Likely*
T4: Non-native species spread	*Somewhat Likely*
T5: Future urbanization	*Somewhat Likely*



STRATEGY 9

Increase awareness of the value of GDEs and the need to protect and reduce impacts to them

Why this strategy is needed

Even though half of Nevada's counties received over 80% of their water supplies from groundwater in 2015 (Dieter et al. 2018), groundwater is a hidden resource that is underground with complex spatial and temporal dynamics (Saito et al. 2021; United Nations 2022), so many people may not be aware of groundwater issues or how they may affect their lives and ecosystems they care about. Increased public awareness of groundwater at all levels (i.e., K-12, university, citizens, stakeholders, and decision-makers) enables informed action on water issues (Cherry 2023) and knowledge democratization (Cherry 2020), but a study of media coverage on California's Sustainable Groundwater Management Act between 2014 and 2019 found that gaps in representation of stakeholders (especially disadvantaged communities), and lack of knowledge about GDEs and solutions could contribute to low levels of engagement by the public in groundwater planning (Bernacchi et al. 2020). A recent study of threats to rare plants in Nevada, some of which are GDEs, found that a majority of Nevada's rare plants occur on BLM land and the largest observed threats were due to recreation (McClinton et al. 2022), so educating people accessing GDEs for recreation may help reduce impacts. Resources such as The Groundwater Project and the Nevada Indicators of Groundwater Dependent Ecosystems story map can be useful for educating people about groundwater and GDEs.

Examples of actions associated with this strategy

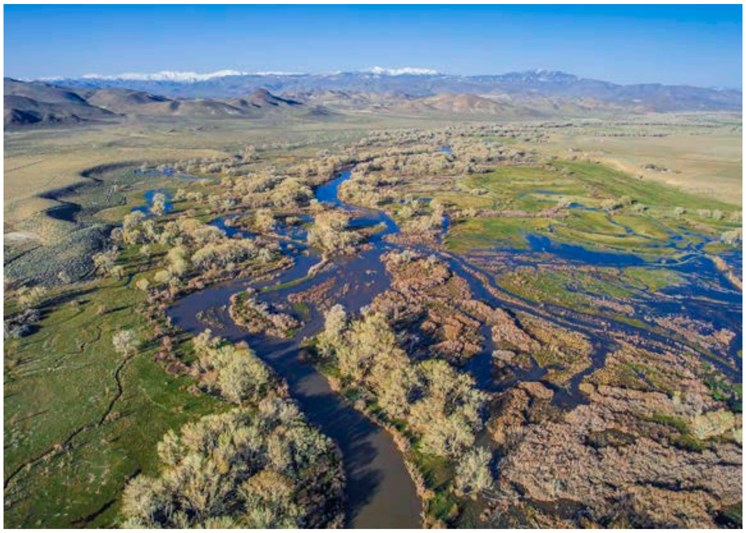
- Partner with networks and local groups to learn about management options and share knowledge of GDEs
- Build and use accessible K-12 and higher education curricula about groundwater and GDEs (see The Groundwater Project for some examples)
- Involve K-12 and higher education students in monitoring and reporting about GDEs
- Educate legislators and judges about groundwater and GDEs to enable informed decision-making on issues that can affect GDEs
- Educate and involve disadvantaged communities to empower them to take action and participate in sustainable planning for GDEs and groundwater
- Educate recreational users about GDEs, their value, and how to reduce impacts

Challenges and considerations

Increasing awareness of GDEs is a long-term strategy that involves a social shift and may be slow to influence change and can be difficult to measure. It will also require funding and capacity to develop curricula and public resources, which might also involve using public relations specialists to develop a campaign to truly reach a broad base that will translate understanding to action. This strategy will be more effective if done in conjunction with Strategy 1 to fill knowledge gaps about GDEs, and it is unlikely to make substantial impacts unless other strategies are in place or developed from the increased awareness (e.g., Management Strategies). However, none of the stressors and threats can be reduced without education; when people are more educated about a topic, they can be more conscientious about it, choose direct action to reduce the stressor or threat, or reduce a stressor or threat by participating in the decision-making process in their communities.

Qualitative assessment of the effectiveness of Strategy 9's ability to reduce the impacts of each GDE stressor and threat.

STRESSOR RISK	EFFECTIVENESS
S1: Groundwater pumping status	Somewhat Likely
S2: Declining groundwater level trends	Somewhat Likely
S3: Current climate	
S4: Ungulate impacts	
S5: Non-native species presence	Somewhat Likely
S6: Surface diversions	Somewhat Likely
S7: Urbanization	
THREAT RISK	**EFFECTIVENESS**
T1: Appropriation status	Somewhat Likely
T2: Potential withdrawal proximity to GDEs	Somewhat Likely
T3: Future climate	Somewhat Likely
T4: Non-native species spread	
T5: Future urbanization	Somewhat Likely



STRATEGY 10

Increase communication among water users, administrators, managers and academics about GDEs

Why this strategy is needed

Research has shown that polycentric approaches (e.g., co-management) that enable participants to develop rules and organizations at multiple levels can be effective for governance of common pool resources like water (Ostrom and Cox 2010), especially when different actors can find common interests; can agree on common practices, share social, economic or other ties; and share information (Kark et al. 2015). To facilitate changes for sustainability, Steger et al. (2021) argue for the incorporation of actor diversity (i.e., scientists from multiple disciplines and practitioners or stakeholders from diverse sectors and backgrounds), reflexivity (i.e., examining and questioning one's beliefs, values, assumptions and understandings), and mutual learning (i.e., participants explore current knowledge, exchange and generate new knowledge, and understand how knowledge interacts with social and cultural contexts). Fillmore (2017) notes how traditional values and cultures of indigenous communities have often not been considered in hydrologic and environmental models but can be helpful perspectives for considering uncertainty in natural environments the indigenous communities have been resilient to for generations. Maintaining communication about ongoing and future work and new data, knowledge and tools, while building collaborative relationships, can be beneficial for managing and sustaining GDEs.

Examples of actions associated with this strategy

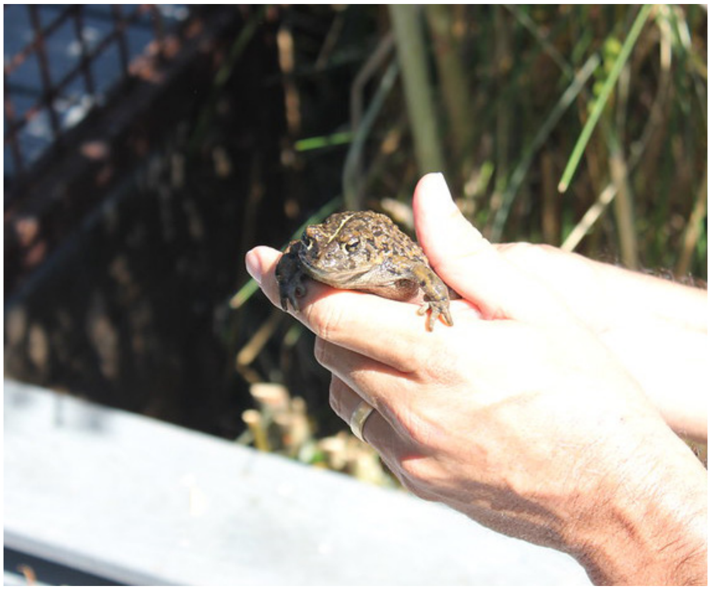
- Promote communication between different levels of agencies (i.e., local, state, federal, tribal), organizations, landowners and the public to coordinate management
- Interact with Indigenous communities while respecting sovereign ownership of knowledge (Fillmore 2017)

Challenges and considerations

It can be challenging to communicate in ways that diverse stakeholders can understand and translate into action. If sharing data is an objective, combining data from multiple sources into a cohesive dataset may be difficult, especially when integrating several ways of knowing. It is important to include coordination with Tribes, ideally from the beginning of a coordinated process to consider cultural perspectives on GDEs and because indigenous knowledge can be a great source of information and potential actions. Coordination among different entities on data collection and management (e.g., a monitoring network) could enable pooling of resources and could be more effective at determining where impacts are occurring or what actions could be done to reduce impacts. As with policy strategies, it may be hard to get buy-in from senior water right holders to share information if potential actions might appear to challenge prior appropriation. This strategy could be important for moving Science and Monitoring, Policy, and Management strategies forward, however it may be difficult to establish milestones and measure impacts of this strategy because it may need to be ongoing.

Qualitative assessment of the effectiveness of Strategy 10's ability to reduce the impacts of each GDE stressor and threat.

STRESSOR RISK	EFFECTIVENESS
S1: Groundwater pumping status	
S2: Declining groundwater level trends	Somewhat Likely
S3: Current climate	
S4: Ungulate impacts	Somewhat Lik ely
S5: Non-native species presence	Somewhat Likely
S6: Surface diversions	Somewhat Likely
S7: Urbanization	
THREAT RISK	**EFFECTIVENESS**
T1: Appropriation status	
T2: Potential withdrawal proximity to GDEs	Somewhat Likely
T3: Future climate	Somewhat Likely
T4: Non-native species spread	
T5: Future urbanization	Somewhat Likely



Summary

The ten strategies presented here are independently unlikely to be sufficient to improve the resiliency of GDEs over the long term, but collectively they are somewhat likely to highly likely to address almost all of the stressors and threats assessed in Saito et al. (2022a) (see Box 2 for an example). Only stressor S7 (current urbanization) was qualitatively not considered to have its impacts reduced by any of the strategies.

This report is part of TNC-Nevada's work on its sustainable waters goal of ensuring reliable water supplies for groundwater-dependent ecosystems and species in Nevada and enhancing their resilience in a changing climate. To address that goal, TNC-Nevada first mapped indicators of groundwater-dependent ecosystems (Byer et al. 2019; Saito et al. 2020), and then assessed the stressors and threats to GDEs in Nevada (Saito et al. 2022a). Information from that work informed discussion on developing the 10 strategies presented in this report. TNC-Nevada also has an ongoing project to quantify water requirements for GDEs under varying conditions of soil and climate conditions with Dr. Christine Albano at Desert Research Institute and Dr. Steven Loheide at University of Wisconsin-Madision. While all of these efforts will help TNC-Nevada prioritize its work on groundwater-dependent ecosystems in Nevada, it is hoped that this body of work is also useful to other agencies and entities.

Summary of effectiveness of ability of strategies to address impacts of stressors and threats to GDEs. HL=Highly Likely; SL=Somewhat Likely. Stressors: S1: Groundwater pumping status; S2: Declining groundwater level trends; S3: Current climate; S4: Ungulate impacts; S5: Non-native species presence; S6: Surface diversions; S7: Urbanization. Threats: T1: Appropriation status; T2: Potential withdrawal proximity to GDEs; T3: Future climate; T4: Non-native species spread; T5: Future urbanization

Strategies	STRESSORS							THREATS				
	S1	S2	S3	S4	S5	S6	S7	T1	T2	T3	T4	T5
SCIENCE/MONITORING												
Strategy 1: Increase understanding of co-benefits of GDEs, including carbon dynamics	SL	SL		SL	SL	SL		SL	SL	SL	SL	SL
Strategy 2: Increase monitoring and reporting over space and time	SL	SL		SL	SL	SL		HL	SL	SL		
POLICY												
Strategy 3: Enact policies to reduce current excessive groundwater withdrawals and overappropriation	HL	HL						HL	SL	SL		SL
Strategy 4: Enact policies to prevent future groundwater withdrawals that would negatively affect GDEs	HL	SL						HL	HL	SL		SL
Strategy 5: Include requirements for maintaining or protecting GDEs in regulations, codes and laws for land and water management and economic development	SL	SL		SL	SL	SL		SL	HL	SL	SL	HL
MANAGEMENT												
Strategy 6: Consider GDEs in permitting, guidance and large-scale planning documents to identify and prioritize areas for protection and management of GDEs	SL	SL		HL	SL	SL		HL	HL	SL	HL	HL
Strategy 7: Increase the pace and scale of restoration of GDEs in time and space		SL	SL	HL	HL	SL				HL	SL	
Strategy 8: Incorporate collaboration to manage and sustain GDEs	SL	SL	SL	SL	SL	SL		SL	SL	SL	SL	SL
EDUCATION/OUTREACH												
Strategy 9: Increase awareness of the value of GDEs and the need to protect and reduce impacts to them	SL	SL			SL	SL		SL	SL	SL		SL
Strategy 10: Increase communication about GDEs		SL		SL	SL	SL			SL	SL		SL

Box 2. Example of applying multiple strategies to improve resiliency of GDEs in Nevada.

An example of the application of more than one strategy involves the use of nature-based solutions to provide multiple benefits that include improving the resiliency of GDEs. Nature-based solutions involve the use of nature to provide benefits for both human well-being and biodiversity, which requires an understanding of the science of the potential benefits (Strategy 1) that could include climate change adaptation, biodiversity protection, enhanced human well-being and greenhouse gas reductions (Seddon 2022). However, just understanding the science is not enough to reduce the impacts of stressors and threats to GDEs. There must also be policy (Strategy 5), funding and programmatic initiatives (Strategy 7), and support from local communities (Strategy 9) to implement such solutions (Seddon 2022).

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Appendix A

List of organizations The Nature Conservancy met with to share Nevada GDE stressor and threat report and discuss strategies for managing and sustaining GDEs in Nevada.

ORGANIZATION
Bureau of Land Management
Cattlemens Association
Center for Biological Diversity
Central Nevada Regional Water Authority
Eureka County Natural Resources
Fallon Paiute-Shoshone Tribe
Great Basin Water Network
Humboldt River Basin Water Authority
Nevada Division of Natural Heritage
Nevada Division of Water Resources
Nevada Department of Wildlife
Nevada Farm Bureau
Nevada Mining Association
Nye County Water District
Pyramid Lake Paiute Tribe
U.S. Forest Service
U.S. Fish and Wildlife Service
US Geological Survey
Walker Basin Conservancy

Appendix B

Results of stressor and threat assessment of groundwater dependent ecosystems in Nevada.

Figure B.1. Groundwater dependent ecosystem (GDE) types at high risk for stressor risk factors from Saito et al. (2022a). Asterisk (*) indicates GDEs at moderate to high risk for the respective stressor risk factor.

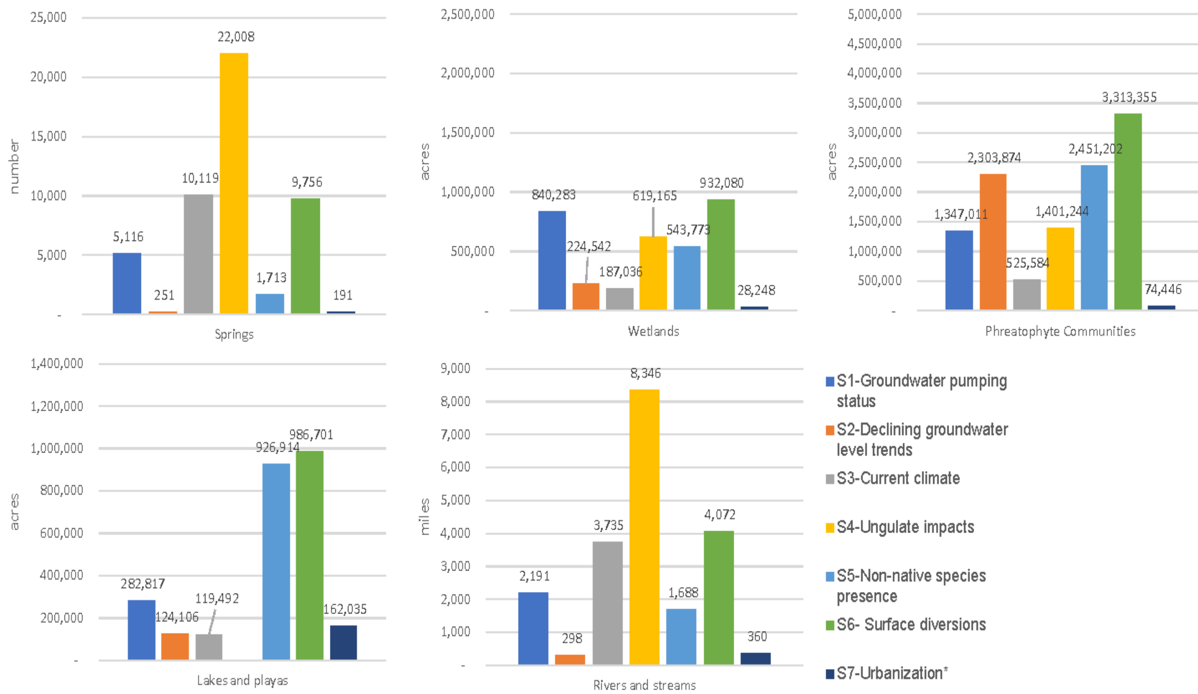

Figure B.2. Groundwater dependent ecosystem (GDE) types at high risk for threat risk factors from Saito et al. (2022a). Asterisk (*) indicates GDEs at moderate to high risk for the respective threat risk factor.