CPB Exh 22

Expert Report of Bruce A. Roundy, Ph.D.

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Evidentiary report prepared by Dr. Bruce A. Roundy, professor of rangeland ecology at Brigham Young University at the request of Kirton McConkie on behalf of the Cleveland Ranch and The Corporation of the Presiding Bishopric for the Church of Jesus Christ of Latter-day Saints

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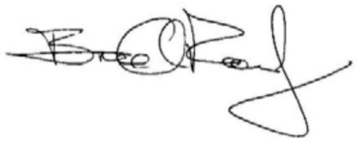

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Review of potential effects of water withdrawal on vegetation of the Cleveland Ranch, Spring Valley, Nevada

Brief summary

1) I reviewed reports and transcripts of the State Engineer's hearing from 2011. I also checked soils and ecological site types on the Web Soil Survey. In addition, I reviewed literature on effects of water availability and groundwater drawdown on the ecology of wetland and riparian plants.

2) Soil and plant community surveys indicate that if water availability is decreased for wetland, wet and dry meadows, and obligate phreatophytic vegetation, production of forage will be decreased and these communities will succeed to vegetation types sustained by annual rainfall. Facultative phreatophytic shrub lands have much lower productivity than these wetter types but would also decrease in cover and productivity. The unique Rocky Mountain juniper population depends on extra water beyond natural precipitation and could be lost if ground water is withdrawn.

3) There is substantial uncertainty about the water dynamics in Spring Valley that leads to uncertainty in predicting vegetation and other environmental responses. For example, how much will draw down change water availability from surface runoff, spring discharge, irrigation, and ground water? Projections on rate of withdrawal and timing of plant succession to drier conditions seem to infer that such drying is acceptable or allows sufficient time for mitigation by water restoration or some other means. The McClendon projections of plant succession to drier communities may be reasonable, but the timing of these transitions is too uncertain to be used for timing of mitigation. Succession to drier and much less-productive plant communities will not allow the Cleveland Ranch to sustain its current productivity. Studies show that the most shallow-rooted and wetter vegetation types are most sensitive to groundwater withdrawal, but studies that show responses of these types to restored water availability are lacking. Vegetation responses to timing of water withdrawal or restoration are uncertain and will be affected by drying climatic conditions. The resilience of other wetlands and riparian vegetation types suggest that wetland and wet meadow areas in Spring Valley could recover from loss of

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water availability if water is restored in a timely manner. However, how quickly water must be restored to recover prior composition and production is uncertain. Wetland and riparian species are greatly affected by drought lasting greater than a few weeks or more. Dry meadows are likely to pass through a threshold of increased surface salinity and invasive species dominance and their restoration may require irrigation to reestablish forage plants. Rangeland improvements and grazing management have been proposed to mitigate forage loss from water withdrawal, but these practices cannot compensate for the season-long quality and quantity of forage currently sustained by season-long water availability on the wetlands and wet meadows.

4) The risk of installing an expensive groundwater pumping system without knowing for certain whether or not that the water withdrawn will have to be substantially reduced to support environmental mitigation seems implausible. The uncertainty makes withdrawal an experiment that could result in limited withdrawal and project failure unless negative environmental consequences are tolerated.

5) The SNWA needs to clearly state thresholds and triggers for mitigation and then detail proposed mitigation actions for proper vetting.

1. **Objective:** The objective of this report is to review reports of plant communities, water availability, and soils and comment on effects of water availability changes to plant community production, succession, and restoration. The approach is to summarize known information from past reports, present some water management scenarios, and comment on successional outcomes and restoration potential.

2. Plant communities and abiotic controls

Available Information comes from McLendon (2011) who mapped and measured cover of plant communities in Spring Valley that he considered most susceptible to decreasing depth to the water table (DWT) or decreased water availability from runoff, spring flow, or irrigation. In addition, information on plant communities and soils comes from the Long Now Soils report (LONG 2011) and the Natural Resources Conservation Service (NRCS) Web Soil Survey (2017). The NRCS groups plant communities and related soils into ecological site types (ES) for interpreting productivity and successional trajectories associated with disturbances and management actions (Caudle et al. 2013). However, such state and transition models have not been posted on the Web Soil Survey for the lowland ecological site types in Spring Valley. Stringham et al. (2015) described state and transition models for a number of relevant ecological site types, such as for a Saline Bottom ecological site type, noting mainly transitions related to grazing and fire. I did not have McClendon's vegetation maps to overlay with soils and ecological sites from the Web Soil Survey. However, the Web Soil Survey allowed me to see the range of soils associated with the ranch. These mainly included associations of the Kolda, Biji, Ewelac, Duffer, and Medlaval soils on wetland, wet meadow, dry meadow, dry saline meadow, saline bottom, sodic terrace, sodic flat, and saline floodplain ecological site types many of which lacked plant community descriptions on the Web Soil Survey. However, the soil descriptions present a wide range of soil salinities, sodicities, and depths to water table. Salinity ranged from 0-32 mmhos/cm (dS/m), maximum sodium absorption ratios (SAR) from 12-90, and water table depth from 0 to 72 inches. Some of these soils are considered hydric. This indicates that the soil is saturated enough during the year to produce anaerobic conditions. The hydric classification is one criterion for classifying a site as a wetland.

The wide range of salinity/sodicity and depth to the water table (DWT) and the lack of more detailed soil and ecological site information, as well as lack of studies showing successional changes associated with increases in water table depths all add some degree of uncertainty to successional projections under changing water availability.

Plant distribution in the Cleveland Ranch area follows gradients in water availability and salinity and can be divided into many different units. The categories developed by McClendon (2011) are useful in showing susceptibility to changes in water availability in Spring Valley which would affect the Cleveland Ranch operation. He used microtopography and observed plant community transitions, as well as published studies to infer plant community-water availability relationships. He did not measure water table depths in piezometer wells to directly associate specific plant communities with DWT on site in Spring Valley. Although there are many community associations related to these gradients (McLendon 2011), they can be conveniently discussed by combining them into a few categories.

<u>Highly productive communities:</u> The most highly productive communities are those that receive enough additional water to support growth through the spring, summer, and fall when temperatures are warm enough for growth. The additional water above limited natural precipitation (10 inches/ year) comes from runoff, springs, irrigation, or the subsurface water table. These communities are the most sensitive to changes in water availability. They include aquatic and wetland vegetation, and wet meadows, as well as obligate phreatophytic communities. The wetlands and meadows may produce 2000 lbs/acre annually and are critical in supplying the private land forage that constitutes 70% of the total forage requirement for the Cleveland Ranch livestock (Resource Concepts 2011a). Obligate phreatophytes like willow and cottonwood depend on groundwater to occupy limited areas, but they supply important ecological services.

<u>Moderately productive communities:</u> Also supported by additional water beyond annual precipitation are dry meadows and dry saline meadows. These communities receive additional water for growth beyond precipitation similar to wetlands and wet meadows, but not enough to stay wet throughout the growing season. These meadows produce around 1000 lbs/acre annually (Resource Concepts 2011a), but are still much more productive than Wyoming big sagebrush communities above them and therefore an essential component of the Cleveland Ranch's private forage base.

<u>Less productive saline and non-saline shrublands below the sagebrush zone:</u> Dominants here are salt grass and greasewood, which are facultative phreatophytes and increased DWT may reduce their productivity. These areas are important for their extent, but generally have less additional available water and plant growth compared to wet and dry meadows. Production is much less than wetlands and wet and dry meadows at 45 to 75 lbs/acre annually on a sodic flat ecological site (Web Soil Survey 2017).

<u>Less productive upland sagebrush zone:</u> These are Wyoming big sagebrush or black sagebrush/bunch grass communities located on alluvial fans and terraces with typically non-saline, well-drained soils, and that are entirely dependent on natural rainfall. Typical Wyoming sagebrush-bunch grass plant communities in good condition with Spring Valley precipitation (10 inches, 30 year average from PRISM 2017) produce 250 to 440 lbs/acre annually (Web Soil Survey 2017). However, much of this land in Spring Valley has converted to cheatgrass annual grassland due to repeated fires and would require substantial investments in range improvements to reach its forage production potential.

Rocky Mountain juniper communities are a special case because they are located at much lower natural precipitation than occurs where this species is normally adapted. Extra water availability from the capillary fringe of groundwater, perched water tables, or from runoff-run-in surface water apparently supports this population (McLendon 2011). McClendon (2011) observed a gradient in understory species apparently associated with a gradient in water availability within the requirements of Rocky Mountain juniper itself. Without knowing the exact hydrology that supports this population, there is uncertainty in projecting its survival under groundwater withdrawal. If the population is mainly supported by ground water, withdrawal below 10 feet could doom it to extinction (McLendon 2011).

4. Water scenarios and plant response

Composition and productivity of upland vegetation in Wyoming big sagebrush zones of the Great Basin are dependent on climatic conditions that generally support a short period of growth in spring to early summer when soil water is available from winter and spring precipitation and temperatures are warm enough for growth (Caldwell 1985). Typically, high enough soil water availability to allow soluble nitrogen movement to roots and growth ends in late May to mid June, depending on the year (Leffler and Ryel 2012; Roundy et al. 2014). Plants below the Wyoming big sagebrush zone that receive additional water from runoff, springs, irrigation, or ground water can grow through the summer and early fall because of continued warm temperatures and can be much more productive than those in the sagebrush zone above.

Scenario 1: No decrease in water availability beyond changes associated with climate. Productivity stays similar to current and is mainly dependent on overall climate and annual weather.

Scenario 2: Ground water is pumped in stages from the Spring Valley aquifer, changes in water availability are mitigated by cessation of pumping or redistribution of water.

This is the SWNA-proposed approach to avoiding or mitigating environmental damage. However, unless the pumping is staged, carefully monitored, and mitigated by quickly returning water availability to its pre-pumping state, loss of water availability will result in succession to drier and less productive plant communities. Since specific hydrologic conditions are the ecological basis of wetlands and riparian areas, they are generally resilient to disturbance when the hydrology that supported them is restored in a timely manner and appropriate grazing management is implemented (Middleton 1999; Stromberg 2001; George et al. 2011; Brooks et al. 2013). However, the effects of withdrawal timing and water restoration are not known for the wetter Spring Valley vegetation types. We do not know how long the growing points of plants in these wetter areas will remain viable when dry. This uncertainty creates a risk for withdrawal and proposed mitigation. Alkali meadows dewatered by ground water withdrawal and decoupled from the water table in Owens Valley had greatly reduced cover when ground water depth was decreased below their threshold rooting depth (Elmore et al. 2006). Plants with shallower rooting depth may be lost with ground water withdrawal and replaced by deeper-rooted shrubs or invasive, non-native annuals that do not require ground water (Elmore et al. 2003; Elmore et al. 2006). Even short periods of drought (> a few weeks to >30 days) substantially reduce growth, biomass, and seedling survival of wetland and riparian species (Touchette and Steudler 2009; Garseen et al. 2014). Water table declines could favor replacement of wetland and riparian species by tamarisk that has especially rapid seedling root growth (Garseen et al. 2014).

Scenario 3: If, for many plausible reasons, water availability is lost and not restored in a timely manner, major changes in plant dominance and production will occur.

Projection of details for specific vegetation types, areas, and extents aside, removal of water availability and failure to restore in a timely manner will most affect the aquatic, wetland, wet meadow, and dry meadow communities, as well as the obligate phreatophytes, all of which will succeed to drier communities, as described by McClendon (2011). His successional timing projections in figures 4-3 and 4-4 may be reasonable. He did not describe the methodology for estimating transition times to drier communities and his projections must be considered general anyway, given specific uncertainties in Spring Valley including annual precipitation, runoff water distribution, spring discharge, irrigation, soil salinity/sodicity changes, potential for invasive weed dominance, and actual loss of ground water availability. Tolerance to water table decline varies greatly among wetland and riparian species, but more shallow-rooted herbaceous species are more sensitive than deeper-rooted woody species (Garseen et al. 2014). At any rate, is succession to drier and much less productive plant communities an acceptable environmental impact?

<u>Effects of dewatering on wetlands, wet meadows, and dry or dry saline meadows.</u> Current successional theories in ecology consider that plant succession may not necessarily follow a linear, predictable pathway, but could follow a variety of trajectories with different probabilities (Briske et al. 2008). A system could pass through a biotic (related to living organisms) or abiotic (related to the physical environment) threshold after disturbance or a change in the supporting environment, which could greatly reduce the probability that the system could return to a former state without major restoration inputs (Wisenant 1999). Dominance of a community by an aggressive weed is an example of a biotic threshold. A change in the hydrology and water relations or soil loss in a system are examples of an abiotic threshold. Factors that affect probabilities of returning to a former state include propagule and residual plant availability and potential to return to the abiotic environment that previously supported the system. In the case of wetlands, wet and dry meadows, and obligate phreatophytes this requires that residual wetland plants or their seeds or vegetatively-reproductive parts and the supporting hydrology and water availability be restored. The longer the period of drying, the less likely residuals and propagules will be available for natural restoration. As water is depleted, wetlands and meadows could be salinized near the soil surface through soil water evaporation where subsoils are saline (Roundy 1984; Roundy et al. 1984; Roundy et al. 1987). Although cheatgrass is not very salt tolerant and would not move in and dominate even moderately saline areas, it could be a problem on non-saline soils. More salt tolerant species could move in and dominate the saline soils, making it difficult for original species to return. On dried wetlands and meadows, halogeton, greasewood, and tamarisk could move in and potentially increase the salinity of surface soils by accumulating subsurface salts and dropping their leaves (Duda eta al. 2003; Rickard 1965; Yin et al. 2010). If the original hydrology and water availability is returned, wetlands and wet meadows could eventually return to their original areas as flooding discourages non-adapted plants and salts are diluted or leached away in surface runoff or drainage. We do not really know what timing of water restoration is required to restore these wetter communities to the composition and productivity that they had prior to being dewatered.

Effects of water loss on dry meadows and dry saline meadows are of major concern. These meadows are those that have extended water availability beyond what would occur with just precipitation, but not enough to make them wetlands or wet meadows. The additional water availability above that supplied by precipitation comes from surface runoff, springs, irrigation, or a shallow water table. These dry meadow areas are most susceptible to expansion by greasewood and rabbitbrush, as well as glycophyte (non-salt tolerant) and halophyte (salt tolerant) invasives. Restoration of grasses on dry meadows will probably require seeding and irrigation, since limited natural precipitation and salinity may constrain seed germination and seedling root growth (Roundy et al. 1985). Alkali sacaton requires high water availability for seedling establishment (Aldon 1975) and will probably require irrigation for successful revegetation in Spring Valley. Saltgrass requires high water availability and alternating seedbed temperatures for germination (Cluff and Roundy 1988), a condition unlikely to occur in dewatered dry meadows without irrigation. Successful revegetation plant establishment in dewatered dry meadows is also constrained by low infiltration rates and physical soil crusts associated with silty and sodic soils (Roundy 1985; Roundy et al. 1987).

Effects of dewatering on facultative phreatophytic shrublands.

Because greasewood and saltgrass are facultative phreatophytes, they do not necessarily depend on groundwater. Much of their growth could be supported by soil moisture from precipitation when the water table is less accessible (McLendon et al. 2008; Goedhart and Pataki 2010). Shrublands dominated by these species and some species of rabbitbrush should still persist at some level of reduced productivity if withdrawal lowers the fringe of the water table beyond their roots. Stringham et al. (2015) noted that decrease in DWT would result in a decrease in greasewood and allow rubber rabbitbrush to increase. McClendon (2011) indicated that greasewood/saltgrass areas would eventually succeed to sagebrush, but natural plant distribution in the Great Basin indicates that would only occur on relatively small areas. Sagebrush is adapted to and occurs in areas that transition from sagebrush to greasewood-dominated zones (ecotone). Its lack of salt tolerance and tolerance to even periodic flooding, as well as its water requirements restrict it from occurring, and therefore dominating over extensive areas once occupied by greasewood. As noted by McLendon (2011), with lack of ground water, greasewood and saltgrass cover would decrease in cover but not necessarily disappear over time. Greasewood shrubs are smaller where little or no groundwater is available, compared to shrubs that access ground water, as would also be expected to occur in Spring Valley if ground water is no longer available.

5. Observations on water withdrawal in Spring Valley and proposed mitigation

The McClendon (2011) report emphasized the important effects of draw down timing on succession responses, as inferred from microtopography vegetation composition and DWT in the literature. However, with the broad range of model predictions for this large-scale and complex system, management of DWT over the scale of a few feet seems difficult. If we consider that even a small amount of draw down (1-4 ft) could change the most productive wetlands and wet meadows, the question becomes what the real effect of drawdown will be on water availability. The proposed withdrawal project is a major capital investment, yet its success depends on a major uncertainty: how will withdrawal affect the environment when these effects must be mitigated as proscribed by law. This really begs the question of where the water will come from to sustain and restore resources if water withdrawal continues. The Cleveland Ranch plant communities that receive water in addition to natural precipitation get that water from surface runoff and springs that are fed from mountain runoff through the alluvial fans. If drawdown drains this water from the root zone, then wetlands and meadows are locally dewatered unless they are mainly watered by irrigation from deeper wells. The Resource Concepts, Inc. report (2011b) shows that many acres of the Cleveland Ranch's most productive areas are sprinkler or flood irrigated and McClendon's (2011) report considers that the many of the wetter communities on the Cleveland Ranch are supplied from irrigation water. The Mayo and Jones report (2011) states that water withdrawal will dry up the many springs discharging runoff from the alluvial fans. This all indicates major uncertainties in the effects of withdrawal on water availability, not the least of which is effect on irrigation well water supply.

If withdrawal does not reduce water availability from surface runoff, spring discharge, ponding, and irrigation, then impacts to wetlands, meadows and obligate phreatophytes should be limited. But this uncertainty affects the potential success of a huge capital investment. Using ground water without impacting existing plant communities seems to imply either non connectivity of the aquifer being pumped and the upper water table (0-30 ft), or the use of evaporating water (E) while not impacting water transpired through plants (T). However, how do you reduce E without affecting T in vegetated areas? If the deep aquifer is to come to equilibrium under withdrawal, it must be recharged from somewhere, and that amount of withdrawal must not reduce water currently available for plant growth if it is to avoid environmental damage.

On the other hand, the withdrawal to equilibrium approach could expect to sacrifice the wetland, meadow, and obligate phreatophyte areas over time. However, that occurs at the expense and viability of the Cleveland Ranch. Is this inferred by the McLendon (2011) report that states succession can be managed as wetter soils and plant communities change to drier ones? It has also been suggested that upland areas can be improved to replace lost forage in lowland areas. Those mitigation approaches should be detailed. However, we already know the challenges of restoring upland cheatgrass-dominated sagebrush rangelands to perennial grass under the natural rainfall of Spring Valley (Roundy and Call 1988; Hardegree et al. 2016). It could take multiple applications of herbicide and reseeding over many years until wetter years result in some success. Cheatgrass dominance indicates the system has passed through a biotic threshold, which requires substantial investment to cross back to the former system. In addition, successful upland seeding still cannot compensate for lowland forage conditions because it only provides quality spring forage until water is unavailable in May or June. Although introduced grasses like crested wheatgrass could be established in Spring Valley on sagebrush ecological site types during a wetter year, these grasses mature early and would not provide the green and highly nutritional forage nor quantity that wetlands and wet meadows do through the summer. In addition, plant tolerance and response to grazing is highly resource dependent because resources such as soil water are necessary for regrowth and continued resource uptake (Briske and Richards 1995). Therefore, grasses that are grazed in the spring growing season under short periods of water availability from winter and spring precipitation must have lower utilization and more frequent non-grazing periods to maintain leaf tissue and photosynthesis in order to sustain themselves compared to those that have water available through the summer.

Successful seeding of non-salt tolerant or salt-tolerant vegetation to use only natural rainfall on former wetlands and meadows without irrigation is also unlikely. Plant establishment will be constrained by lack of consistent precipitation, silty-crusting soils, low infiltration on silty and sodic soils, and invasive weeds (Roundy 1984, 1985; Roundy et al. 1984, 1987).

Improving forage production on facultative phreatophyte shrublands (greasewood and rabbitbrush) areas has the similar establishment challenges as mentioned above. Seeding of saltbush was mentioned in one transcript. Four-wing saltbush has been successfully seeded on some upland seedings in the sagebrush zone. However, its establishment can be erratic under semiarid precipitation and it can be short-lived if seeded in areas for which specific ecotypes are not adapted.

In summary, all of these concerns should be addressed in detail in the monitoring and mitigation plan. The 2011 plan only presented a short list of general mitigation actions. The court ruling that SNWA must develop specific monitoring triggers should be accompanied by specific proposed mitigation actions that can be properly vetted.

If withdrawal reduces water availability within the upper 0-30 feet where runoff, spring discharge or natural subirrigation occur, or if it reduces irrigation water from much deeper wells, and the environmental consequences make withdrawal prohibitive, the "pump and mitigate" approach seems to be at risk for becoming a major capital loss.

References

Aldon, E. 1975. Establishing alkali sacaton on harsh sites in the Southwest. Journal of Range Management 28:129-132.

Briske, D.D., B.T. Bestelmeyer, T.K. Stringham, and P.L. Shaver. 2008. Recommendations for development of resilience-based state-and-transition-models. Rangeland Ecology and Management 61: 359-367.

Briske, D. A. and J. H. Richards. 1995. Plant responses to defoliation: a physiological, morphological, and demographic eva

Brooks, K. N., P. F. Fflolliot, and J. A. Magner. 2013. Hydrology and management of watersheds. Fourth edition. Wiley-B

Caldwell, M. 1985. Cold desert. In: B. F. Chabot and H. A. Mooney, editors. Physiological ecology of North American plant communities. Chapman and Hall, New York, New York. 198-212.

Caudle, D., DiBenedetto, J., Karl, M., Sanchez, H., Talbot, C., 2013. Interagency ecological site handbook for rangelands. Available at: http://jornada.nmsu.edu/sites/jornada. nmsu.edu/files/InteragencyEcolSiteHandbook.pdf

Cluff, G.J. and B.A. Roundy. 1988. Germination responses of desert saltgrass to temperature and osmotic potential. J. Range Manage. 41:150-153.

Duda, J.J., D. Carl Freeman, J. M. Emlen, J. Belnap, S. G. Kitchen, J. C. zak, E. Sobek, M. Tracy, and J. Montante. 2003. Differences in native soil ecology associated with invasion of the exotic annual chenopod, *Halogeton glomeratus*. Biology and Fertility of Soils 38:72-77.

Elmore, A. J., J. F. Mustard, and S. J. Manning. 2003. Regional patterns of plant community response to changes in water: Owens Valley, California. Ecological Applications 13:443-460.

Elmore, A. J., S. J. Manning, J. F. Mustard, and J. M. Craine. 2006. Decline in alkali meadow vegetation cover in California: the effects of groundwater extraction and drought. Journal of Applied Ecology 43:770-779.

Garseen, A. G., J. T. A. Verhoeven, and M. B. Soons. 2014. Effects of climate-induced increases in summer drought on riparian species: a meta-analysis. Freshwater Biology 59:1052-1063.

George, M. R., R. D. Jackson, C. S. Boyd, and K. W. Tate. 2011. A scientific assessment of the effectiveness of riparian management practices. In: D. A. Briske, editor. Conservation benefits of rangeland practices. USDA Natural Resources Conservation Service, Washington, DC.

Goedhart, C. M. and D. E. Pataki. 2010. Ecosystem effects of groundwater depth in Owens Valley, California. Ecohydrology (www.interscience.wiley.com) DOI: 10.1002/eco.154

Hardegree, S., T. A. Jones, B. A. Roundy, N. L. Shaw, and T. A. Monaco. 2016. Assessment of range planting as a conservation practice. Rangeland Ecology & Management 69: 237-247.

Leffler, A. J. and R. J. Ryel. 2012. Resource pool dynamics: conditions that regulate species interactions and dominance. In: T. A. Monaco and R. L. Sheley (Editors). Invasive plant ecology and management. Linking processes to practice. Oxfordshire, UK: CAB International. p. 57–78.

LONG_Exh_004. 2011 Expert report to Nevada State Engineer Water Rights Hearing, Spring Valley, Nevada, Soils.

PRISM Climate Group. 2016. PRISM climate data. Available at http://prism.oregonstate.edu. Accessed May 31, 2017.

Mayo, A. L. and N.L. Jones. 2011. CBE Exhibit 11.

McLendon, T, P. J. Hubbard, and D. W. Martin. 2008. Partitioning the use of precipitation and groundwater-derived soil moisture by vegetation in an arid ecosystem in California. Journal of Arid Environments 72:986-1001.

McLendon, T. 2011. Potential effects of change in depth to water on vegetation in Spring Valley,Nevada. Presentation to the Office of the Nevada State Engineer. Prepared for the Southern Nevada Water Authority by KS2 Ecological Field Services. LLC. Anton, Texas.

Middleton, B. 1999. Wetland restoration, flood pulsing, and disturbance dynamics. John Wiley & Sons, New York. 388 p.

Resource Concepts, Inc. 2011a. Technical Review and Comments on McLendon, T. 2011. Potential effects of change in depth to water on vegetation in Spring Valley, Nevada. Presentation to the Office of the Nevada State Engineer. Prepared for the Southern Nevada Water Authority by KS2 Ecological Field Services. LLC. Anton, Texas. Resource Concepts, Inc., Carson City, Nevada.

Resource Concepts, Inc. 2011b. Water rights, land, and water resources report for North Spring Valley, Nevada. Prepared for Kirton and McConkie. CPB EXH-001. Resource Concepts, Inc., Carson City, Nevada.

Rickard, W. H. 1965. Sodium and potassium accumulation by greasewood and hopsage leaves. Botanical Gazette: 126:116-119.

Roundy, B.A. 1984. Estimation of water potential components of saline soils of Great Basin rangelands. Soil Sci. Soc. Amer. J. 48:645-650.

Roundy, B.A., R.A. Evans and J.A. Young. 1984. Surface soil and seedbed ecology of salt desert plant communities. p. 66-74. In: Tiedemann, A.R., E.D. McArthur, H.C. Stutz, R. Stevens and K.L. Johnson (compilers). Proceedings symposium on the biology of Atriplex and related chenopods. USDA For. Ser. Intmnt. For. and Range Exp. Sta. Gen. Tech. Rep. INT-172. Ogden, Utah.

Roundy, B.A. 1985. Emergence and establishment of basin wildrye and tall wheatgrass in relation to moisture and salinity. J. Range Manage. 38:126-131.

Roundy, B.A. 1987. Seedbed salinity and the establishment of range plants. p. 68-81 In: G. W. Frasier and R.A. Evans (eds.). Proceedings of symposium "Seed andseedbed ecology of rangeland plants." U.S. Dept. Agric., Agric. Res. Serv.,National Technical Information Service, Springfield, Virginia.

Roundy, B.A. and C.A. Call. 1988. Revegetation of arid and semiarid rangelands. p. 607-635. In: P.T. Tueller (ed.), Vegetation science applications to rangeland analysis and management. Kluwer Academic Publishers, Boston.

Roundy, B.A., K. Young, N. Cline, A. Hulet, R.F. Miller, R.J. Tausch, J.C. Chambers, and B. Rau. 2014b. Piñon-juniper reduction increases soil water availability of the resource growth pool. Rangeland Ecology and Management 67: 495-505.

Stringham, T. K., P. Novak-Echeneque, P. Blackburn, C. Coombs, D. Snyder, and A. Wartgow. 2015. Final report to USDA ecological site description state-and-transition models. Major Land Resource Area 28A and 28B Nevada. University of Nevada, Reno, Nevada Agricultural Experiment Station Report 2015-01. P. 1524.

Stromberg, J. C. 2001. Restoration of riparian vegetation in the south-western United States: importance of flow regimes and fluvial dynamism. Journal of Arid Environments 49:17-34.

Touchette, B. W. and S. E. Steudler. 2009. Climate change, drought, and wetland vegetation. In: G. A. Uzochuckwu et al. (editors), Proceedings of the 2007 National Conference on Environmental Science and Technology. DOI: 10.1007/978-0-387-88483-7_32

Web Soil Survey. Accessed May 31, 2017. https://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx).

Wisenant, S. 1999. Repairing damaged wildlands. Cambridge University Press. 312 p.

Yin, C. H., G. Feng, F. Zhang, C. Y. Tian, and C. Tang. 2010. Enrichment of soil fertility and salinity by tamarisk in saline soils on the northern edge of the Taklamakan desert. Agricultural Water Management 12:1978-1986.