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Abstracts

Wetland Revitalization and Channel Stabilization at Clover Springs, Mogollon Rim, Arizona

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The Clover Springs wetland meadow is located in the Mogollon Rim country of central Arizona, a region that currently receives the highest average annual precipitation values in the state (over 36 inches/yr). The half-mile long wetland was in a degraded condition due to channelization resulting from construction of adjacent roads and large in-stream log structures that were causing bank erosion and widening of the stream that was accelerated during rare flood events. A restoration plan was developed by an interdisciplinary team from the fields of geomorphology, hydrology, engineering, and forestry, in collaboration with U. S. Forest Service land managers. Geomorphic analysis suggested that prior to incision at the turn of the century, the floodplain had been in a stable condition for the past 7,000 years, with no major erosive episodes. Hydraulic analyses and characterization of a reference reach were used to determine the stream's stable geometry, meander patterns, and gradient to form a template for the new channel design. On-site wetland revitalization, channel stabilization and revegetation activities took place in July and August 2001. Revitalization of the wetland involved removal of a local forest service road and re-attachment of a bankfull channel to the abandoned floodplain. Upland revegetation involved hydromulch that included a seedmix of native species. The riparian area was revegetated using hand-planted plugs of sedge and rush species. Erosion matting and an 8-foot high fence to exclude elk grazing were also used to help facilitate revegetation. Ongoing monitoring activities include spring and channel hydrology, channel stability surveying, vegetation monitoring, and repeat photography.

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Contributions of Local Recharge at High Discharge Springs, Death Valley, California

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Springs in the Furnace Creek and Scotty's Castle areas of Death Valley exhibit high discharge rates and depleted $\delta^{18}O_{VSMOW}$ [~ -13 to -14‰] and δD_{VSMOW} [~ -102 to -112‰] values. Conventional wisdom suggests that modern depleted local recharge is unlikely, yet interbasin flow is difficult envisage due to lithology and the regional dip of bedrock in intervening ranges.

High-flux springs at Furnace Creek and Scotty's Castle respond to climate in terms of discharge rate and isotopic composition. Hydrographs show a climate response and variations in time-series stable isotope data track one another, suggesting a climate effect. Tracking occurs not only locally, but regionally. For example, $\delta^{18}O$ shows a remarkably similar pattern between Nevares [Furnace Creek] and Staininger [Scotty's Castle] Spring, even though they are widely separated.

Estimates of discharge at Willow Spring [Gold Basin, Black Mountains] produce a discharge flux/km^2 of catchment that, by analogy, could support ~25% of the current discharge at Furnace Creek. Yet ^{14}C data [calculated ^{14}C ages are between 7,500 and 11,000 yr; Pearson and Fontes models] suggest much of the water at Furnace Creek was recharged [locally or otherwise] during the most recent pluvial period when net infiltration was much higher and isotopically depleted.

Looking "upgradient," ^{14}C ages at Yucca Mountain and the Amargosa Valley range from 7,000 to 13,500, and 2,500 to 12,500 yr, respectively. Waters in Pahranagat Valley are as old as 17,500 yr, whereas waters at Crystal Pool and Big Spring in Ash Meadows are as old as 13,000 and 24,000 yr, respectively. This suggests that if interbasin flow were important, it must be extremely rapid. Thus, we believe the evidence indicates that local recharge cannot be neglected in regional flow models, nor for the description of the high flux springs in Death Valley.

Boulder City Wetlands Park

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The Bureau of Reclamation’s primary objective in constructing the Boulder City Wetland Project is to demonstrate the restoration of habitat for threatened and endangered species through the use of reclaimed municipal wastewater. Other objectives include research on improving water quality, recreation and public education. The project was cooperatively developed and funded by the city of Boulder City, the Nevada Division of Wildlife, and the Department of the Interior’s Bureau of Reclamation. Design and construction costs totaled approximately $1.2 million.

The exhibit comprises 8-16, 8”x10” sequential color photographs of the construction of the project with short descriptions.

Texas Springs – Leaking Into an Uncertain Future?

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Texas population will double from the present 20 million to almost 40 million in the next 50 years. Existing water supplies will not be sufficient to sustain that growth unless action is taken to better conserve those supplies and supplement them where necessary to meet need. Groundwater withdrawal will increase as part of the solution to meeting increased water demands. Mining of this water resource will affect springflow, which has historically been adversely affected by such action. Approximately 281 major, historical springs have been identified in Texas in the past. Of the four largest, only two remain, the Comal and San Marcos. Altogether, 63 of the State's major springs had stopped flowing by 1973. It is estimated that the number of springs no longer flowing has doubled since that time. The ecological and economic impact of those loses are now being recognized as more spring related species are declared endangered or threatened. Legislative action to address the issue has been driven by court action related to the federal Endangered Species Act. As population pressures continue to stress these resources the impact of failure to protect them will have adverse impacts beyond ecological concern and will demand some level of legislative remedy. The question remains if that attention will come before or after irreparable ecological damage.

Statewide Wetlands Investigation Project: Classification, Inventory and GIS Interface/Database Archive

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The State of Nevada Division of Environmental Protection (NDEP), Bureau of Water Quality Planning retained Harding ESE, Inc. (Harding ESE) to develop a statewide classification and inventory system for wetland and riparian habitats. Funding for this project was secured from the US Environmental Protection Agency and Carson City Open Space Committee. NDEP intends to use the products of this work to create a State level wetland management and preservation program. The goals of that program are to ensure that there is no net loss of Nevada's remaining wetlands and, where possible, identify opportunities to increase the quantity and quality of the state's wetland resource base.

The first step toward identifying a wetland inventory and classification scheme for Nevada included a thorough review of existing wetland programs, followed by the evaluation and ranking of those programs based on their merits. Secondly, a Nevada statewide wetland inventory and classification scheme was developed and tested for its applicability to Nevada's wetland resources. Based on the evaluation of existing wetland classifications and inventories, Harding ESE recommended that NDEP implement an amended version of the hierarchical, multifactorial classification developed by Ferren et al. (1996). Thirdly, remote sensing data was evaluated for its utility as a tool to focus field exercises. Finally, a database archival scheme was developed and interfaced with a geographic information system (GIS).

The Nevada Classification and Inventory System was field tested in the Carson City Pilot Study Area. Classification and inventory methods were found to be repeatable, verifiable and consistent. The database archive system was found to be workable with the data collected by the 2001 NDEP field investigation. Based on the long-term utility resulting project tools it is recommended that the State of Nevada move forward as funding is available to inventory, classify, and archive wetland and riparian resources statewide.

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Restoration of the Kings Spring and Point of Rock Drainages in Ash Meadows, Nevada

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The Kings Spring and Point of Rocks drainages, located in the Ash Meadows National Wildlife Refuge, Nye County, Nevada, are part of an extensive wetland system supporting 24 endemic plants and animals, the largest concentration of endemic species in the United States. Beginning in the 1950s, land developers converted a large portion of the Kings Spring Drainage for agricultural uses. The spring pools were excavated into a much larger size for aesthetic reasons and the outflow channels were obliterated as flows were piped into an open concrete irrigation ditch. Over time, as the concrete ditch began to deteriorate, leakage from the ditch turned an abandoned agricultural field, which was once a mesquite-baccharis dominated riparian forest, into a cattail-rush dominated wetland.

While much of the original ecosystem was drastically altered, Kings and Point of Rocks Springs continued to support the endangered, endemic Ash Meadows Amargosa pupfish (*Cyprinodon nevadensis mionectes*). However, the threatened and endemic Ash Meadows naucorid (*Ambrysus amargosus*) was extirpated from the Kings Spring system and was reduced to only a few individuals in the Point of Rocks system, and the Kings Spring-Point of Rocks speckled dace (*Rhinichthys osculus nevadensis*) population was reduced to a few individuals.

A restoration design was devised from analyses of the undisturbed spring characteristics, geomorphic setting, and hydrologic characteristics. After mechanical manipulation of the springs and outflow channels, according to the design, and sufficient recuperation time, the springs are starting to recover their native flora and fauna. Pupfish have abundantly colonized the new spring pools and outflow channels and, after the reintroduction of 35 individuals, the estimated naucorid population now numbers in the tens of thousands. Also, the mesquite- baccharis riparian forest, as well as endemic plants such as the threatened spring-loving centaury (*Centaurium namophilum*), is recolonizing along the spring outflow channels.

Hydrobiid Snails of the Intermountain West: An Underappreciated Biodiversity Jewel at the Crossroads

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Hydrobiid gastropods form an integral and highly diverse component of spring ecosystems of the Intermountain West. More than 100 species of these tiny, gill-breathing snails have been described from the region and discovery of many more new species is anticipated in the wake of more thorough field surveys and development of a more refined species-level taxonomy with the use of molecular markers. Most of these snails are restricted to single springs or spring systems. Individual drainage basins often contain several endemic species, forming local "hot spots" of biodiversity (e.g., Ash Meadows, Railroad Valley, Steptoe Valley). Aside from taxonomy, scientific study of this fauna has focused on biogeography, with pioneering work provided by Dwight Taylor, who recognized that the distribution and relationships of these obligate aquatic and poorly dispersing animals can serve as tools to help delineate drainage history. This line of investigation is continuing today with renewed vigor as molecular studies are permitting finer taxonomic resolution, a more robust understanding of relationships, and a means of constraining the timing of branching events. This huge fauna, composed of narrowly endemic species which are typically concentrated in the clean, flowing water of headsprings, is highly vulnerable to habitat modification. Several species have become extinct in recent times as a result of anthropogenic activities and many others are in jeopardy, although very few have been federally listed. Adequate protection of snails and their habitats usually can be provided in a relatively inexpensive manner and within the context of multiple use of aquatic resources. However, such can only occur if responsible parties are armed with both a basic understanding of the biology of these snails, and an appreciation that these small, inconspicuous organisms represent a tremendous scientific resource and a key element of western biodiversity that should be saved.

Water Chemistry at Snowshoe Mountain, Southwestern Colorado: Mixed Processes in a Common Bedrock

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Typically, soil and ground waters with longer residence times in a given rock become more solute rich, but hydrochemical data are often interpreted without looking at the reacting minerals. To understand the evolution of water chemistry from dilute snowmelt to stream and spring effluent, we studied water chemistry, hydrology and rock/mineral characteristics in the soil zone and in unsaturated and saturated waters in an Oligocene welded-tuff bedrock near Creede, Colorado. Field analyses and experimental results demonstrated the dominance of various solute-producing processes in different hydrologic reaction environments within the same lithology.

In the thin soil, physical degradation of tuff facilitates preferential dissolution of K^+-rich glass within the rock matrix, while other silicate minerals remain unaltered. Under the soil in the upper few meters of fractured bedrock, dilute water infiltrates during spring snowmelt and summer storms, leading to preferential dissolution of augite exposed on fracture surfaces. Deeper yet, in the phreatic zone of the fractured bedrock, Pleistocene calcite fracture fillings dissolve and dioctahedral and trioctahedral clays form as penetrative weathering alters feldspar and pyroxene, simultaneously generating alkalinity and buffering SiO_2 concentrations.

Ephemeral springs near the top of the mountain and the creek that drains the center of the mountain maintain a strong phreatic chemical signal year round, indicating that deep, slow weathering processes dominate water chemistry.

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Inventory of Water Sources and Associated Biological Resources of the Mojave National Preserve

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Approximately 120 springs are known to occur in the Mojave National Preserve. Most have been extensively modified for human and livestock use. Since there are no permanent lakes or rivers in the Preserve, these springs are loci of biological diversity in a desert environment. The National Park Service has funded a two-year study, beginning this year, to locate and inventory all springs and wetlands within the Preserve. Priorities of this inventory include vascular plants, aquatic invertebrates, and basic information necessary for resource management. An electronic form was developed in collaboration with federal and state agencies of the Desert Managers Group for recording data using handheld computers and GPS devices. A definitive map of water sources; quality, quantity, and associated biota resulting from this study will provide the basis for prioritizing restoration of scarce natural water supplies in the desert ecosystem. Our precursory assessment is that many of the water sources, identified as springs, are better described as qanats where groundwater is brought to the surface by gravity flow through tunnels or pipes for human and livestock use. In addition, most natural wetlands in the Preserve have been partially drained to fill tanks and troughs. Ponds also exist in open mining pits, either from collected runoff or interception of the water table. These anthropogenic factors, especially modifications that bring groundwater to the surface, may be the primary consideration in restoring desert ecohydrology to a naturally functioning condition.

Estimates of Evapotranspiration from Major Discharge Areas of Death Valley Regional Flow System

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The Death Valley regional flow system (DVRFS) encompasses about 16,000 square miles of the Mojave and Great Basin Deserts in southern Nevada and eastern California. Within this arid region, natural occurrences of surface and near-surface water are limited to areas where geologic and hydrologic conditions force deep-flowing ground water upward to discharge at springs and seeps. Much of this emerging flow infiltrates into contiguous soils where it is transpired by local phreatophytes or evaporates into the atmosphere. ET (evaporation and transpiration) from these wetland areas is difficult to measure directly, but reliable estimates are critical in the desert southwest for developing strategies to best balance increasing water demands with the preservation of riparian habitats.

Evapotranspiration is estimated from ten major discharge areas within the DVRFS. Ten unique areas of similar vegetation and soil moisture conditions (ET units) are delineated. Identification of ET units is based on similarities in reflectance signatures derived from satellite imagery. ET units include areas dominated by open playa, moist bare soil, different densities of phreatophytic vegetation, and open water. An ET rate is estimated for each ET unit from locally collected, micrometeorological data. Rates range from a few tenths of a foot per year for open playa to nearly 9 feet per year for open water. Annual ET for each ET unit within a discharge area is computed as the product of the unit's acreage and annual ET rate.

Mean annual ET from each discharge area is estimated by summing annual ET computed for each component ET unit. Estimates range from 450 acre-feet in the Franklin Well area to 30,000 acre-feet in Sarcobatus Flat. Mean annual loss of ground water through ET is computed for each discharge area by removing the precipitation component. Ground-water ET estimates range from 350 acre-feet in the Franklin Well area to 18,000 acre-feet in Ash Meadows. These estimates are greater for northern discharge areas than those reported in the literature; whereas, ET estimates for southern discharge areas are less than those reported in the literature.

Hydrology and Function of Remnant Owens Basin Wetlands

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Owens Lake lies within one of the most arid geomorphic regions of North America. Desiccation caused by the City of Los Angeles' water diversions since the early 1900s has exposed unconsolidated lakebed sediments and salt deposits. The unstable condition of these sediments facilitates lofting by winds, and Owens (dry) Lake has become the largest single source of particulate matter air pollution in the United States. These dust storms violate state and federal air quality standards for particulate matter.

From the large aquatic habitat that it once was, Owens Lake has become reduced to a ring of spring fed wetlands around the old shoreline. A monitoring program for spring-fed wetlands was initiated in February 1997, in order to obtain detailed information about the hydrology and functional values of remnant Owens Basin wetlands. Studies have shown that these wetlands now serve as refugia for aquatic plants and animals, and support migratory birds. Rare shorebirds such as snowy plovers rely on Owens Lake as nesting habitat. Furthermore, wetland monitoring is important to the design and operation of dust control projects. The record of baseline conditions that has been compiled will be vital to discerning impacts of projects on wetland resources.

Baseline patterns at 24 reference wetlands have been documented. On-site instrumentation includes nested 4 ft and 10 ft shallow groundwater wells, and flumes to quantify flows. Some sites are fitted with transducers and dataloggers to collect hourly data. Data at remaining sites has been collected manually. Intensive baseline sampling was transitioned to project-related monitoring in 2001, as dust control implementation has begun.

Some spring flows show evapotranspiration-driven seasonal and diurnal variation, others are constant with no seasonal or daily variation. Groundwater levels also exhibit seasonal and daily variation, being lower during the day and in the warmer months due to increased evapotranspirative demand. The pH and salinity of spring water ranges from 6.4 to 35.7, and 0.3 to 35.7 dS/m, respectively. Salinity of shallow groundwater ranges from 1 to 191 dS/m. Water chemistry of most of the springs remains constant year around, while shallow groundwater chemistry changes seasonally.

Study of the Physical and Chemical Characteristics of Spring Flow Along the South Rim, Grand Canyon, Arizona

Stephen A. Monroe[1], Robert J. Hart[2], Howard E. Taylor[3], Tracey J. Felger[4], and John R. Rihs[5]

Spring flow from the south rim of the Grand Canyon is a significant resource of Grand Canyon. Springs offer refuge to endemic and exotic terrestrial wildlife species and maintain valuable riparian areas. Hikers use springs as a source of drinking water, and the springs are culturally and economically important to Native Americans in the region. Population growth on the Coconino Plateau has increased the demand for additional development of ground-water resources. Resource managers, Native Americans, and environmental groups have concerns about the potential effects of ground-water development on springs along the south rim. In 1999, the National Park Service and the U.S. Geological Survey began a study of the water chemistry and quality of these springs. The study area extends from the Little Colorado River westward to Mohawk Canyon. Objectives of the study are to determine baseline water quality and provide information on ground-water flow paths and residence times.

The principal springs along the south rim discharge from the Mississippian Redwall Limestone and the Cambrian Muav Limestone. The relation of these springs to the regional ground-water system is unknown. During 2000 and 2001, samples were collected from 26 sites. Most of these sites have not been studied previously. Physical characteristics of each spring were described and water samples were analyzed for major ions, trace and rare-earth elements, nutrients, and stable and radiogenic isotopes.

Preliminary results suggest a relation between physical setting and spring chemistry and indicate that many of the springs share similar chemical characteristics. Most springs yield water that is a mixture of young and old waters; at several springs, younger water is absent. The quality of water at most springs is suitable for human consumption. More information about this project may be obtained on the World Wide Web at URL http://az.water.usgs.gov/projects/az176.html and http://www.nps.gov/grca/water.

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Distribution, Dispersal, and Population Genetics of Caddisflies (Insecta:Trichoptera) from Springs of the Western Great Basin

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Twenty-eight isolated springs were sampled intensively to document the biodiversity of caddisflies and to examine what physicochemical characteristics determined species composition at a site. Although several springs had very similar physicochemical characteristics, none had an identical trichopteran species composition. Fifty-eight species of caddisflies were collected including three undescribed species. The greatest number of species at one spring was 18. Species composition at a site was determined primarily by elevation and spring temperature. Mitochondrial DNA sequences from COI were used to investigate the dispersal capabilities and population genetics of two species of caddisflies, *Hesperophylax designatus*, and *Lepidostoma ojanum*. We found that the limnephilid, *H. designatus* makes long distance flights within and between mountain ranges and has many haplotypes represented in several springs. In contrast, the lepidostomatid, *L. ojanum* is capable of only short distance flight. Either it does not leave its natal spring or if it does, it is not surviving the trip to more distant springs. Each population had a unique haplotype found only in a localized area or single spring. Loss of one of these populations would result in the loss of a unique genetic resource.

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Fish and Free Trade, Cultures and Conservation: Management Challenges at a Historic Border Oasis

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Quitobaquito is a Sonoran Desert aquifer-fed wetland in arid southwest Arizona on the U.S./Mexico border. The permanent waters in this area have been a focal point of human migration and occupation for thousands of years, and the complicated cultural/natural interactions persist to this day. The National Park Service acquired the wetland from the last Hia'ced O'odham inhabitant in 1958, and since then has faced the difficulty of managing a human-manipulated landscape as a natural preserve, which is the principal remaining habitat for the endangered Quitobaquito Desert Pupfish (*Cyprinodon eremus*). The springs, channel, seeps and pond also support an endemic spring snail, an isolated population of Sonoran mud turtle, a diverse resident and migrant avian fauna, foraging free-tailed bat species, and medicinal wetland plants.

In the past 15 years, Quitobaquito's aquatic environment has been improved by modifications to the water delivery system from the springs to the pond, creating additional upstream channel habitat. Numerous research and monitoring projects have increased knowledge of the geohydrology, water flow and chemistry, vegetation composition change, and the ecology of many faunal species.

Future protection of this oasis ecosystem and its significant historic and prehistoric resources will depend on education and management within a holistic, multi-cultural context. Mexico Highway 2, a busy commercial truck route linking Baja California with mainland Mexico, passes within 100 meters of Quitobaquito. This proximity to highway and adjacent agricultural lands, and the ease of access by visitors from both sides of the border, has made this site vulnerable to threats such as litter, fire, introduction of exotic species, and chemical contamination from airborne pollutants and fuel spills.

Paleoenvironmental and Archaeological Investigations at a Northern Mojave Spring Mound

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Burnt Rock Spring Mound is one of several dozen artesian spring mounds that came into existence during the Terminal Pleistocene in the Las Vegas Valley of southern Nevada. These features have rarely been investigated by archaeologists, however, geologists and Quaternary scientists have studied several southern Nevada mounds and their associated fault scarps.

A multi-disciplinary team investigated the archaeology and paleo-spring deposits of Burnt Rock Spring Mound during March of 2000. The results of this investigation include 25 ^{14}C dates from black mat and archaeological contexts that range from 11,175 to 10,715 B.P. to 235 to 65 B.P. This data extends the onset of Quade et al. (1998) spring-fed stream and black mat chronology and correlates with the commonly accepted Late Archaic and Ceramic period archaeological chronologies of the area.

Water and the Human Spirit: Conservation of Natural Surface Waters as Traditional Cultural Places and Sacred Sites

Adrianne G. Rankin[1], Lorraine Eiler[2], and Joseph Joaquin[3]

The paper examines natural surface waters (springs, tinajas, and cienegas) as both part of the archaeological record and as part of the traditional cultural values and sacred sites among Native American cultures, specifically the Tohono O'odham, Hia C-ed O'odham, and Pee Posh. The cultural and natural surface resource values of these places have been overlooked, and they have not been afforded designation and protection under the National Historic Preservation Act and EX 13007 (Sacred Sites). The cultural value of natural surface waters must be taken into account when there are proposed undertakings alterations) under National Environmental Policy Act and the National Historic Preservation Act.

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Effects of Extreme Lake Levels and Drainage Integration on Fish in the Western Great Basin

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Fish living in isolated desert springs and spring-fed creeks will go extinct in geologic time if these habitats do not persist. Yet genetic and morphologic relations show that many modern fish species show close affinity to ancestral species that were widely distributed in western North America during the Pliocene. Living species were previously thought to have originated by rapid change since about 12,000 years ago, but are now believed to have derived from Tertiary populations by evolutionary processes driven by climatic and tectonic changes that led to isolation of many fish populations.

Geologic research since 1995 shows that many aquatic connections existed in the western Great Basin prior to the late Pleistocene episode of expanded lakes. Lake deposits of Pliocene age suggest connections among Lake Lahontan and several basins to the south. Mono Basin linked the now hydrologically separate Lahontan and Owens-Death Valley systems during the Pliocene, and also linked these systems during the Pleistocene for strong swimmers such as cutthroat trout and whitefish. The highest shorelines recorded in several lake basins were attained in the early middle Pleistocene, likely at about 660 ka. During this time, Lake Lahontan submerged some basins previously thought to have been isolated. These large lakes connected most of the fish-bearing desert springs in northern and central Nevada, providing fishes with aquatic pathways throughout the region. Coeval overflows of lakes in other basins created both permanent and temporary enlargements of the Lahontan drainage basin, including integration of the upper Humboldt River. These long lacustrine histories allow observed divergences between some species to be averaged over hundreds of thousands of years, greatly reducing the apparent discrepancy in evolutionary rates. In addition, the sudden connections between previously isolated lakes may explain the coexistence of endemic and cosmopolitan fish in the same and adjoining basins.

Prehistoric Settlement and Subsistence Strategies at Springs and Creeks in the Las Vegas Valley

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Native peoples have utilized water resources of springs and creeks in the Las Vegas Valley for thousands of years. Prehistoric ceramic analysis as well as other data suggests a correlation between point vs. linear water sources and cultural affinity. Archaeological sites between AD 500 and 1700 situated along the Las Vegas and Duck Creeks have different characteristics when compared to selected spring sites. Postulated reasons for this include divergent subsistence strategies, targeted patch foraging, and seasonality. A revised Southern Nevada specific ceramic period culture chronology can be defined based on a reexamination of these combined resource data.

Coupling Ethnohistorical Information and Groundwater Models for the Coconino Plateau of the South Rim of the Grand Canyon

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Ecosystems and cultures at seeps and springs of the South Rim of the Grand Canyon are supplied with groundwater from a large regional carbonate aquifer under the Coconino Plateau. Field surveys were conducted and combined with existing measurements to determine that approximately 30,200 gpm of water discharges into three major springs (~29,600 gpm), 20 minor springs (510 to 640 gpm), and about 60 seeps (7 to 26 gpm). Although these seeps and springs occupy less than one percent of the area of this arid to semi-arid region, they support a diversity of species, sites culturally significant to Native Americans, and wilderness areas. A numerical ground-water flow model was constructed from a digital geologic framework model to delineate capture zones for the major and minor springs and to predict the impacts of pumping from deep wells since 1989. This information was combined with ethnohistorical information to understand the impacts from groundwater pumping on the Havasupai. Prior to Euro-American settlement, the Havasupai used a territory roughly the size of the bounds of the aquifer. Up until 1972, the bounds of their territory were restricted to a small area around the largest spring. Although the Havasupai have the rights to the water which discharges from this large spring, they are unable to manage groundwater pumping from non-tribal lands which occupy most of the aquifer upgradient from the springs. Since 1989, non-tribal groundwater extractions from the aquifer exceed about 500 gpm. Models predict that this and any future groundwater extraction through wells will lead to a commensurate reduction in spring discharge.

Restoration of a Desert Spring System at Moapa Valley National Wildlife Refuge

Kathie Taylor[1], Cynthia Martinez[2], and Amy Sprunger-Allworth[3]

Restoration of desert spring ecosystems is vital to the survival and recovery of many threatened and endangered species. The Moapa Valley National Wildlife Refuge is located near the headwaters of the Muddy River ecosystem. The thermal spring complex encompassed by the refuge once supported a variety of endemic and native fish and invertebrate species, such as the endangered Moapa dace (*Moapa coriacea*), Moapa White River springfish (*Crenichthys baileyi moapae*), Moapa pebblesnail (*Pyrgulopsis avernalis*), Grated tryonia (*Tryonia clathrata*), two endemic elmid riffle beetles (*Microcylloepus moapus* and *Stenelmis moapa*), and an endemic predaceous water bug (*Limnocoris moapensis*). Much of the historic habitat was altered during the mid 1900s for recreational uses rendering the spring pools and outflows unsuitable for native fish and plants. Several impacts including the confinement of springs into concrete lined swimming pools, relocation and channelization of spring outflow channels, removal of native vegetation, and introduction of non-native plants and animals, have made this area a prime candidate for restoration. Restoration efforts will focus on restoration of the Pedersen property, which includes the "Upper Pool" and its connecting channel. Restoration, constructed in April 2002 included restoring the springheads to their natural size, shape, and pool depth, creating a diversity of hydraulic habitats, removing exotic vegetation, re-establishing native riparian vegetation, and creating habitat suitable for thermal endemic and native species. Following restoration efforts, it is expected that these springs and their outflows will provide suitable habitat and support viable populations of endemic species once again.

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Knowing the Sources of Water Flowing from Springs in the Great Basin is Critical to their Management

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Understanding the origin of springs in the Great Basin is critical for planning the protection and management of these valuable natural resources. Geochemical and isotopic data can be used in conjunction with other hydrogeologic information to identify sources of recharge and delineate groundwater flow systems from recharge areas to discharge areas. Small springs in the Great Basin generally are supported by local recharge sources, with recharge occurring over short and/or long time periods. Whereas, large springs generally discharge from regional groundwater flow systems with water originating from multiple recharge sources and numerous topographic basins. In both cases, isotopic data such as deuterium, oxygen-18, and uranium can be used to distinguish the different sources of water discharging from a spring and relate them to regional and local flow systems. Major ion and trace element data along with hydrogeologic information are also important for evaluating spring water sources identified by isotopic data.

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Australian Desert Spring Fishes: Their Extreme Habitats and Ecological Attributes

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Approximately 190 strictly freshwater fish species occur in Australia, most in wetter northern and eastern areas. Central Australia, despite its aridity, contains 32 fishes of which 12 occur in springs. These springs represent the natural outlets from the Great Artesian Basin, a huge groundwater system that mostly receives recharge from the wetter Eastern Highlands. There are around 600 individually named springs, although many have multiple discrete outlets (up to 400 in extreme cases). Great Artesian Basin springs are categorized into 11 "supergroups" based on geographic proximity. The four supergroups that contain fishes all occur in Central Australia. Dalhousie Springs Supergroup (South Australia) has the highest richness with six fish species (five endemic), followed by Edgbaston Springs (Springsure Supergroup, Queensland) with three species (one endemic). The Lake Eyre Supergroup (South Australia) has two species, although one is only ephemerally present. Finally, Elizabeth Springs (Springvale Supergroup, Queensland) has one species which is endemic. The fish fauna of each spring system differs ecologically due to major geomorphological differences between spring groups. These include overall spring size, height and extent of spring mound formation, discharge volume and spring outflow geomorphology. The result of these differences is that some springs have large pools and streams with fairly constant physico-chemical characteristics, others lack pools, but have smaller discrete outflow channels with moderately constant conditions, and some have miniscule discharges with indiscrete outflows typified by extremely shallow water and highly variable physico-chemical conditions. This presentation reviews Central Australian springfishes and focuses on their characteristics allowing survival under extreme physical conditions.

Audacious Schemes, Unintended Consequences: Managing the Las Vegas Artesian Basin, 1855-1975

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The science of managing water has changed drastically since water policies and practices instituted by Anglo-Europeans came into play in the Las Vegas Artesian Basin. Although the native Paiute people diverted creek and spring surface flows to irrigate small garden plots, urban and industrial use of water only began in the 20th century. In the first decades of the century, steady, irresistible land development placed heavy pressure on the artesian basin, especially in and around the City of Las Vegas and unincorporated Paradise Valley to the south. In the early 1940s, massive war plant construction southeast of Las Vegas brought water from Lake Mead into the valley. While plans were laid for Las Vegas to tap this source, such a project would require a huge investment of cash and more than a few years to accomplish. What could be done in the meantime?

In answer, Nevada's State Engineer proposed a water policy designed to turn the artesian aquifer into a water table. Water "wasted" in spring and creek flows would be captured to serve only the needs of the human population. This new direction in water management reflected a change in philosophy as well, as water practices turned from conservation to mining of water. Historic Las Vegas Springs, the major water source in the center of this Mojave Desert valley, were targeted by the State Engineer in his quest to control the artesian system. By 1962, the water management practices put in place in 1957 succeeded in drying up most of the valley's surface springs and creating a water table.

The State Engineer's approach to the aquifer also had unintended consequences, which continue to cause significant problems for local and regional governments in the 21st century: continued uncontrolled growth, "leapfrog" development, and land subsidence. This paper will present a brief picture of historic settlement of Las Vegas Valley and the effects of development on the artesian aquifer, especially the critical role water management policies instituted in mid 20th century had on Las Vegas Valley's springs and their dependent wetlands.