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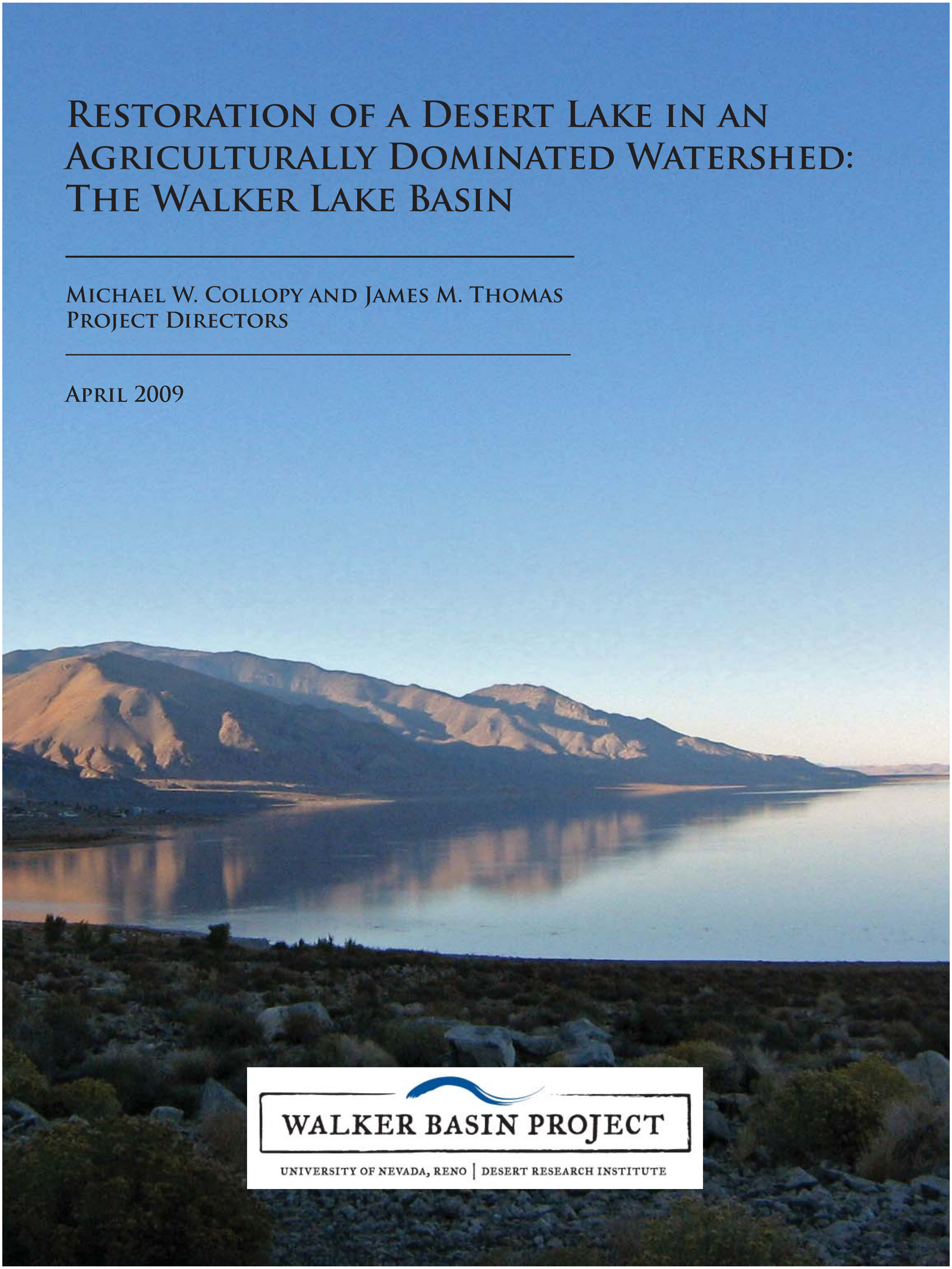

WALKER BASIN PROJECT

UNIVERSITY OF NEVADA, RENO | DESERT RESEARCH INSTITUTE

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EXECUTIVE SUMMARY

Walker Lake is one of three desert terminus lakes in the United States that support a fishery. Over the past 100 years, lake levels have declined about 140 feet and the volume of the lake has decreased from about 10 million to less than 2 million acre feet. During this decline, the total dissolved solids (TDS) of the lake have increased from about 2,500 mg/l to greater than 15,000 mg/l. These changes have had far reaching impacts on the health of the lake and its associated ecosystems. High TDS values have resulted in significant population declines of threatened Lahontan cutthroat trout (LCT), a subspecies that is receiving significant conservation and restoration attention.

Walker Lake is located in a watershed that supports significant agriculture activity. The source of the lake's water comes primarily from snowmelt runoff from the Sierra Nevada, which flows through several agricultural valleys before reaching the lake. There are currently no water rights for the lake, so during low water years the lake receives little or no inflow from the Walker River.

In an effort to save Walker Lake, Congress enacted a law in 2005 (i.e., H.R. 2419 Energy and Water Development Appropriations Act, 2006, Section 208), that created a program to acquire water rights from willing sellers in the Walker Basin. In order to enact an ecologically and economically sustainable program of water acquisitions, a large-scale integrated research program was established. The goal of the Walker Basin Project was to provide the hydrologic, ecologic, economic, and agricultural data needed to inform decisions related to water acquisitions. This report is the product of the research program that was developed in response to direction provided in this federal legislation. Specifically, Desert Research Institute and University of Nevada, Reno faculty were funded to: (1) develop a method to optimize the purchase of water rights in the Walker River Basin, (2) evaluate options for practicing alternative agricultural practices, and (3) evaluate the impacts that water removal from crop-irrigated lands will have on the spread of invasive plants, aquatic and terrestrial ecosystems, and the local economy.

LAKE AND RIVER STUDIES

One of the goals of the overall Walker Basin project was to evaluate the present status of the lake and river system in reference to their existing limnological condition and to evaluate changes in those conditions that may occur in response to changes in water delivery and management practices. The aquatic reports in this volume include summaries for 10 studies conducted by more than 15 scientists. This effort is notable because it is the most extensive study ever conducted examining the ecology of a mid-elevation western Great Basin river and its terminal lake. Each report stands alone with its information, but the strength of this volume lies in the diversity of studies and commonality among findings through divergent methods. The integrated sum of information is vastly greater than the total of individual parts.

Walker Lake was monitored and sampled during 2007– 2008 for the purpose of describing current conditions and to calibrate an ecological model of lake response under different water delivery scenarios. Water quality samples collected from several sites in the lake were used to identify and assess ecological parameters important to lake ecosystem health. Physical, chemical and biological datasets were developed across depth profiles over time to explore factors governing intra-lake circulation and the resulting nutrient cycling, summertime oxygen minima, and accumulations of deleterious substances (e.g., ammonia and hydrogen sulfide). These data were compiled with available historical data and used to parameterize the Walker Lake ecological model. Sensitivity analysis then identified the factors most important to lake function and its ecological condition. These results and the professional judgment of participating researchers have contributed to recommendations for long-term monitoring that would provide a consistent and comprehensive dataset on environmental conditions in the lake and river system over time, including specific indicators vital to improved diagnostic models for Walker Lake assessment and management as future water acquisitions deliver water to the lake.

Observations, data and analysis indicate that large nuisance algal blooms and deepwater hypoxia will continue in Walker Lake. These conditions will continue in the lake because it is in the midst of successional processes that enhance internal nutrient loading through oxygen depletion in the hypolimnion, which in turn enhances algal blooms. The volume and areal extent of the hypolimnion oxygen depletion has been decreasing simply due to the reduction in the volume of the hypolimnion as lake levels have declined. The production of organic matter leading to the hypoxia is sustained by exceedingly high levels of phosphorous [in excess of 20 microMolar (uM)] sustaining the Nitrogen-fixing *Nodularia* blooms. Given the rate of water-level decline the lake could soon make the transition to polymictic status. In the event that water management creates a situation where lake level rises, although the hypolimnetic oxygen depleted zone will decrease in size it is not likely to disappear completely unless means are found to minimize the internal loading of nutrients.

Past fluctuations in lake level and salinity occurred rapidly, possibly within several decades, particularly when the Walker River changed course and diverted flow from or returned flow to the lake. Certain taxa quickly re-colonized the lake, evidenced by the sudden occurrence or transition of ostracode and diatom taxa in the sediment record. This strongly suggests that the taxa found in Walker Lake are adapted to rapid recolonization when conditions are favorable. However, the river is the lifeline which many Walker Lake taxa need to survive unfavorable lake conditions and it has served as such for many tens of thousands of years. Little information is available and few studies have been conducted on Walker River taxa, most likely because the rivers tremendous value in sustaining Walker Lake taxa has not been fully recognized.

For this project, Walker River studies quantitatively examined its physical characteristics, water chemistry and quality, and ecology (i.e., algae, macrophytes, macroinvertebrates, and fish communities) in different reaches of the river. These studies were designed to:

- define healthy and functioning conditions in the river
- predict changes in riverine ecosystems that can be anticipated from increased flow and change in the timing of water delivery from water acquisitions
- integrate this information with future hydrology studies to reveal strategies that will maximize the increase in ecosystem health and recreational opportunities.

Water quality, salient metrics describing physical characteristics of aquatic habitat, periphyton and benthic macroinvertebrates (BMIs) were sampled at eight river sites during the spring, summer, and autumn of 2007 and 2008.

River water chemistry sampling results were compared to historical data and long-term trends in water quality were identified. Seasonal water-quality changes along the length of the river were assessed. Mass loadings of important water-quality constituents from the Walker River into Walker Lake were calculated based upon measured river flows and constituent concentrations over the sampling period of this study. Results provided a basis for comparison to potential changes in river water quality as new water acquisitions are introduced into the river.

Biomass and community composition of periphyton in the Walker River were evaluated to establish a present-day knowledge of algal taxa in different river habitats. Standing stocks of algal biomass were present at levels that often signify eutrophic conditions at two of the eight sites, East Fork and Mason Valley. The river had high abundances of siltation-tolerant diatom taxa with the most notable abundances (exceeding 60%) at the most down river site locations. The near ubiquitous presence of filamentous green algae (especially *Cladophora* and *Oedogonium*) throughout the system (excepting the West Walker) is indicative of a system having a high potential for nutrient-algal interactions that produce oxygen slumps during the summer months. Taxonomic richness and the community tolerance values of riffle and woody debris BMIs exhibited spatial and temporal trends. Both metrics show that ecological health of upstream reaches is generally better than reaches through and below Mason Valley. Multivariate analyses found a strong relationship among water temperature, discharge (and factors affected by discharge, such as current velocity, wetted width of the stream and water depth), nutrient concentrations, and BMI community structure. These relationships indicate that Walker River BMI communities are affected by activities that influence these factors, including water management, flow reduction, and livestock grazing.

The drop in Walker Lake level has caused Walker River to extend by about 20 km across the former lake bed. In addition to lengthening, the river has also severely down cut in response to lowering of the lake (base) level. Rectified aerial photographs, beginning in 1938 and proceeding to the present, were used in combination with detailed topography from 1995, 1997, and 2005 in a geographic information systems (GIS) database to document the conditions under which lateral and vertical erosion have occurred. From 1995 to 1997, approximately 1.02 million metric tons (MT) of sediment was eroded from the bed and banks of the lowermost Walker River (from Weber Dam to the lake). Over the next seven years (1997-2005) about 430,000 MT of sediment was eroded. During the spring 2005 runoff season, approximately 477,000 MT of sediment was eroded and during the spring 2006 runoff season another 936,000 MT of sediment was flushed into the lake from bed and bank erosion.

The amount of erosion in a given year does not only depend on peak discharge but also is directly related to the duration of the runoff event. A 2-D sediment transport model was used to simulate the amount of sediment transport and vertical erosion (down cutting) that may occur under a variety of flows. It is difficult to directly compare the estimates of erosion made from aerial photography to those made from modeling because the former is better at documenting lateral erosion and the latter focuses on vertical erosion. Regardless, the results from both of these approaches indicate that hundreds of thousands of metric tons of sediment are eroded from the bed and banks of the lower Walker River during an "average" runoff year, attesting to the instability of this system. Most of this instability is concentrated in the lowermost reaches of the river. Thus for future management of the lower Walker River, instead of increasing peak flows down the river, a more sound option would be to increase the duration of spring runoff events or to establish minimum base flows that cumulatively would supply the additional water volume to the lake but at the same time minimize erosion.

The sediment transport (HEC-RAS) model developed for the upper Walker River was run for various flow scenarios. The predicted hydrodynamic characteristics of the flow (i.e., bed shear stress, mean velocity, water surface elevation, Froude number, and maximum channel depth) were obtained. A number of methods were used to determine the susceptibility of sediments in the upper Walker River to erode and be transported under varying flow conditions. The flow model analyses consistently indicated that the sediments in the upper Walker River would be actively transported under most of the anticipated flow conditions. This was consistent with what was observed in the field at each of the locations where sediment samples were collected. Even at relatively low flow conditions, active sediment transport was visually observed. Particles were being transported along the surface of the sediment beds. If it became important to reduce sediment transport from the upper to lower Walker River basin, a potential solution would be the installation of settling basins or grit tanks in series throughout the watershed to trap sediments being transported. Periodically, these basins would require cleaning to remove settled materials, which could potentially be used for different types of building construction or road construction projects.

DECISION SUPPORT TOOL MODELS, WATER FLOW MODELS, GIS DATABASES AND DISTRIBUTED TEMPERATURE MEASUREMENTS

A computer-based decision support tool (DST) capable of evaluating the efficacy of proposed water rights acquisitions in the Walker River basin was developed and tested. This represents a major step forward in understanding the complex hydrologic relationships within the real system. Climate, streamflow, upstream storage areas, irrigation practices, crop and non-agricultural ET, groundwater-surface water exchange in the river corridor, groundwater pumping and recharge, and all known existing water rights (decree, storage, and flood) all play a role in the Walker River system and are simulated by the DST. The DST allows users to track water from the headwaters, where streamflow originates, through the complicated deliveries and returns in the heavily irrigated Smith and Mason valleys, to the USGS gage near Wabuska where Walker River leaves Mason Valley.

Three different models were integrated to generate results for the DST project. The USGS Precipitation-Runoff Modeling System (PRMS) was used to model streamflow in the headwater supply areas of the Walker River basin. The model performs well in the West Walker headwaters: timing of the annual hydrograph was well represented, although streamflow peaks were slightly underestimated by the model. The affects of reservoir operations and diversions for agricultural irrigation in the East Walker are not captured by the model, which causes poor representation of annual hydrograph timing as well as overestimation of streamflow peaks. The East Walker model, or at least estimated inflows to

Bridgeport Reservoir, might be improved by simulating additional subbasins utilizing historic streamflow data from discontinued USGS gages.

The USGS groundwater flow model MODFLOW was used to model the agricultural demand areas and groundwater-surface water interactions in Mason and Smith valleys. Mason Valley, in particular, is well modeled: low root mean square error (RMSE) values were calculated for groundwater levels, streamflows, and river responses. The Mason Valley groundwater model indicates that groundwater fluxes into the river/drain network account for about four percent of the river's water budget during wet periods, and nearly 25 percent during extended drought. Smith Valley was not modeled with the same degree of accuracy as Mason Valley, but contrasting the two models provides insight to the Walker River system. The groundwater models are limited by their non-unique solutions, poor representation of water levels in parts of Smith Valley, and the unknown errors associated with the simulated groundwater-surface water interactions.

The MODSIM model was used to simulate reservoir operations, streamflow routing, and water rights allocations in the Walker River basin from the headwaters to the Wabuska gage. Given the complexity of the water distribution system in the Walker River basin, the results are reasonable. The model is able to maintain target volumes in the reservoirs while supplying water to downstream demands, which indicates that reservoir operations are simulated realistically. Generally, simulated water allocations correspond to historical allocations during the simulation period. In spite of the problems encountered with model calibration, the simulation model allocates the different categories of water reasonably well.

A geographic information system (GIS) database of vector, raster and tabular data was developed. This was not a stand-alone effort, but rather a service task with the principal objective of acquiring, developing and analyzing the requisite spatial and tabular data needed to successfully support many of the Walker Basin Project studies. A majority of the GIS development process focused on providing data for the DST water flow modeling effort. The GIS database includes both surface and groundwater distribution networks and water rights. These data were used as inputs for the DST described above, providing spatial and tabular data to the supply, demand, and basin management components, as well as calibration data to assist in the validation of the models.

In addition to data sets for the DST, a wide variety of other spatial data sets were developed and integrated into the GIS database in support of other Walker studies, as well as outside entities requesting spatial data. GIS spatial data sets were created for the alternative agriculture and vegetation management; the plant, soil and water interactions; the health of Walker River and Lake; the economic impacts and strategies; and the demographics and economic development studies. In addition, GIS spatial data sets were provided to the United States Fish and Wildlife Service (USFWS) restoration project; the Western Development and Storage acquisitions team; and the Jones and Stokes Environmental Impact Statement (EIS) development team.

Researchers constructed an extensive GIS database of the entire Walker Basin, with data sets from federal, state, and local agencies combined and integrated with derivative data sets. The result is a scalable, georeferenced collection of spatial data (i.e. geodatabases, shapefiles, rasters, and tables) representing a wide variety of spatial and temporal features as well as tabular information for the entire Walker Basin. The database could be used in the future by resource managers and researchers from agencies and private interests for investigating hydrologic, ecological and economical phenomena in the Walker Basin.

Distributed temperature sensing (DTS) analysis showed the groundwater - surface water interaction to be highly variable in both space and time. The DTS study found that ground water inflows and outflows to and from the river were easily identifiable and quantifiable using the combination of DTS and vertical temperature measurements. DTS measurements indicate gaining conditions over short periods of time and long spatial extent along the Walker River. DTS identified long reaches of the Walker River where groundwater was flowing into the river channel during the limited periods with gaining conditions.

DTS was shown to be a useful tool for measuring groundwater inflows to stream environments year round. Care must be exercised when choosing the season or time of day for measurement, and knowledge or independent measurement of groundwater temperatures is essential to successful assessment of surface-water groundwater interactions with DTS. Use of time series from vertical temperature profilers and piezometers outfitted with temperature and water level loggers yields long records of seepage rates, hydraulic gradients, and hydraulic conductivity, providing insight into the dynamics of stream-groundwater systems over time.

LAND USE CHANGE, VEGETATION MANAGEMENT AND PLANT SOIL WATER INTERACTIONS

Over the past 150 years, the Walker River riparian zone has experienced massive land cover conversion from native riparian vegetation to extensive agricultural landscapes characterized by irrigated pastures and alfalfa fields. Water withdrawals and diversions for agriculture have greatly reduced flows of water to Walker Lake, influencing aquatic ecosystem integrity. River regulation and reduced in-stream flows have altered riparian vegetation even in locations not devoted to agricultural use. In response to recent environmental concerns, purchase of water rights from agricultural producers is being considered. However, past abandonment of irrigated fields in the region has resulted in ecologically and economically undesirable effects, including surface soil erosion, salinization, and spread of invasive plant species. Careful orchestration is required for land use conversion to result in benefits for ecosystems and society.

Results from this study support the potential for well-planned land use conversion by:

- utilizing historical data to quantify historical land use/land cover change from the late 1800s to the present
- quantifying contemporary species-environment relationships for vegetation to characterize reference conditions for ecological restoration of irrigated agricultural fields
- predictive modeling of the implications of historical and future land cover change for plant water use.

These three tasks were supported by direct historical reconstruction of land use/land cover change, extensive mapping and mensurative vegetation sampling throughout the basin, integration of detailed results from irrigation experiments, and development of spatial models that allow assessment of water use by vegetation given alternative land cover scenarios.

The performance of 14 varieties of 13 low-water use alternative crops were compared by researchers involved in another study for the Walker Project. These alternative crops included annual grain and biomass crops, and different watering regimes (4, 3, and 2 feet/acre) were employed on several soil types in the basin. The cultural practices and crop types needed to maximize productivity while minimizing water use, as well as minimizing weed establishment and proliferation, were determined. When previously farmed land is reverted back to an unmanaged state, this can lead to soil loss and/or the creation of weedy acreage with low-quality forage. The establishment of multiple restoration species (a mix of native grasses and shrubs) was compared, monitoring the relative success of planted species with either little (1 foot/acre) or no water addition.

One study investigated plant water use during a year in which water allotments for the Walker River were below average (i.e. low water availability for irrigation). The study focused on the evapotranspirative water losses of a selection of alternative crop species planted on a site in the basin that was cultivated up to the late 1980s and has since been used as a livestock feedlot. The results of this study indicate that evapotranspirative water losses differ between alternative crop species indicating the potential for improved water savings and greater water availability. Improvements in overall water use by some alternative crops correspond to enhanced water use efficiencies—expressed as aboveground biomass production per unit of water evapotranspired or per unit of water applied—and higher ecosystem CO_2 uptake per unit of water evapotranspired. Alternative crop species demonstrating higher water use efficiencies may achieve this by allocating less shoot growth to leaves, by producing leaves with lower carbon investment per unit area (i.e. higher specific leaf areas), or by creating closed plant canopies even at low water availability that reduce atmospheric incursions into the canopy and allow vapor pressure deficits to remain below levels that cause stomata to close and reduce leaf CO_2 assimilation. Thus, data from this study demonstrate the potential for large water savings by substituting high water use efficiency forage/biomass species (e.g., tef) for traditional forage species such as alfalfa. Market factors must of course be considered when choosing which alternative crop to plant.

Another study examined alternative crops that would enable producers to remain economically viable while using less water. A combination of a crop yield model, WinEPIC, and a risk simulation model, SIMETAR, were used to analyze and answer the agronomic and economic questions. Results showed that there are alternative crops that could be feasibly substituted for alfalfa and reduce water use by at least one-half while providing net returns that meet or exceed returns from alfalfa and keep producers profitable in agriculture.

ECONOMICS, SOCIAL HISTORY AND WILD HORSE AND BURRO POLICY

In order to quantify any economic impact to the Walker Basin as the result of water right acquisitions, the current economic and demographic characteristics of the communities within the Walker Basin were developed and analyzed using local, state, and federal databases and GIS software. Although agriculture is a predominant and traditional industry in the Walker Basin, employment and industry totals indicate a diverse economy. Almost a quarter billion in taxable sales is generated in the Walker Basin, with the majority of sales generated from retail industries. Another $58 million in revenue is estimated to be generated from crop production in Mason and Smith Valleys (Lyon County) covering over 50,000 acres. Current and future residential and commercial construction activity is mostly targeted to populated areas and is consistent with the current economic conditions.

The acquisition of water rights that have historically been used for agriculture could have a variety of economic and fiscal impacts in subareas within the Walker Basin. This study examined four scenarios related to how water rights might be acquired, along with the resultant potential uses for the land following water rights acquisition, and estimates of economic and fiscal impacts for those scenarios. Additionally, the study examined the potential economic impacts in the vicinity of Walker Lake based upon an assumption that sufficient water can flow into the lake to save and restore the Lahontan Cutthroat Trout fishery. Finally, this study makes some recommendations regarding economic development efforts in the basin that would be consistent with the desire of citizens in the communities and that might tend to offset economic dislocations that could result from the acquisition of water rights.

When completed, a social and political historical account of the Walker Basin area will provide an overview of the context in which the acquisition of water rights for ecosystem restoration in the Walker River system occurred. This will be published as a book, of which currently three chapters are completed, as follows:

- Changing Contexts in Western Water Policy
- The Past as Prologue—the Walker River Basin
- P. L. 109-103 and the Walker Basin Project

Further chapters will report on results of the individual Walker Basin Project components.

Wild horse and burro policy is currently driven by several goals that include the mitigation of damage to rangeland, the commitment to humane treatment of the animals, and the control of regulatory costs. Placing animals with private owners and raising revenue from the distribution of the horses complements all these goals. This study has investigated past studies to derive characteristics of wild horses that could increase rates of adoption. This study also investigated alternative auction strategies that potentially could increase adoption rates of wild horses, and has employed stochastic simulation procedures to provide wild horse adoption decision makers with a range of potential revenues for wild horse adoptions. This range of revenues combined with capital and operation cost estimates of a potential wild horse and burro interpretive center provides decision makers with information as to potential distribution of net returns. From the distribution of net returns, decision makers could decide on construction and operation of a national wild horse and burro interpretive center in a risk adverse vantage.

ACKNOWLEDGMENTS

This project was funded by a grant under Public Law 109-103, Section 208(a), through the U.S. Bureau of Reclamation (Cooperative Agreement 06FC204044).